CHOICE BASED CREDIT SYSTEM
CBCS

M.E. DEGREE (Power System Engineering) PROGRAMME

CURRICULUM AND DETAILED SYLLABI

FOR THE STUDENTS ADMITTED FROM THE
ACADEMIC YEAR 2018-2019 ONWARDS

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.

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 carry out 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.

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.

M.E./M.Tech Programme Structure (CBCS)

Credit Distribution:

S.No	Category		Credits
A.	**Foundation Course**		**3 - 6**
B.	**Programme Core Courses***		**19 – 25**
C.	**Elective Courses**		**17 – 23**
	a.	Programme Elective	15 – 21
	b.	Open Elective	2 – 6
D.	**Common Core Course**		**2**
E.	**Mini Project and Dissertation**		**27**
E	Value Added Courses (Not to be included in CGPA) - Mandatory		**4**
	Minimum Credits to be earned for the award of the degree		**68** (from A to E) and 4 (from F)

*TCP and Laboratory courses are Mandatory in the Programme Core Courses.

Credit Details:

Theory: 3 Credits
Theory Cum Practical (TCP) : 3 Credits,
Lab: 2 Credits
Open Elective: 2 Credits
Mini Project: 2 Credits
Dissertation Phase I: 10 Credits
Dissertation Phase I: 15 Credits
Common Core: Research Methodology and IPR: 2 Credits

THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI- 625 015

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

CHOICE BASED CREDIT SYSTEM

Categorization of Courses

Degree: M.E. **Programme: Power System Engineering**
Batch: 2018-19

A. FOUNDATION COURSES: Total Credits to be earned: (03-06)

S.No.	Course Code	Name of the Course	Number of Hours / Week			Credit	Pre requisite if any
			L	T	P		
		THEORY					
1.	18PS110	Optimization & Applied Mathematics	2	1	-	3	Nil

B. CORE COURSES Credits to be earned: (19-25)

S.No.	Course Code	Name of the Course	Number of Hours / Week			Credit
			L	T	P	
THEORY						
1	18PS120	Power System Dynamics and Stability	3	-	-	3
2	18PS130	Design of Renewable Energy System	3	-	-	3
3	18PS210	Power System Security and control	3	-	-	3
THEORY CUM PRACTICAL						
1.	18PS160	Analysis of modern power system	2	-	2	3
2	18PS260	Power System Protection	2	-	2	3
PRACTICALS						
1.	18PS170	Power System Laboratory	-	-	4	2
2.	18PS270	Energy Management System Laboratory	-	-	4	2

C. ELECTIVE COURSES: Credits to be earned: (17-23)

a. Programme Electives Credits to be earned:15-21

S.No.	Course code	Name of the Course	Number of Hours / Week			Credit
			L	T	P	
1	18PSPA0	Systems Theory	2	1	-	3
2	18PSPB0	Smart Grid	3	-	-	3
3	18PSPC0	Power Converters for Power System Applications	3	-	-	3
4	18PSPD0	Power System Voltage Stability	3	-	-	3
5	18PSPE0	Electrical Transients in Power system	3	-	-	3
6	18PSPF0	Design of Power Distribution systems	3	-	-	3
7	18PSPG0	Distributed Generation Systems	2	1	-	3
8	18PSPH0	Flexible AC Transmission Systems	3	-	-	3
9	18PSPJ0	Energy Conservation and Management	3	-	-	3
10	18PSPK0	Power Quality	2	1	-	3
11	18PSPL0	Power Plant Instrumentation and Control	3	-	-	3
12	18PSPM0	Power System Reliability	3	-	-	3
13	18PSPN0	SCADA Systems and Applications	3	-	-	3
14	18PSPP0	HVDC Transmission				
15	18PSPQ0	Soft Computing Techniques	2	-	2	3
16	18PSPR0	Substation Automation	3	-	-	3
17	18PSPS0	Electric and Hybrid Vehicles	3	-	-	3

b. Open Electives Credits to be earned:2-6

D. Common Core Course

S.No.	Course Code	Name of the Course	Number of Hours / Week			Credit	Pre requisite if any
			L	T	P		
1.	18PG250	Research Methodology and IPR	2	-	-	2	Nil

E. Mini Project and Dissertation **Credits to be earned:27**

Mini Project: 2 Credits
Dissertation Phase I: 10 Credits
Dissertation Phase I: 15 Credits

F. Value added Courses (Not to be included in CGPA)
Credits to be earned: 04

Minimum credits to be earned for the award of the degree =68 (From A to E) and 4 from F

Thiagarajar College of Engineering: Madurai-625015

Department of Electrical and Electronics Engineering

M.E. POWER SYSTEM ENGINEERING

For the students admitted from 2018-19

Scheduling of Courses

Semester	Theory					Theory Cum Practical	Laboratory	Project	Total credits
I	18PS110 Optimization & Applied Mathematics (3 Credits)	18PS120 Power System Dynamics and Stability (3 Credits)	18PS130 Design of Renewable Energy System (3 Credits)	18PSPX0 Prog. Elective 1 (3 Credits)	-	18PS160 Analysis of modern power system (3 Credits)	18PS170 Lab 1 Power System Laboratory (2 Credits, 4 hours)		17
II	18PS210 Power System Security and control (3 Credits)	18PSPX0 Prog. Elective 2 (3 Credits)	18PSPX0 Prog. Elective 3 (3 Credits)	18PSPX0 Prog. Elective 4 (3 Credits)	18PG250 Research Methodology and IPR (2 Credits)	18PS260 Power System Protection (3 Credits)	18PS270 Lab 2 Energy Management System Laboratory (2 Credits, 4 hours)	18PS280 Mini Project (2 Credits)	21
III	18PSPX0 Prog. Elective 5 (3 Credits)	-	-	-	18PGPX0 Open Elective (2 Credits)	-	-	18PS380 Dissertation Phase I (10 Credits)	15
IV	-	-	-	-	-	-	-	18PS480 Dissertation Phase II (15 Credits)	15

A student has to complete 2 audit courses of 24 hours duration. The courses will normally be conducted on week-ends.

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power System Engineering) PROGRAM

COURSES OF STUDY

(For the students admitted from 2018-2019)

FIRST SEMESTER

Course code	Name of the course	Category	No. of Hours / Week L	T	P	Credits C
THEORY						
18PS110	Optimization & Applied Mathematics	FC	2	1	-	3
18PS120	Power System Dynamics and Stability	PC	3	-	-	3
18PS130	Design of Renewable Energy System	PC	3	-	-	3
18PSPX0	Programme Elective-I	PE				3
THEORY CUM PRACTICAL						
16PS160	Analysis of modern power systems	PC	3	-	-	3
PRACTICAL						
18PS170	Power System Laboratory	PC	-	-	4	2
Total						**17**

SECOND SEMESTER

Course code	Name of the course	Category	No. of Hours / Week L	T	P	Credits C
THEORY						
18PS210	Power System Security and control	PC	3	-	-	3
18PSPx0	Programme Elective II	PE				3
18PSPx0	Programme Elective III	PE				3
18PSPx0	Programme Elective IV	PE				3
18PG250	Research Methodology and IPR	CC	2	-	-	2
THEORY CUM PRACTICAL						
18PS260	Power System Protection	PC	3	-	-	3
PRACTICAL						
18PS270	Energy Management System Laboratory	PC	-	-	4	2
18PS280	Mini Project		-	-	4	2
Total						**21**

THIRD SEMESTER

Course code	Name of the course	Category	No. of Hours / Week L	T	P	Credits C
THEORY						
18PSPx0	Programme Elective-V	PE				3
18PGPX0	Open Elective-I	OE				2
PRACTICAL						
18PS380	Dissertation Phase I	PC	-	-	20	10
Total						**15**

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power System Engineering) PROGRAM

COURSES OF STUDY

(For the students admitted from 2018-2019)

FIRST SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
18PS110	Optimization & Applied Mathematics	FC	2	1	-	3
18PS120	Power System Dynamics and Stability	PC	3	-	-	3
18PS130	Design of Renewable Energy System	PC	3	-	-	3
18PSPX0	Programme Elective-I	PE				3
THEORY CUM PRACTICAL						
16PS160	Analysis of modern power systems	PC	3	-	-	3
PRACTICAL						
18PS170	Power Engineering Laboratory	PC	-	-	4	2
Total						**17**

SECOND SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
18PS210	Power System Security and control	PC	3	-	-	3
18PSPx0	Programme Elective II	PE				3
18PSPx0	Programme Elective III	PE				3
18PSPx0	Programme Elective IV	PE				3
18PG250	Research Methodology and IPR	CC	2	-	-	2
THEORY CUM PRACTICAL						
18PS260	Power System Protection	PC	3	-	-	3
PRACTICAL						
18PS270	Energy Management System Laboratory	PC	-	-	4	2
18PS280	Mini Project		-	-	4	2
Total						**21**

THIRD SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
18PSPx0	Programme Elective-V	PE				3

18yyGX0	Open Elective-I	OE		2
PRACTICAL				
18PS380	Dissertation Phase I	PC	- - 20	10
Total				**15**

FOURTH SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
PRACTICAL						
18PS480	Dissertation Phase II	PC	-	-	30	15
Total			**-**	**-**	**30**	**15**

Total credits: 68

AUDIT COURSES

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
18PGAA0	Professional Authoring	AC	2	-	-	2
18PGAB0	Value Education	AC	2	-	-	2

FC : Foundation Course
PC : Programme Core
PE : Programme Elective
OE : Open Elective
L : Lecture
T : Tutorial
P : Practical

Note:
1 Hour Lecture is equivalent to 1 credit
1 Hour Tutorial is equivalent to 1 credit
2 Hours 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 2018-2019)
Date of Modification: 03.06.2020

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	18PS110	Optimization & Applied Mathematics	3	50	50	100	25	50
2	18PS120	Power System Dynamics and Stability	3	50	50	100	25	50
3	18PS130	Design of Renewable Energy System	3	50	50	100	25	50
4	18PSPX0	Programme Elective-I	3	50	50	100	25	50
THEORY CUM PRACTICAL								
6	16PS160	Analysis of modern power systems	3	50	50	100	25	50
PRACTICAL								
7	18PS170	Power System Laboratory	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	18PS210	Power System Security and control	3	50	50	100	25	50
2	18PSPx0	Programme Elective II	3	50	50	100	25	50
3	18PSPx0	Programme Elective III	3	50	50	100	25	50
4	18PSPx0	Programme Elective IV	3	50	50	100	25	50
5	18PG250	Research Methodology and IPR	3	50	50	100	25	50
THEORY CUM PRACTICAL								
6	18PS260	Power System Protection	3	50	50	100	25	50
PRACTICAL								
7	18PS270	Energy Management	3	50	50	100	25	50

		System Laboratory						
8	18PS280	Mini Project	-	**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	18PSPx0	Programme Elective-V	3	50	50	100	25	50
2	18PGPX0	Open Elective-I	3	50	50	100	25	50
PRACTICAL								
4	18PS380	Dissertation Phase I	-	**50**	**50**	**100**	**25**	**50**

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	18PS480	Dissertation Phase II	-	**50**	**50**	**100**	**25**	**50**

* 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.

18PS110	OPTIMIZATION & APPLIED MATHEMATICS	Category	L	T	P	Credit
		FC	2	1	0	3

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, Jointly distributed random variables, Test of hypotheses for Large Samples, Random Process to deal the Random Experiments with the state space S and parameter set T, stationary Functions, Gaussian process and Numerical methods to solve partial differential equation and Linear Programming Problem.

Prerequisite

- Matrix
- Probability and Statistics
- Calculus.

Course Outcomes

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

CO1.	Decompose a given matrix using Cholesky, QR and SVD methods	Apply
CO2.	Calculate Pseudo inverse for a given matrix	Apply
CO3.	Calculate expected value, covariance and correlation from jointly distributed random variables.	Apply
CO4.	Test the hypothesis using Z-Test about a population mean and population proportion	Apply
CO5.	Calculate the response of a linear dynamic system with stochastic input.	Apply
CO6.	Solving partial differential equation using Numerical methods.	Apply
CO7.	Apply steepest Descent, Fletcher Reeves and Newton's methods to solve the given unconstrained nonlinear optimization problem	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		
CO5.	S	S	S	S	M	S	M	S	S		
CO6.	S	S	S	S	M	S	L	S	S		
CO7.	S	S	S	S	S	M	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	0	0
Understand	20	20	30	30
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. Determine the Cholesky decomposition for $\begin{bmatrix} 16 & -3 & 5 & -8 \\ -3 & 16 & -5 & -8 \\ 5 & -5 & 24 & 0 \\ -8 & -8 & 0 & 21 \end{bmatrix}$
2. Determine the singular value decomposition of i) $\begin{pmatrix} 1 & 2 \\ 1 & 1 \\ 1 & 3 \end{pmatrix}$ ii) $\begin{bmatrix} 1 & 1 & 3 \\ 1 & 1 & 3 \end{bmatrix}$
3. construct QR decomposition of the matrix i) $\begin{pmatrix} -4 & 2 & 2 \\ 3 & -3 & 3 \\ 6 & 6 & 0 \end{pmatrix}$ ii) $\begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$

Course Outcome 2(CO2)

1. Define generalised eigen vectors.
2. Find the canonical basis for the matrix A = $\begin{pmatrix} 2 & 2 & 2 \\ 0 & 4 & 0 \\ 3 & -3 & 1 \end{pmatrix}$
3. Obtain the generalized inverse of A = $\begin{pmatrix} 2 & 2 & -2 \\ 2 & 2 & -2 \\ -2 & -2 & 6 \end{pmatrix}$

Course Outcome 3(CO3)

4. 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

2. Each front tire on a particular type of vehicle is supposed to be filled to a pressure of 26 psi. Suppose the actual air pressure in each tire is a random variable—*X* and *Y* for the left tire, with joint pdf *f* (*x*, *y*) = $\begin{cases} k(x^2+y^2) & 20 \le x \le 30,\ 20 \le y \le 30 \\ 0 & otherwise \end{cases}$

a. What is the value of *K*?
b. What is the probability that both tires are under 'f '.

c. What is the probability that the difference in air pressure between the two tires is at most 2psi?
d. Determine the (marginal) distribution of air pressure in the right tire alone.
e. Are *X* and *Y* independent rv's?

3. An instructor has given a short quiz consisting of two parts. For a randomly selected student, let *X* _ the number of points earned on the first part and *Y* _ the number of points earned on the second part. Suppose that the joint pmf of *X* and *Y* is given in the accompanying table.

P(x,y)	0	5	10	15
0	.02	.06	.02	.10
5	.04	.15	.20	.10
10	.01	.15	.14	.01

a. If the score recorded in the grade book is the total number of points earned on the two parts, what is the expected recorded score *E*(*X* + *Y*)?
b. If the maximum of the two scores is recorded, what is the expected recorded score?

4. Compute the covariance and correlation coefficient 'r' for *X* and *Y* where joint pdf of X and Y is given by $f(x, y) = \begin{cases} 24xy & 0 \le x \le 1,\ 0 \le y \le 1,\ x + y \le 1 \\ 0 & otherwise \end{cases}$

Course Outcome 4(CO4)

1. A manufacturer of sprinkler systems used for fire protection in office buildings claims that the true average system-activation temperature is 130°. A sample of n=9 sys- tems, when tested, yields a sample average activation temperature of 131.08°F. If the distribution of activation times is normal with standard deviation 1.5°F, does the data contradict the manufacturer's claim at significance level $\alpha = .01$?

(i). Parameter of interest: $\mu =$ average activation temperature.

(ii) . Null hypothesis: $H_0 : \mu = 130 (null\ value = \mu_0 = 130)$

(iii). Alternative hypothesis: $H_a : \mu \neq 130$ (a departure from the claimed value in *either* direction is of concern).

(iv). Test statistic value: $z = \dfrac{\bar{x} - \mu_0}{\sigma/\sqrt{n}} = = \dfrac{\bar{x} - 130}{1.5/\sqrt{n}}$

2. Determine the confidence level for each of the following large-sample one-sided confidence bounds:

a. Upper bound: $\bar{x} + .84 s / \sqrt{n}$

b. Lower bound: $\bar{x} - 2.05 s / \sqrt{n}$

c. Upper bound: $\bar{x} + .67 s / \sqrt{n}$

3. In a certain factory there are two independent processes manufacturing the same item.The average weight in a sample of 250 items is found to be 120 ozs with a standard deviation of 12ozs. While the corresponding figures in a sample of 400 items from the other processes are124 and 14. Obtain the standard error of difference between two sample means. Is the difference significant ? Also find the 99% confidence limits for the difference in the average weights of items produced by the two processes respectively.

Course Outcome 5(CO5)

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. A wide sense stationary noise process N(t) has an autocorrelation function $R_{nn}(\tau) = Pe^{-3|\tau|}$ where P is a constant. Find its power spectrum.

Course Outcome 6(CO6)

1. Solve the Laplace equations $u_{xx} + u_{yy} = 0$ over the square mesh of side 4 units; satisfying the following conditions. u(x, 0) = 3x for $0 \le x \le 4$;u(x, 4) = x^2 for $0 \le x \le 4$; u(0, y) = 0 for $0 \le y \le 4$; u(4, y) = 12 + y for $0 \le y \le 4$.

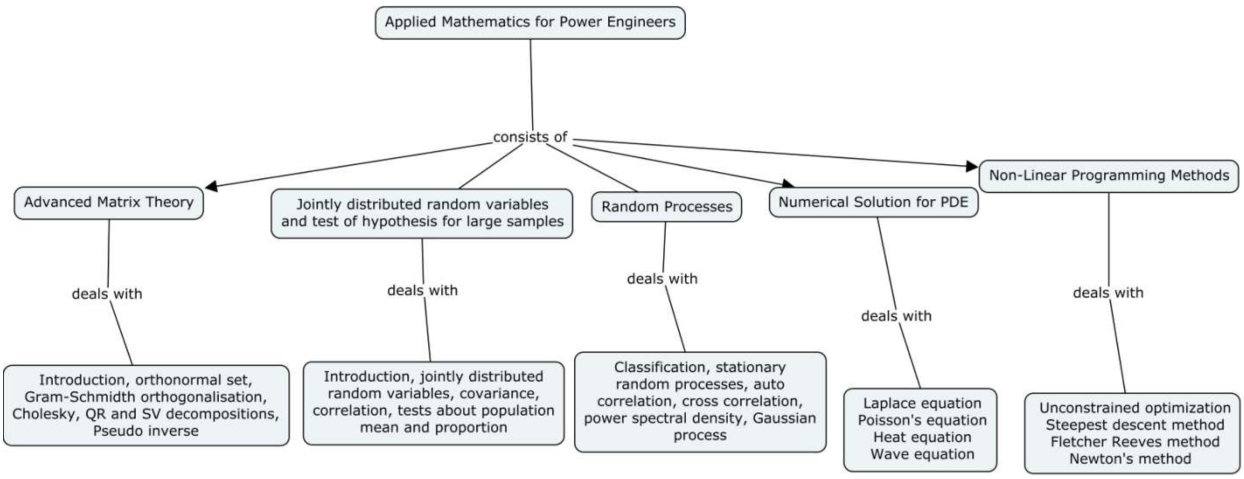
.

2. Solve the Poisson equations $u_{xx} + u_{yy} = -81xy$, 0 < x < 1, 0 < y < 1 given u(0,y) = 0, u(x,0) = 0, u(1,y) =100, u(x,1) =100 and h = 1/3

Course Outcome 7 (CO7)

1. Minimize $f(x_1, x_2) = x_1 - x_2 + 2x_1^2 + 2x_1x_2 + x_2^2$ starting from the point X1 =(0,0) using Steepest Descent method.
2. Explain the generation of search directions in the Fletcher–Reeves method
3. An electric power of 100MW generated at a hydroelectric power plant is to be transmitted 400 km to a stepdown transformer for distribution at 11 kV. The power dissipated due to the resistance of conductors is i^2c^{-1}, where i is the line current in amperes and c is the conductance in mhos. The resistance loss, based on the cost of power delivered, can be expressed as $0.15i^2c^{-1}$ dollars. The power transmitted (k) is related to the transmission line voltage at the power plant (e) by the relation k = √3ei, where e is in kilovolts. The cost of conductors is given by 2c millions of dollars, and the investment in equipment needed to accommodate the voltage e is given by 500e dollars. Find the values of e and c to minimize the total cost of transmission using Newton's method (one iteration only).

Concept Map



Syllabus

Advanced Matrix Theory

Vector spaces: Definition and examples-subspaces-Linear independence-Basis and dimension-orthogonal subspaces-Inner product spaces-Orthonormal sets-Gram-Schmidt orthogonalization process-Eigen values and eigen vectors- Generalized Eigen vectors -Diagonalisation-Cholesky decomposition- Least Square approximation -QR decomposition Singular Value Decomposition – Pseudo inverse.(Treatment as per text book 1).

Jointly Distributed Random Variables & Test of Hypotheses for large samples :

Introduction –Jointly distributed Random Variables – Expected Values –Covariance-Correlation-Basic properties of Confidence Intervals – Tests About a population mean & Population Proportion – P-Values - Z- Tests and Confidence Interval for a difference between two population means & population proportion. (Treatment as per text books 3 &4).

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 5).

Numerical solution for partial differential equation:

Classification of second order partial differential equation-Solution of Laplace equation, - Solution of Poisson equation Solution of heat equation - solution of wave equation (Treatment as per text book 6).

Non Linear Programming Methods:
Introduction - Unconstrained Optimization - Steepest descent method- Fletcher Reeves method - Newton's method (Treatment as per text book 7)

Reference Books

1. Steven J. Leon, "Linear Algebra with Applications", Ninth edition, Pearson Education Limited, 2015.
2. Bronson,R, " Matrix Operations, Schaums Outline Series", McGraw Hill, New York, 1989.
3. Jay L.Devore, " Probability and Statistics for Engineering and the Sciences", 8th Edition, Brooks/Cole Cengage Learning, 2012.
4. S.C.Gupta, V.K.Kapoor ," Fundamental of Mathematical Statistics",10th Revised Edition, Sultan Chand & Sons Educational Publisher, New Delhi.
5. T.Veerarajan "Probability, Statistics and Random Processes" Tata McGraw-Hill, New Delhi, 2003.
6. ,B.S. Grewal ," Higher Engineering Mathematics" khanna publishers,44 th edition.2017.
7. S.S.Rao, "Engineering Optimization - Theory and Practice", John Wiley and Sons Inc,New Jersey, 4th Edition, 2009.

Course Contents and Lecture Schedule

Module No	Topic	No. of Lecture Hours
1.0	**Advanced Matrix Theory**	
1.1	Introduction - Vector spaces, Basis, dimension and Inner product spaces	1
1.2	Orthonormal sets-Gram-Schmidt orthogonalization process	2
1.3	Tutorial - I	1
1.4	Cholesky decomposition-QR decomposition	2
1.5	Singular Value Decomposition – Pseudo inverse	2
1.6	Tutorial - II	1
2.0	**Jointly Distributed Random Variables & Test of Hypotheses for large samples**	
2.1	Introduction to random variables	1
2.2	Jointly distributed Random Variables	2
2.3	Expected Values –Covariance-Correlation	2
2.4	Tutorial - I	1
2.5	Basic properties of Confidence Intervals	2
2.6	Tests About a population mean & Population Proportion – P-Values	2
2.7	Tutorial - II	1
3.0	**Random Process**	
3.1	Classification and Stationary random processes	2
3.2	Auto Correlation, Cross Correlation	2
3.3	Tutorial - I	1
3.4	Power spectral density	1
3.5	Linear system with random input	2
3.6	Gaussian Process	1
3.7	Tutorial - II	1
4.0	**Numerical solution for partial differential equation**	
	Solving partial differential equation	

4.5	Classification of second order partial differential equation,solution of Laplace equation	1
4.6	Solution of Poisson equation	1
4.7	Solution of heat equation	1
4.8	Solution of wave equation	1
4.9	Tutorial - I	1
5.0	**Non Linear Programming Methods:**	
5.1	Introduction - Unconstrained Optimization	1
5.2	Steepest descent method	1
5.3	Fletcher Reeves method	1
5.4	Newton's method	1
5.5	Tutorial - I	1
	Total	**40**

Course Designers:

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18PS120	POWER SYSTEM DYNAMICS AND STABILITY	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

The need for power system dynamic analysis has grown significantly in recent years. This is due largely to the desire to utilize transmission networks for more flexible interchange transactions. Dynamics and stability have been studied for years in a long-term planning and design environment. The aim of the course is to develop an understanding of the basic concepts of synchronous machine modelling, power system dynamics, transient stability and voltage stability.

Prerequisite

- Nil

Course Outcomes

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

Course Outcome NO.	Course Outcomes	Blooms level
CO1	Explain the physical and time scale structure of power system	Understand
CO2	Explain synchronous machine modelling in stability studies	Understand
CO3	Explain and Classify power system stability problem.	Understand
CO4	Apply equal area criterion to power system	Apply
CO5	Apply Numerical methods to solve the swing equation	Apply
CO6	Apply voltage stability phenomena and methods to assess voltage stability	Apply

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		

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. Define power system stability.
2. Explain the time scale structure of power system dynamics.
3. Draw the dynamic structure of power system

Course Outcome 2 (CO2):

1. Draw the schematic diagram of synchronous machine with d and q axis.
2. Write and explain the basic equations of a synchronous machine.
3. Explain dq0 transformation.

Course Outcome 3 (CO3):

1. Classify power system stability problem
2. Define Transient stability
3. Derive the swing equation of a synchronous machine.

Course Outcome 4 (CO4):

1.

A three-phase, 60-Hz synchronous machine is driven at constant synchronous speed by a prime mover. The armature windings are initially open-circuited and field voltage is adjusted so that the armature terminal voltage is at the rated value (i.e., 1.0 per unit). The machine has the following per unit reactances and time constants.

$X''_d = 0.15$ pu $\quad \tau''_d = 0.035$ sec
$X'_d = 0.40$ pu $\quad \tau'_d = 1.0$ sec
$X_d = 1.20$ pu

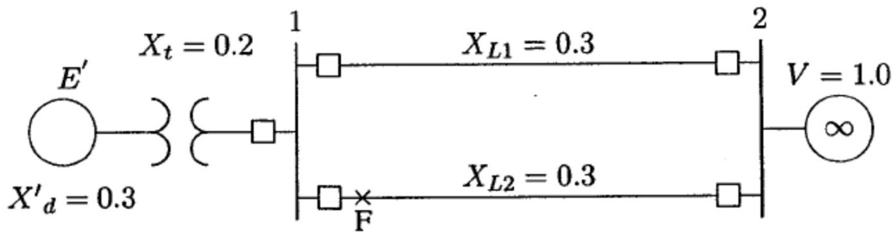
a) Determine the steady state, transient and subtransient short circuit currents.

2.

A 60-Hz synchronous generator having inertia constant $H = 5$ MJ/MVA and a direct axis transient reactance $X'_d = 0.3$ per unit is connected to an infinite bus through a purely reactive circuit as shown in Figure 11.21. Reactances are marked on the diagram on a common system base. The generator is delivering real power $P_e = 0.8$ per unit and $Q = 0.074$ per unit to the infinite bus at a voltage of $V = 1$ per unit.

(a) A temporary three-phase fault occurs at the sending end of the line at point F. When the fault is cleared, both lines are intact. Determine the critical clearing angle and the critical fault clearing time.

(b) A three-phase fault occurs at the middle of one of the lines, the fault is cleared, and the faulted line is isolated. Determine the critical clearing angle.



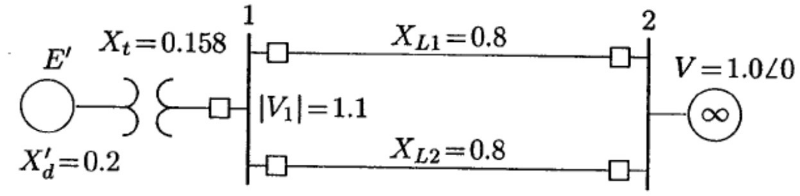
3.

A two-pole, 60-Hz synchronous generator has a rating of 250 MVA, 0.8 power factor lagging. The kinetic energy of the machine at synchronous speed is 1080 MJ. The machine is running steadily at synchronous speed and delivering 60 MW to a load at a power angle of 8 electrical degrees. The load is suddenly removed. Determine the acceleration of the rotor. If the acceleration computed for the generator is constant for a period of 12 cycles, determine the value of the power angle and the rpm at the end of this time.

Course Outcome 5 (CO5):

1.

A 60-Hz synchronous generator has a transient reactance of 0.2 per unit and an inertia constant of 5.66 MJ/MVA. The generator is connected to an infinite bus through a transformer and a double circuit transmission line, as shown in Figure 11.35. Resistances are neglected and reactances are expressed on a common MVA base and are marked on the diagram. The generator is delivering a real power of 0.77 per unit to bus bar 1. Voltage magnitude at bus 1 is 1.1. The infinite bus voltage $V = 1.0\angle 0°$ per unit. Determine the generator excitation voltage and obtain the swing equation as given by (11.36).



2. Explain the methodology of solving swing equation using Euler's method.
3. Explain the methodology of solving swing equation using Runke Kutta method.
4.

The machine of Problem 11.6 is delivering a real power input of 0.77 per unit to the infinite bus at a voltage of 1.0 per unit. The generator excitation voltage is $E' = 1.25$ per unit. A three-phase fault at the middle of one line is cleared by isolating the faulted circuit simultaneously at both ends.

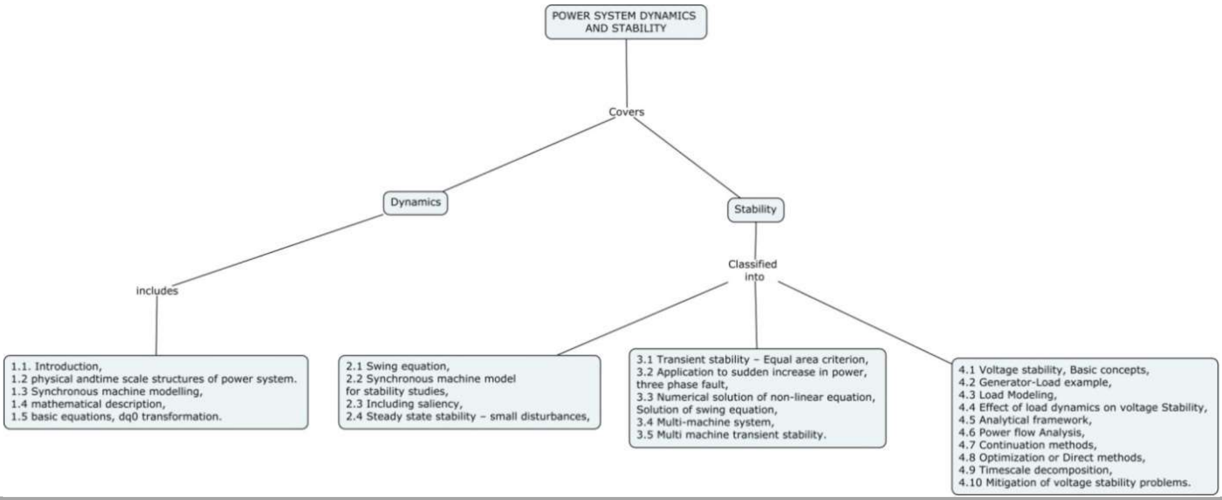
(a) The fault is cleared in 0.2 second. Obtain the numerical solution of the swing equation for 1.5 seconds. Select one of the functions **swingmeu**, **swingrk2**, or **swingrk4**.

(b) Repeat the simulation and obtain the swing plots when fault is cleared in 0.4 second, and for the critical clearing time.

Course Outcome 6 (CO6):

1. Define the term voltage stability
2. Explain the phenomenon of voltage collapse
3. Explain in detail load modelling in voltage stability studies.
4. Explain the method voltage stability assessment using continuation power flow method.

Concept Map



Syllabus

Introduction, physical and time scale structures of power system. Synchronous machine modelling, mathematical description, basic equations, dq0 transformation.
Swing equation, Synchronous machine model for stability studies, including saliency, Steady state stability – small disturbances, Transient stability – Equal area criterion, Application to sudden increase in power, three phase fault,
Numerical solution of non-linear equation, Solution of swing equation, Multi-machine system, Multi machine transient stability.
Voltage stability, Basic concepts, Generator-Load example, Load Modelling, Effect of load dynamics on voltage Stability, Analytical framework, Continuation methods, Direct methods, Timescale decomposition, Mitigation of voltage stability problems.

Reference Books

1. Peter W. Sauer, M. A. Pai, Joe H. Chow "Power System Dynamics and Stability: With Synchrophasor Measurement and Power System Toolbox, 2nd Edition, Sep 2017, Wiley-IEEE Press
2. P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
3. Leonard L. Grigsby, "The Electric Power Engineering Handbook", 3rd Edition, CRC Press, 2012.
4. HadiSaadat., 'Power System Analysis' Tata McGraw Hill Publishing Company, New Delhi, 2002

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	Introduction to Power System Dynamics and Stability	2
2	Physical and time scale structure	1
3	Synchronous machine modeling - Mathematical description	3
4	Basic equations of synchronous machine and dq0 transformation	3
5	Swing equation, Synchronous machine model for stability studies	3
6	Including saliency, Steady state stability – small disturbances,	2
7	Transient stability – Equal area criterion	3
8	Application to sudden increase in power, three phase fault,	2
9	Numerical solution of non-linear equation, Solution of swing equation	4

Module No.	Topic	No. of Lecture Hours
10	Multi-machine system, Multi-machine transient stability.	2
11	Voltage stability, Basic concepts, Generator-Load example	1
12	Load Modeling	1
13	Effect of load dynamics on voltage Stability	1
14	Analytical framework	2
15	Continuation power flow method	2
16	Direct methods	2
17	Timescale decomposition	1
18	Mitigation of voltage stability problems	1
	Total	**36**

Course Designers:

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18PS130	DESIGN OF RENEWABLE ENERGY SYSTEM	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

India's substantial and sustained economic growth is placing enormous demand on its energy resources. India has set an ambitious target of reaching 175 GW of installed capacity from renewable energy sources by the year 2022, which includes 100 GW of solar and 60 GW of wind power capacity. At the end of 2017-18 the total renewable power installed capacity in the country was almost 70 GW. In align with our national policy; this course creates awareness on various forms of renewable energy. And also makes the students to understand the design aspects of three major renewable source harvesting system such as Solar Photovoltaic system, wind energy conversion system and Small hydro power plant.

Prerequisite

Basic Electronics and Machines

Course Outcomes

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

CO No	Course Outcomes	Bloom's Level
CO1	Explain the Renewable Energy Development Policies in India and International context	Understand
CO2	Describe the concept of power generation using Solar PV cells	Understand
CO3	Evaluate a suitable solar PV power plant for the given specifications /requirements.	Evaluate
CO4	Describe the concept of power generation using wind energy	Understand
CO5	Design a Wind power generation unit to meet the given requirements.	Apply
CO6	Design a small hydro power plant for the given power generation requirements.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	M	M					L	L		L
CO2.	M	M	M					L	L		M
CO3.	M	M	M					L	L		M
CO4.	S	S	S	M	S	M	M		M	M	M
CO5.	S	S	S	M	S	M	M		M	M	M
CO6.	S	S	S	M	M	M	M		M	L	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	40	30	30	30
Apply	30	40	40	40
Analyse	10	10	10	10
Evaluate	--	--	--	--
Create	--	--	--	--

Assignment need to be given to cover the course outcome of CO3 in evaluate level.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the term ‘Primary and Secondary Energy’ with three examples.
2. What are the major pollutants in burning fossil fuels?
3. How much % of our Country’s oil consumption is imported and how much does it cost (approximately) per year?

Course Outcome 2 (CO2):

1. Annotate about the following: (i) Grid tied Solar PV systems.
2. Annotate about the following: (i) Standalone Solar PV systems & (ii) Hybrid Solar PV system
3. Suggest the best choice of inverters (Central, String and Micro) for Large, Medium and Small Scale Solar PV System. Also justify your choice.

Course Outcome 3 (CO3)

1. Design a Solar PV system for a house which contains 3 fans of 70 watts each running for 4 hours a day, 3 tube lights of 35 watts each running for 8 hours a day and a refrigerator of 250 watts running for 6 hours a day What are the hazards against which a transformer requires protection?
2. Calculate the battery size required to meet the energy requirement of a house, which demand a back-up power of 450VA load for 3 Hours daily. Assume, DC to AC energy conversion efficiency is 96% & Maximum permissible limit of energy drain is 85% of rated battery capacity.
3. Design a 1MW Gird-Tie Solar PV Plant, using a 200Watt Rated 33Volts Solar Module. Calculate the No. of Modules per String, No. of Strings per Row and No. of Rows for the Plant. The rated operating voltage of the String is 594Volts. Assume the required relevant data and also specify the same during the area calculation.

Course Outcome 4 (CO4)

1. What are the advantages of vertical axis turbine over to horizontal axis wind turbine?
2. Annotate about the following: (i) Basic components of wind electric system.
3. Discuss the factors to be considered while selecting a site for wind power plant

Course Outcome 5 (CO5)

1. Derive the power developed through a wind energy conversion mechanism. Also calculate the power in a wind moving with the speed of 5m/sec incident on a wind turbine with blades of 100m diameter. Also discuss how the power changes if the wind speed increases to 10m/sec.
2. Estimate the required size and cost of the wind turbine for the industry to meet it’s the annual energy requirement of 25000kwh. Consider the following additional details: Propeller type wind machine is selected; Co efficient of performance – 0.4; Wind speed at 15metre height is 8 metre/sec (Assume turbine hub is placed at the height of 15metre); Density of air - 1kg/m3; capacity factor – 0.30; No of hours in a year - 8760hours; the turbine generator unit overall losses is considered as 0.90; the cost of a wind turbine - 40000/kw.
3. A 1.2MW wind turbine cost Rs.7 Crores. The cost of energy sold to state electricity board is Rs.3.70 per kWh. The auxiliaries and Transformer loss is around 3.6% of overall energy generation. Calculate the simple payback period of the 1.2MW wind turbine installed in a place has the following wind energy frequency distribution data.

Wind Speed in m/s	Less than 5	5	6	7	8	10	12	14	15 to 24	More than 24
Power in	0	100	150	240	390	520	780	1050	1200	0

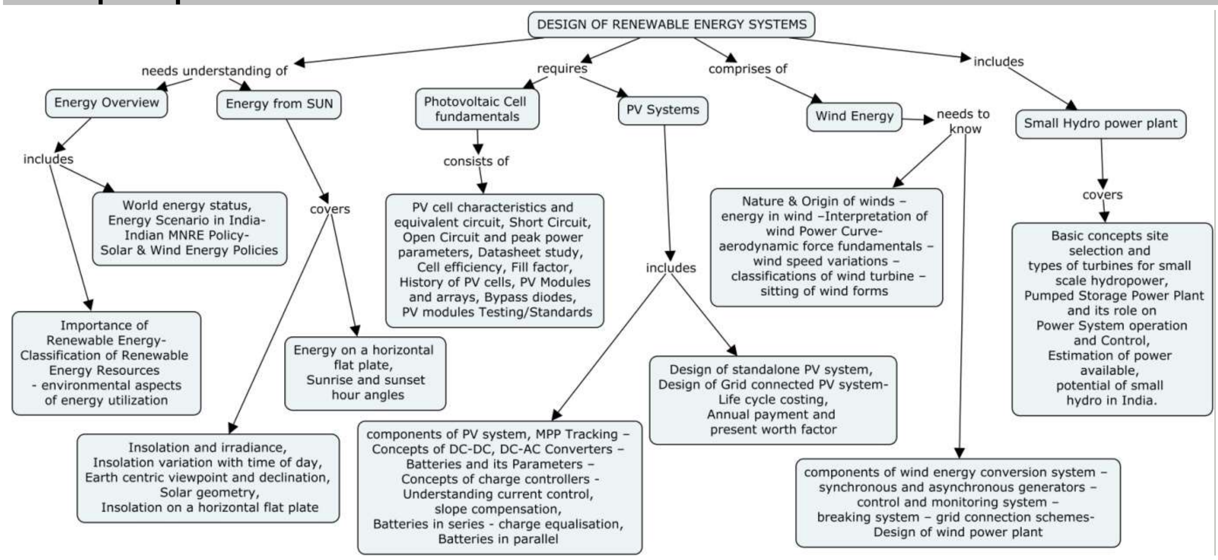
kW										
Hours in an Year	1900	500	400	600	600	2000	1000	760	500	500

4. A spinning mill plans to install a wind farm to meet 50% of their energy requirement with wind energy. Their daily yarn production is 15Tons. The mill operates 350days in a year. The specific energy consumption to produce 1kg of yarn is 4kwh. The wheeling charge is 2% of actual energy required for the power transfer between the wind turbine locations to the spinning mill locations. Design a wind farm for the mill. Assume Capacity Utilization factor of wind Turbine is 35%.

Course Outcome 6 (CO6)

1. A Pumped Storage Power plant runs in Generating Mode between 6.00 P.M to 9.00 P.M to supply 45MW to Grid during peak hour. The cost of power sold to grid is Rs.4.5 per kWh. The operating efficiency as generating mode is 95%. The plant runs at Pump Mode during Off-peak hours between 2.00 A.M to 5.00 A.M to pump back the water to upper basin at an operating efficiency of 94%. If, the cost of power consumed is Rs.2.5 per kWh. The plant operates 150Days in a year to meet the peak demand, Calculate the Cost savings.
2. A mini hydro electric plant proposed to install in a site, where the water stream flow rate is 60cubicmeter per second and head availability is 45 meter. A cross flow turbine having 75% conversion efficiency is installed. The generator efficiency is 90% and designe to operated between 0.8 Leading to 0.9 Lagging power factor codition. Calculate the power output from the hydro electric power plant. Also select a suitable KVA rating of the Generator for the plant.
3. A Small scale hydro power plant with pondage constructed across a river stream has an average flow rate of 4.5cubic meters per second. The head availability is 60meters. The stream flow is stored on daily basis in a pondage and utilized during peak hours between evening 6.00 P.M to 8.00.P.M to produce power to meet peak demand. A multijet turgo turbine having 72% conversion efficiency is used. The generator efficiency is 92%. Calculate the power and energy produce per day.

Concept Map



Syllabus

Energy Overview: Importance of Renewable Energy-Classification of Renewable Energy Resources - environmental aspects of energy utilization - World energy status, Energy Scenario in India- Indian MNRE Policy- Solar & Wind Energy Policies.

Energy from SUN: Insolation and irradiance, Insolation variation with time of day, Earth centric viewpoint and declination, Solar geometry, Insolation on a horizontal flat plate, Energy on a horizontal flat plate, Sunrise and sunset hour angles.

Photovoltaic Cell fundamentals: PV cell characteristics and equivalent circuit, Short Circuit, Open Circuit and peak power parameters, Datasheet study, Cell efficiency, Fill factor, History of PV cells, PV Modules and arrays, Bypass diodes, PV modules Testing/Standards, IEC Technical Committee 82 Solar Photovoltaic Energy System (IEC TC82).

PV Systems: components of PV system, MPP Tracking – Concepts of DC-DC, DC-AC Converters , Micro, String and Central inverters- Multi master inverter – Batteries and its Parameters – Concepts of charge controllers - Understanding current control, slope compensation, Batteries in series - charge equalisation, Batteries in parallel - Design of standalone PV system, Design of Grid connected PV system- Life cycle costing, Annual payment and present worth factor.

Wind Energy: Nature & Origin of winds – energy in wind –Interpretation of wind Power Curve-aerodynamic force fundamentals – wind speed variations – classifications of wind turbine – sitting of wind forms - components of wind energy conversion system – synchronous and asynchronous generators – control and monitoring system – breaking system – grid connection schemes- Design of wind power plant, Solar Wind hybrid System.

Small Hydro power plant: Basic concepts site selection and types of turbines for small scale hydropower, Pumped Storage Power Plant and its role on Power System operation and Control, Estimation of power available, potential of small hydro in India.

Reference Books

1. Chetan singh solanki, 'Solar Photovoltaic – fundamentals, technologies and applications', PHI learning Pvt. Ltd., New Delhi – 2011
2. Siraj Ahmed, 'Wind energy Theory and Practice', PHI learning Pvt. Ltd., New Delhi – 2013
3. M. M. El-Wakil, 'Power plant Technology', McGraw Hill Education, 2017
4. Abbasi S.A, Abbasi Naseema, Renewable Energy Resources & Their Environmental Impact, Prentice Hall of India, 2001
5. Garg.H.P, Prakash.J, Solar Energy, Tata McGraw Hill, New Delhi, 2000
6. Razykov et al., 'Solar photovoltaic electricity: Current status and future prospects', Volume 85, Issue 8, August 2011, Pages 1580-1608.
7. Dongxiao Wang et al., 'Utilisation of kinetic energy from wind turbine for grid connections: a review paper', IET Renewable Power Generation, 2018, Volume: 12, Issue: 6, Pages: 615 – 624.
8. Rishabh Abhinav et al., 'Grid integration of wind turbine and battery energy storage system: Review and key challenges', 2016 IEEE 6th International Conference on Power Systems (ICPS), pages 1-6.
9. M. Ramesh et al., 'A concise review on different aspects of wind energy system', 2016 3rd International Conference on Electrical Energy Systems (ICEES), Pages: 222 - 227
10. Edward Baleke Ssekulima et al., 'Wind speed and solar irradiance forecasting techniques for enhanced renewable energy integration with the grid: a review', IET Renewable Power Generation,Year: 2016, Volume: 10, Issue: 7,Pages: 885 – 989.
11. G.D.Rai, Non-Conventional Energy Sources, Khanna Publishers, 2015

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	**Energy Overview:**	
1.1	Importance of Renewable Energy-Classification of Renewable Energy Resources	1
1.2	Environmental aspects of energy utilization - World energy status, Energy Scenario in India	1
1.3	Indian MNRE Policy- Solar & Wind Energy Policies.	1

Module No.	Topic	No. of Lectures
2.	**Energy from SUN:**	
2.1	Insolation and irradiance, Insolation variation with time of day	1
2.2	Earth centric viewpoint and declination, Solar geometry	1
2.3	Insolation on a horizontal flat plate, Energy on a horizontal flat plate, Sunrise and sunset hour angles.	1
3.	**Photovoltaic Cell fundamentals**:	
3.1	PV cell characteristics and equivalent circuit, Short Circuit, Open Circuit and peak power parameters	2
3.2	Datasheet study, Cell efficiency, Fill factor	2
3.3	History of PV cells, PV Modules and arrays	2
3.4	Bypass diodes, PV modules Testing/Standards, IEC Technical Committee 82 Solar Photovoltaic Energy System (IEC TC82).	2
4.	**PV Systems**:	
4.1	components of PV system, MPP Tracking – Concepts of DC-DC, DC-AC Converters- Micro, String and Central inverters- Multi Master Inverter	2
4.2	Batteries and its Parameters – Concepts of charge controllers - Understanding current control, slope compensation	2
4.3	Batteries in series - charge equalisation, Batteries in parallel -	2
4.4	Design of standalone PV system, Design of Grid connected PV system	2
4.5	Life cycle costing, Annual payment and present worth factor	2
5.	**Wind Energy**:	
5.1	Nature & Origin of winds – energy in wind	2
5.2	Interpretation of wind Power Curve- aerodynamic force fundamentals – wind speed variations	2
5.3	Classifications of wind turbine –sitting of wind forms - components of wind energy conversion system – synchronous and asynchronous generators	2
5.4	Control and monitoring system – breaking system – grid connection schemes- Design of wind power plant	2
5.5	Solar - Wind Hybrid System	
6	**Small Hydro power plant:**	
6.1	Basic concepts site selection and types of turbines for small scale hydropower	1
6.2	Pumped Storage Power Plant and its role on Power System operation and Control	2
6.3	Estimation of power available, potential of small hydro in India.	2
	Total	**38**

Course Designers:

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18PS160	ANALYSIS OF MODERN POWER SYSTEM	Category	L	T	P	Credit
		PC	2	0	2	3

Preamble

Power system modeling and analysis is a vital one to understand the existing power system. The electricity industry throughout the world, which has long been dominated by vertically integrated utilities, is undergoing enormous changes. Restructuring is a fairly new paradigm and just as in the case of other industries where it has been introduced, the goal of restructuring 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. Therefore in the restructuring of modern power system faces many technical challenges. Transmission Pricing, Available Transfer Capability and congestion management have to be dealt.

Course Outcomes

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

Course Outcome NO.	Course Outcomes	Blooms level
CO1	Modelling of power system components, Formation of bus admittance matrix with and without mutual coupling	Apply
CO2	Perform power flow analysis using Gauss- Siedel, Newton-Raphson, and Fast decoupled load flow methods	Apply
CO3	Explain the restructuring process, new entities in power market and benefits.	Understand
CO4	Explain the concepts of power pools and transaction issues.	Understand
CO5	Determine transmission price, available transfer capability and congestion management issues in modern power system.	Apply
CO6	Analyze the power flow of given power system by Gauss-Siedel, Newton-Raphson, and Fast decoupled load flow methods using simulation software	Analyze
CO7	Analyze the available transfer capability of the given restructured power system using Simulation software.	Analyze

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Practical test	Terminal Examination
	1	2	3		
Remember	20	20	20	0	20
Understand	40	40	40	0	40
Apply	40	40	40	40	40
Analyse	0	0	0	60	0
Evaluate	0	0	0	0	0
Create	0	0	0	0	0

Practical test should be conducted as a practical examination for evaluating the attainment of CO6 and CO7

Course Level Assessment Questions

Course Outcome 1 (CO1):

1.What is single line diagram ?

2.What are the advantages of per unit system?

3.Draw the reactance diagram for the power system shown in Fig.1. Neglect the resistance and use a base of 50 MVA and 13.8 KV on generator G_1.

G_1: 20MVA, 13.8KV, X''=20% ; G_2: 30MVA, 18.0KV, X''=20%
G_3: 30MVA, 20.0KV, X''=20% ;T_1: 25MVA, 220/13.8 KV, X =10%
T_2:3Single phase unit each rated 10MVA, 127/18 KV, X =10%
T_3: 35MVA, 220/22 KV, X =10%

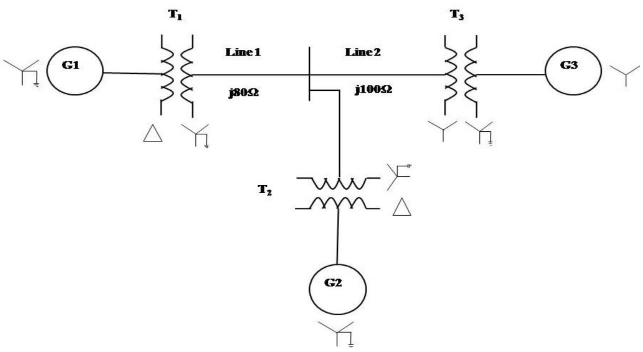


Fig.1

4. Develop the relation between bus admittance matrix, bus incidence matrix and primitive admittance matrix.

Course Outcome 2 (CO2):

1. State the load flow problem.

What are the three types of buses used to define the power flow problem?

2. The following is the system data for a load flow solution. Determine the voltages at the end of first iteration using Gauss-Seidel method and Newton Raphson method. Take α=1.6.

The line admittances:

Bus code	*Admittance*
1-2	2-j8.0
1-3	1-j4.0
2-3	0.666-j2.664
2-4	1-j4.0
3-4	2-j8.0

The schedule of active and reactive powers:

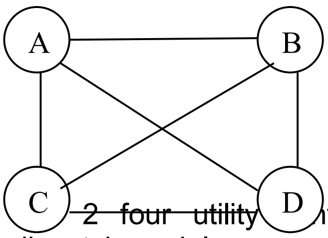
Bus code	P in p.u	Q in p.u	V in p.u	Remarks
1	-	-	1.06	Slack
2	0.5	0.2	1+j0.0	PQ
3	0.4	0.3	1+j0.0	PQ
4	0.3	0.1	1+j0.0	PQ

Course Outcome 3 (CO3):

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 4 (CO4):

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 Fig 2 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



2 four utility t 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 5 (CO5):

1. Explain the Mw-mile method of transmission pricing with a suitable example.
2. 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
3. What are the various methods used to determine Available transfer capability.
4. what are the various congestion management methods and explain it in detail

Course Outcome 6 (CO6):

1. Determine the Ybus matrix of the representative power system network diagram as shown below. Verify the result using MATLAB program

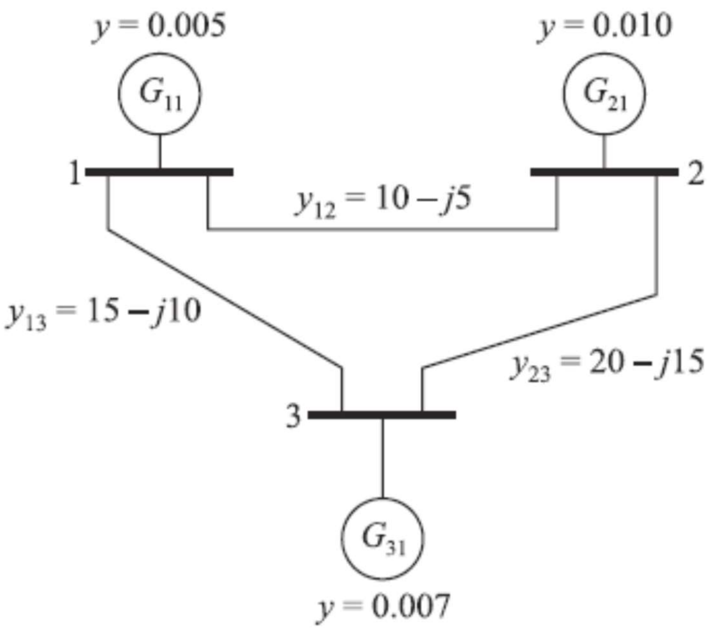


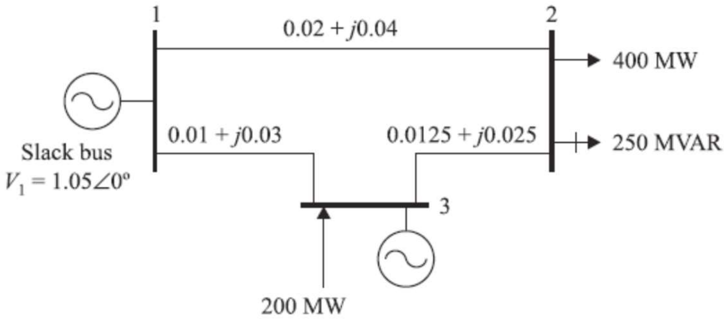
Fig.3

Form Y bus using power world simulator software and the visualisation is as shown in figure below

	Number	Name	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5
1	1	1	6.25 - j18.70	-5.00 + j15.00	-1.25 + j3.75		
2	2	2	-5.00 + j15.00	10.83 - j32.42	-1.67 + j5.00	-1.67 + j5.00	-2.50 + j7.50
3	3	3	-1.25 + j3.75	-1.67 + j5.00	12.92 - j38.70	-10.00 + j30.00	
4	4	4		-1.67 + j5.00	-10.00 + j30.00	12.92 - j38.70	-1.25 + j3.75
5	5	5		-2.50 + j7.50		-1.25 + j3.75	3.75 - j11.21

Fig 4

Obtain the load flow result using power world simulator software of the given system as shown below



	Number	Name	Jacobian Equation	Angle Bus 2	Angle Bus 3	Volt Mag Bus 2	Volt Mag Bus 3
1	2	2	Real Power	51.71	-31.76	21.24	-16.80
2	3	3	Real Power	-33.03	65.71	-15.32	28.99
3	2	2	Reactive Power	-28.66	17.47	48.23	-30.53
4	3	3	Voltage Magnitude				1.00

Fig: 5 Jacobian values

```
Bus Flows
BUS        1 1              138.0    MW      Mvar       MVA    % 1.0500    0.00    1 1
 GENERATOR 1                       213.54   136.29R   253.3
 TO        2 2              1      177.35   113.36    210.5    0
 TO        3 3              1       36.18    22.94     42.8    0
 **** Mismatch ****                213.54   136.29
BUS        2 2              138.0    MW      Mvar       MVA    % 0.9741   -2.70    1 1
 LOAD 1                            400.00   250.00    471.7
 TO        1 1              1     -169.32   -97.28    195.3    0
 TO        3 3              1     -229.08  -139.14    268.0    0
 **** Mismatch ****                 -1.60   -13.58
BUS        3 3              138.0    MW      Mvar       MVA    % 1.0400   -0.45    1 1
 GENERATOR 1                       200.00   135.63R   241.6
 TO        1 1              1      -36.01   -22.44     42.4    0
 TO        2 2              1      238.54   158.07    286.2    0
 **** Mismatch ****                197.47   135.62
```

Fig.: 6 Power flow results

Course Outcome 7 (CO7):

1. Determine the ATC for the assumed transaction in the MATLAB using Power transfer Distribution factor (PTDF)
2. Determine the ATC for the transaction between bus 2 and 28 of the IEEE 30 bus system in the MATLAB using Power transfer Distribution factor (PTDF)

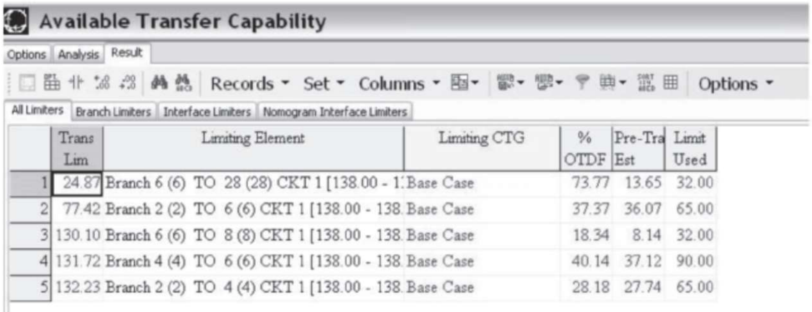


Fig. 7

List of Experiments using simulation software

Form the Ybus matrix of the given power system without mutual coupling.

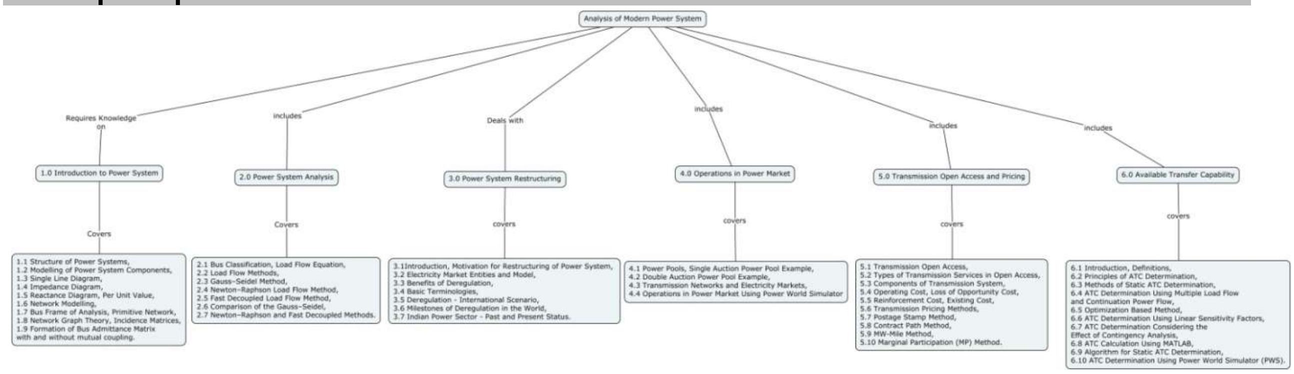
Form the Ybus matrix of the given power system with mutual coupling

Perform the load flow of the given power system using Gauss seidel method

Perform the load flow of the given power system using Newton Raphson method

Determine the Available Transfer Capability of the given power system

Concept Map



Syllabus

Introduction to Power System

Structure of Power Systems, Modelling of Power System Components, Single Line Diagram, Impedance Diagram, Reactance Diagram, Per Unit Value, Network Modelling, Bus Frame of Analysis, Primitive Network, Network Graph Theory, Incidence Matrices, Formation of Bus Admittance Matrix with and without mutual coupling.

Power Flow Analysis

Bus Classification, Load Flow Equation, Load Flow Methods, Gauss–Seidel Method, Newton–Raphson Load Flow Method, Fast Decoupled Load Flow Method, Comparison of the Gauss–Seidel, Newton–Raphson and Fast Decoupled Methods, Three phase load flow.

Power System Restructuring

Introduction, Motivation for Restructuring of Power System, Electricity Market Entities and Model, Benefits of Deregulation, Basic Terminologies, Deregulation - International Scenario, Milestones of Deregulation in the World, Indian Power Sector - Past and Present Status.

Operations in Power Market
Power Pools, Single Auction Power Pool Example, Double Auction Power Pool Example, Transmission Networks and Electricity Markets, Operations in Power Market Using Power World Simulator

Transmission Open Access and Pricing
Transmission Open Access, Types of Transmission Services in Open Access, Components of Transmission System, Transmission Pricing Methods

Available Transfer Capability
Introduction, Definitions, Principles of ATC Determination, Methods of Static ATC Determination, ATC Determination Using Multiple Load Flow and Continuation Power Flow, Optimization Based Method, ATC Determination Using Linear Sensitivity Factors, ATC Calculation Using MATLAB, Algorithm for Static ATC Determination, ATC Determination Using Power World Simulator (PWS).

Transmission Congestion Management
Introduction, Congestion, Classification of Congestion Management, Existing Cluster / Zone Based Approach, Cluster / Zone Based Transmission Congestion Management. Re-dispatch, Load Curtailment, Rescheduling Cost.

Reference books:

1. P. Venkatesh, B. V. Manikandan, S. Charles Raja and A. Srinivasan, 'Electrical Power Systems: Analysis, Security and Deregulation', PHI Learning Pvt. Ltd., Second Edition, 2017.
2. John J. Grainger and Stevenson Jr. W.D., 'Power System Analysis', McGraw Hill International Edition, Fourth Edition, 1994.
3. Nagarath.I.J, Kothari.D.P, 'Modern Power System Analysis', Tata McGraw Hill Pub. Co. Ltd., Third Edition, 2004.
4. Hadi Saadat., 'Power System Analysis' Tata McGraw Hill Publishing Company, New Delhi, 2002
5. Stagg, G.W. and El-Abiad, A.H., Computer Methods in Power System Analysis", McGraw-Hill Book Co. 1968
6. J. Duncan Glover, Thomas Overbye, Mulukutla S. Sarma,'Power System Analysis and Design' Cengage learning, 5th edition, 2016.
7. www.schneider-electric.com
8. NPTEL courses web: nptel.ac.in/courses/
9. MOOCs course link:https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	Modelling of Power System Components, Single Line Diagram	2
2	Per unit value and reactance diagram	3
3	Network Modelling, Bus Frame of Analysis, Primitive Network, Network Graph Theory, Incidence Matrices	3
4	Formation of Bus Admittance Matrix with and without mutual coupling.	2
5	Load Flow Equation, Load Flow Methods - Gauss–Seidel	1

Module No.	Topic	No. of Lecture Hours
	Method	
6	Newton–Raphson Load Flow Method, Fast Decoupled Load Flow Method	2
7	Three phase load flow	2
8	Introduction, Motivation for Restructuring of Power System	1
9	Electricity Market Entities and Model, Benefits of Deregulation	1
10	Deregulation - International Scenario, Milestones of Deregulation in the World	1
11.	Indian Power Sector- Past and Present status	1
11	Power Pools, Single Auction Power Pool Example,	2
12	Double Auction Power Pool Example,	2
13	Transmission Networks and Electricity Markets	2
14	Operations in Power Market Using Power World Simulator	2
15	Transmission Open Access, Types of Transmission Services in Open Access,	2
16	Cost Components of Transmission System	2
17	Transmission Pricing Methods	2
18	MW-Mile Method	2
19	Marginal Participation (MP) Method	1
20	Available Transfer Capability (ATC), Introduction, Definitions, Principles of ATC Determination	1
21	Methods of Static ATC Determination	2
22	ATC Determination Using Linear Sensitivity Factors	2
23	ATC Calculation Using MATLAB	2
24	ATC Determination Using Power World Simulator	2
25	Transmission congestion management (CM) -introduction	1
26	Cluster / Zone Based Approach CM	1
27	CM using Transmission Congestion Distribution Factors Redispatch and load curtailment	2
	Total	**48**

Course Designers:

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18PS170	**POWER SYSTEM LABORATORY**	Category	L	T	P	Credit
		PC	0	0	4	2

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

NIL

Course Outcomes

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

CO1	Solve power system problems using MATLAB	Analyze
CO2	Perform Power System simulation studies using Power World Simulator, EMTP, Digsilent software	Analyze

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

<u>List of Experiments</u>:

In order to do the simulation studies in power system, MATLAB / Simulink, or industrial software like PWS, Digsilent, EMTP, open source software can be used.

1. Solution of Swing Equation using Step by Step Method.
2. Simulation of SVC for reactive power compensation.
3. Design of state feedback controller and state observer for a given single area power system.
4. Simulation study on power flow analysis.
5. Simulation study on optimal power flow.
6. Analysis of travelling waves impact on transmission line with Line Terminated with load resistance and Line Open at receiving end.
7. Analysis of I-V characteristics of solar cell at different series/parallel configurations using solar simulation system.

Course Designers:

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3.	Dr.V.Mahesh	maheshv@tce.edu

18PS210	POWER SYSTEM SECURITY AND CONTROL	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Power system practices are used 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. Analytical frame work is needed and is used to control the bulk power systems in such a fashion to improve power system security. Also, power system operators have the responsibility to ensure equilibrium between load and generation at all time. As constancy of frequency and voltage are important factors in determining the quality of power is vital to the satisfactory performance of power system. This course deals with both power system security and control related topics.

Prerequisite

- 18PS120:Power System Dynamics and Stability

Course Outcomes

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

Course Outcome No.	Course Outcomes	**Blooms level**
CO1.	Explain the operating state of power system with relevance to security and control.	Understand
CO2.	Determine the performance index (PI) for various contingencies.	Analyse
CO3.	Estimate the state of the power system in terms of its measured values and bad data identification.	Apply
CO4.	Find optimum power flow in terms of real and reactive powers with different objectives and constraints.	Apply
CO5.	Find optimum unit commitment schedule of a power system.	Apply
CO6.	Explain the concept of AGC for power system.	Understand
CO7.	Explain the concept of AVR for power system.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO	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	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	40	50	30	30
Apply	20	30	30	30
Analyse	20	-	20	20
Evaluate	-	-	-	-
Create	-	-	-	-

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. List the various contingencies that are generally considered for steady state security analysis. Explain the major functions of system security control.

Course Outcome 2 (CO2):

1. 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.
2. 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

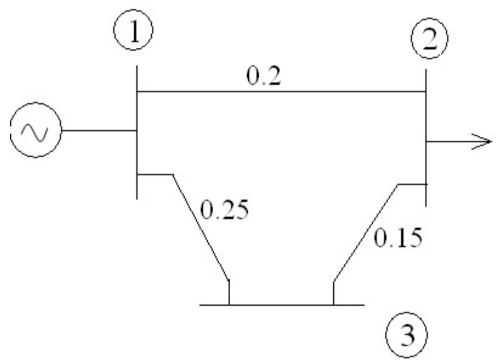
Bus Data

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

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. 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. 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 5 (CO5):

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

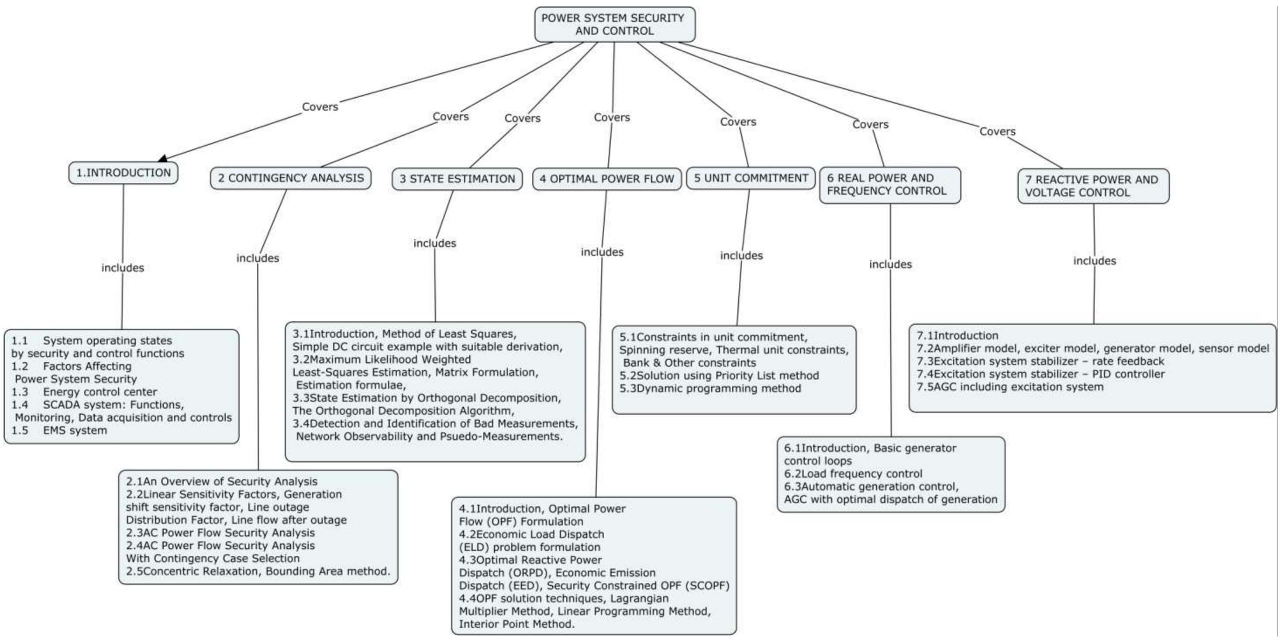
Course Outcome 6 (CO6):

1. Explain the operation of AGC with optimal dispatch of generation.
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 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 excitation system stabilizer with PID controller.
3. Draw the functional block diagram, and explain the working of excitation system stabilizer with rate feedback

Concept Map



Syllabus

INTRODUCTION

System operating states by security and control functions, Factors Affecting Power System Security, Energy control center, SCADA system: Functions, Monitoring, Data acquisition and controls, EMS system.

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.

UNIT COMMITMENT
Constraints in unit commitment, Spinning reserve, Thermal unit constraints, Bank & Other constraints, Solution using Priority List method, Dynamic programming method.

REAL POWER AND FREQUENCY CONTROL
Introduction, Basic generator control loops, load frequency control, Automatic generation control, AGC with optimal dispatch of generation.

REACTIVE POWER AND VOLTAGE CONTROL
Introduction, amplifier model, exciter model, generator model, sensor model, excitation system stabilizer – rate feedback, excitation system stabilizer – PID controller, AGC including excitation system.

Reference Books

1. Allen J.Wood and Bruce.F.Wollenberg, "Power Generation Operation and Control", John Wiley & Sons, New York, 1996.
2. Hadi Saadat., 'Power System Analysis' Tata McGraw Hill Publishing Company, New Delhi, 2002
3. P.Venkatesh, B.V.Manikandan, S.Charles raja and A.Srinivasan, "Electrical power systems analysis, Security and Deregulation", PHI 2012.
4. John J. Graignaer and William D. Stevenson, Power system analysis, Tata Mc Graw Hill, 2003.
5. Kundur.P; "Power System Stability and Control", EPRI Publications, California, 1994.
6. Elgerd.O.I, "Electric Energy System Theory – an Introduction", Tata McGraw Hill, New Delhi – 2002.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	INTRODUCTION	
1.1	System operating states by security and control functions	**1**
1.2	Factors Affecting Power System Security	**1**
1.3	Energy control center	**1**
1.4	SCADA system: Functions, Monitoring, Data acquisition and controls	**1**
1.5	EMS system	**1**
2	**CONTINGENCY ANALYSIS**	
2.1	An Overview of Security Analysis	**1**
2.2	Linear Sensitivity Factors, Generation shift sensitivity factor, Line outage Distribution Factor, Line flow after outage	**2**
2.3	AC Power Flow Security Analysis	**1**
2.4	AC Power Flow Security Analysis With Contingency Case Selection	**1**
2.5	Concentric Relaxation, Bounding Area method.	**1**
3	**STATE ESTIMATION**	
3.1	Introduction, Method of Least Squares, Simple DC circuit example with suitable derivation,	**2**
3.2	Maximum Likelihood Weighted Least-Squares Estimation, Matrix Formulation, Estimation formulae,	**2**

Module No.	Topic	No. of Lectures
3.3	State Estimation by Orthogonal Decomposition, The Orthogonal Decomposition Algorithm,	1
3.4	Detection and Identification of Bad Measurements, Network Observability and Psuedo-Measurements.	2
4	**OPTIMAL POWER FLOW**	
4.1	Introduction, Optimal Power Flow (OPF) Formulation	1
4.2	Economic Load Dispatch (ELD) problem formulation	1
4.3	Optimal Reactive Power Dispatch (ORPD), Economic Emission Dispatch (EED), Security Constrained OPF (SCOPF)	2
4.4	OPF solution techniques, Lagrangian Multiplier Method, Linear Programming Method, Interior Point Method.	2
5	**UNIT COMMITMENT**	
5.1	Constraints in unit commitment, Spinning reserve, Thermal unit constraints, Bank & Other constraints	1
5.2	Solution using Priority List method	1
5.3	Dynamic programming method	2
6	**REAL POWER AND FREQUENCY CONTROL**	
6.1	Introduction, Basic generator control loops	1
6.2	Load frequency control	1
6.3	Automatic generation control, AGC with optimal dispatch of generation	1
7	**REACTIVE POWER AND VOLTAGE CONTROL**	
7.1	Introduction	1
7.2	Amplifier model, exciter model, generator model, sensor model	1
7.3	Excitation system stabilizer – rate feedback	1
7.4	Excitation system stabilizer – PID controller	1
7.5	AGC including excitation system	1
	Total	**36**

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		Category	L	T	P	Credit
18PS260	**POWER SYSTEM PROTECTION**	PC	2	0	2	3

Preamble

The electric power system is a highly complex and dynamic entity. One malfunction or a carelessly set relay can jeopardize the entire grid. The proper operation of a power system requires an efficient, reliable and fast-acting protection scheme, which consists of protective relays and switching devices. There has been continuous improvement in the design of relaying schemes. In order to provide a foolproof protection system to the power system, innovative technology is complementing the conventional protection system. With revolutionary changes in the power system and tremendous developments in computer hardware technology, numerical relays are fast replacing the conventional protective relays. This course has been designed in order to keep abreast of the recent developments in power system protections.

Prerequisite

NIL

Course Outcomes

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

CO1	Explain the various components of a protection system (CO1)	Understand
CO2	Compute the settings of over current relay (CO2)	Apply
CO3	Explain the principles of differential and distance protection relays (CO3)	Understand
CO4	Apply the protection schemes for different power system apparatus (CO4)	Apply
CO5	Explain the basic principles of numerical protection (CO5)	Understand
CO6	Use the numerical relaying algorithms to develop numerical protection of transformer and line (CO6)	Apply
C07	Realize the characteristics of different types of protective relays.	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Practical test**	**Terminal Examination***
	1	**2**	**3**		
Remember	20	20	20	0	20
Understand	40	40	40	0	40
Apply	40	40	40	100	40
Analyse	0	0	0	0	0
Evaluate	0	0	0	0	0
Create	0	0	0	0	0

Practical test should be conducted for assessing the attainment of C07.

***Terminal examination covers theory part only.**

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define ‘pick-up’ and ‘reset level’ of relay.
2. Discuss the essential qualities of a protective relay.
3. Discuss the significance of instrument transformers in protective schemes.
4. Discuss the standards applied for LV protection schemes.
5. Explain the construction and operation of a static relay with a neat block diagram.
6. Explain the duality between phase and amplitude comparators.
7. Compare the technical features of electromechanical relays, static relays and numerical relays.

Course Outcome 2 (CO2):

4. Describe the operating principle and characteristics of various types of over current relays. Also, mention their applications.
5. With a block diagram, discuss how an intentional time delay is introduced in definite time OC relays?
6. The current rating of a relay is 5 A. PSM=1.5, CT ratio 400/5, fault current = 6000 A. Determine the operating time of the relay for a TMS = 0.4. At TMS =1, the operating time at various PSM are:

PSM	2	4	5	8	10	20
Operating Time (s)	10	5	4	3	2.8	2.4

7. Determine the actual time of operation of a 5 ampere, 3 second over current relay having a current setting of 125% and a time setting multiplier of 0.6 connected to supply circuit through a 400/5 current transformer when the circuit carries a fault current of 4000 A. Time of operation is 3.5 seconds for the estimated value of PSM.
8. What are the different inverse-time characteristics of overcurrent relays? Explain in brief.
9. Explain why distance protection schemes are preferred than over current protection for the transmission lines.
10. Show how IDMT characteristics can be realized in a static overcurrent relay.

Course Outcome 3(CO3):

1. Explain why conventional differential protection cannot detect interturn faults on the same phase.
2. Discuss the setting of distance relay.
3. Explain the construction and working of,
   i) Definite distance type impedance relay
   ii) Distance time impedance relay
4. Describe the construction and working principle of percentage differential relay. How the percentage differential relay overcomes the drawbacks of the simple differential relay?
5. Explain the concept of carrier-aided distance protection schemes.

Course Outcome 4(CO4):

1. Suggest suitable type of distance relays for the protection of long, medium and short lines against (i) ground faults and (ii) phase faults. Also give reasons.
2. Select a suitable type of protective scheme employed for the protection of the field winding of the alternator against ground faults? Justify your answer.
3. How to distinguish between the fault current and magnetising inrush current in a power

transformer? Demonstrate the functioning of a suitable protective scheme which protects the transformer against internal faults but does not operate in case of magnetizing inrush current.
4. With a neat sketch, illustrate the differential scheme for buszone protection.
5. What sort of protective devices are used other than the differential protection for the protection of a large transformer? Briefly describe them.
6. Discuss the applications of Buchholz relay.
7. A 11kV, 100 MVA generator is grounded through a resistance of 6Ω. The C.T.s have a ratio of 1000/5. The relay is set to operate when there is an out of balance current of 1A. Calculate the percentage of the generator winding that will be protected by the percentage differential scheme of protection.

Course Outcome 5(CO5)

11. State and explain Shannon's sampling theorem.
12. With the help of block diagram, discuss the operation of the numerical relay.
13. Explain the role of signal conditioner in a data acquisition system. Discuss the functions of various components of the signal conditioner.
14. Compare the various relaying algorithms used for digital protection.

Course Outcome 6(CO6)

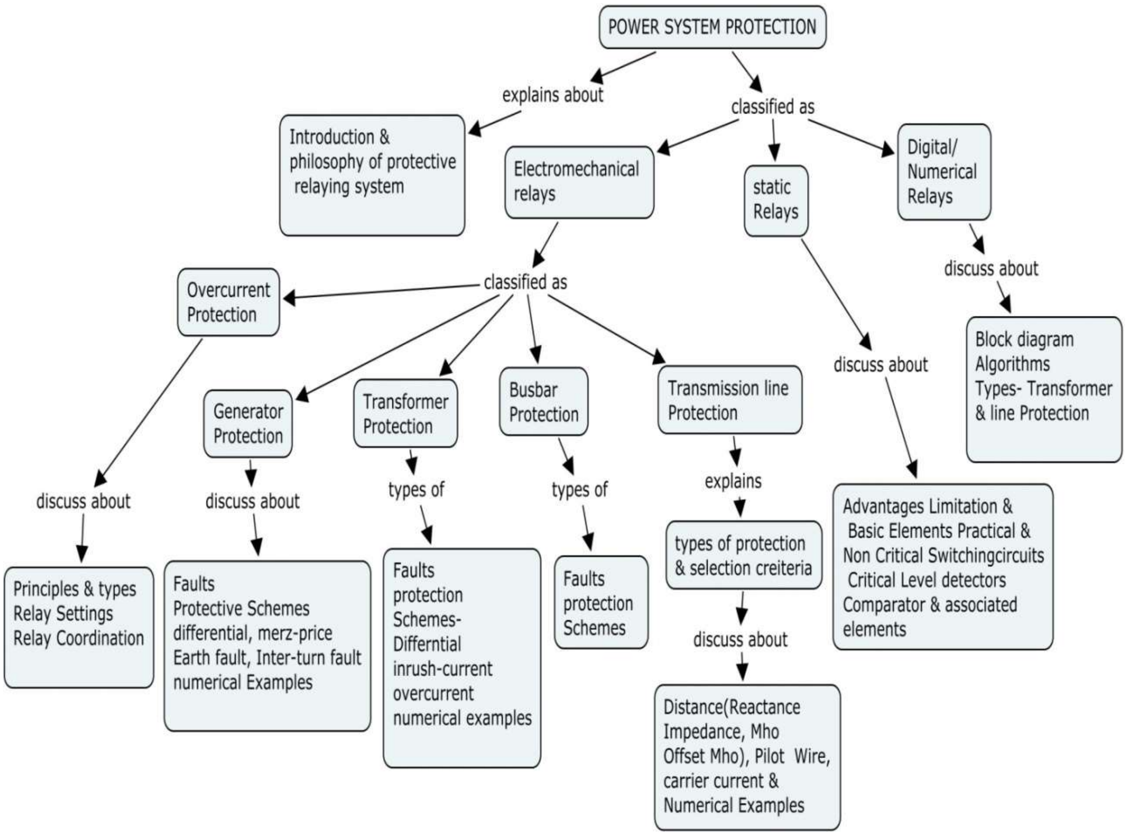
1. Derive a generalized mathematical expression of distance relays for numerical protection.
2. Demonstrate the operation of a numerical transformer protection scheme with a neat block diagram.
   Illustrate how numerical relaying concept is applied for a 200 meter long transmission line.

Course Outcome 7(CO7).

Laboratory Session – Tentative list of experiments (24 Hours)

The evaluation is based on the conduct of following experiments in the laboratory:
1. Simulation of Tripping characteristics of Fuse and MCB.
2. Realization of over current relay characteristics using MATLAB simulink.
3. Realization of over voltage relay using 8051 microcontroller trainer kit
4. Realization of negative sequence relay using hardware module.
5. Realization of differential relay using hardware module.
6. Transformer Differential Relay modelling using MATLAB.
7. Study of Radial Feeder Protection using hardware module.
8. Distance Protection function using DigSILENT software.
9. Steady-state simulation of fault clearance and relay responses using DigSILENT software.
10. Realization of zone protection characteristics of a transformer and a motor in a network using DigSILENT software.

Concept Map



Syllabus

Introduction

General philosophy of protection - Protection system components - circuit breakers- relay terminology – Relay input sources - CT and VT for protective applications –- standards.

Relay construction and operating principles

Electromechanical relays, Static relays, Numerical relays – Time current characteristics and settings of over current relays - over current relay co-ordination - operating principles of differential and distance relays.

Apparatus protection

Protection of generators – Transformer protection – magnetizing inrush current –connection of transformer differential relays – Bus bar protection- Techniques applicable for line protection.

Numerical protection

Introduction- Block diagram of numerical relay - numerical relaying algorithms - numerical over-current protection - Numerical transformer differential protection- Numerical distance protection of transmission line.

Reference Books

1. Lewis Blackburn, J., Thomas J. Domin, Protective Relaying – Principles and Applications‟, 3rd edition, CRC Press, , New York, 2006.
2. Fundamentals of Power System Protection, Y.G.Paithankar and S.R.Bhide, 2003, Prentice Hall of India, New Delhi.
3. Power System Protection and Switchgear, BadriRam and D.N.Vishwakarma, 2nd edition 2011, Tata McGraw Hill, New Delhi.
4. Stanley, H.Horowitz (ED), „Protective relaying for power systems II‟, IEEE Press, 1992.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Introduction**	
1.1	General Philosophy of Protection-Protection system components.	1
1.2	Circuit breakers.	2
1.3	Relay terminology-relay input sources.	1
1.4	CT and VT for protective applications	1
1.5	Standards.	1
2.0	**Relay construction and operating principles**	
2.1	Electro-magnetic relays, static relays, numerical relays.	2
2.2	Time current characteristics and settings of over-current relays	1
2.3	over current relay co-ordination	1
2.4	Numerical examples	1
2.5	Operating principles of differential relays.	1
2.6	Operating principles of distance relays	1
3.0	**Apparatus Protection**	
3.1	Protection of generators.	1
3.2	Transformer protection-Magnetizing inrush current-connection of transformer differential relays.	1
3.3	Bus bar protection	1
3.4	Techniques applicable for line protection.	2
3.5	Numerical examples	1
4.0	**Numerical protection**	
4.1	Introduction to digital protection & block diagram of numerical relay	1
4.2	Numerical relaying algorithms.	1
4.2	Numerical Over-current protection	1
4.3	Numerical transformer differential protection	1
4.4	Numerical distance protection of transmission line.	1
	Total	**24**

Laboratory Session – Tentative list of experiments (24 Hours)

The evaluation is based on the conduct of following experiments in the laboratory:

1. Simulation of Tripping characteristics of Fuse and MCB.
2. Realization of over current relay characteristics using MATLAB simulink.
3. Realization of over voltage relay using 8051 microcontroller trainer kit
4. Realization of negative sequence relay using hardware module.
5. Realization of differential relay using hardware module.
6. Transformer Differential Relay modelling using MATLAB.
7. Study of Radial Feeder Protection using hardware module.
8. Distance Protection function using DigSILENT software.
9. Steady-state simulation of fault clearance and relay responses using DigSILENT software.
10. Realization of zone protection characteristics of a transformer and a motor in a network using DigSILENT software.

Course Designers:

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18PS270	ENERGY MANAGEMENT SYSTEM LABORATORY	Category	L	T	P	Credit
		PC	0	0	4	2

Preamble

The aim of this lab course is to train the Postgraduate students in solving, designing and analysing solar systems, hybrid wind solar microgrid systems, challenges in distribution systems and challenges in smart grid infrastructure using various state of the art hardware/software setups.

Prerequisite

- 18PS160 - Analysis of modern power system
- 18PS170 - Power Engineering Laboratory

Course Outcomes

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

CO1.	Perform simulation studies using a state of the art solar energy experiment system	Apply
CO2.	Perform simulation studies using a state of the art Solar PV WIND Hybrid System with DC Micro Grid setup	Apply
CO3.	Perform simulation studies using DIgSILENT Power factory software	Apply
CO4.	Analyze the energy consumption of an institution using smart metering infrastructure.	Analyze

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Syllabus

1. Compare and analyze the performance of charge controllers for a solar system.
2. Analyze the efficiency of step up and step down converter and DC to AC converter at different power in a solar system.
3. Find the variation of power output of solar panel with the variation frequencies of light.
4. Measurement and comparison of spectral response for different wave lengths of light and obtain spectral response curve.
5. Power flow analysis of in a DC micro-grid system with multiple sources (wind and solar) and battery as energy storage.
6. DC micro grid system operations for the effect of change in wind speed and pitch angle.
7. Control and analysis of the power supplied to the AC grid.
8. DC Optimal Power Flow Formulation Using the Power Transmission Distribution Factors—A DIgSILENT

9. Modelling of Transmission Systems Under Unsymmetrical Conditions and Contingency Analysis - DIgSILENT
10. Analysis of TCE energy report by smart metering infrastructure
11. Import and export energy analysis using 1KW grid tie solar PV System.

Course Designers:

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

18PSPB0	SMART GRID	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Electric power systems throughout the world are facing radical change stimulated by the pressing need to decarbonise electricity supply, to replace ageing assets and to make effective use of rapidly developing information and communication technologies. These aims all converge in the Smart Grid. This course is designed to study about smart grid technologies, distribution automation, information and communication Technologies, and operation of transmission system operation. It is used to get familiarized with smart metering and demand side integration.

Prerequisite

- 18PS160: Analysis of modern power system

Course Outcomes

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

Course Outcome NO.	Course Outcomes	**Blooms level**
CO1	Discuss the concepts and technologies of infrastructure in the Smart Power Grid architecture.	Understand
CO2	Explain the Communication, Measurement and Computing Technologies in the smart grid.	Understand
CO3	Develop Wide Area monitoring and Control system using PMU technologies.	Apply
CO4	Develop the Smart Transmission system using synchrophasor technology.	Apply
CO5	Design a Smart Distribution management systems for the given applications	Apply
CO6	Apply the Smart metering concepts in demand management for the given applications.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L							L		L
CO2	S	L							L		L
CO3	S	L			L	L		L	L	L	M
CO4	S	S	M	M	L	L		L	M	L	M
CO5	S	S	M	M	L	L		L	M	L	M
CO6	S	S	M	M	L	L		L	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**	**50**	**50**	**50**

Apply	**-**	**30**	**30**	**30**
Analyse	**-**	**-**	**-**	**-**
Evaluate	**-**	**-**	**-**	**-**
Create	**-**	**-**	**-**	**-**

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is the need for smart grid?
2. Explain smart Grid with definitions?
3. Describe the benefits of smart grid with respect to utility and consumer?

Course Outcome 2 (CO2):

1. Write short notes on modbus.
2. Explain IEEE 802 series standard, different technologies specified under this standard and architecture in detail.
3. Draw a basic ANSI C 12.22 smart metering architecture and explain in detail.
4. Give the comparison of conventional and smart metering with a neat sketch?

Course Outcome 3 (CO3):

1. What is meant by PMU?
2. Explain phasor measurement unit device and an example of PMU connection?
3. Compare the PMU based measurement of power system parameters with respect to conventional techniques with detailed steps.

Course Outcome 4 (CO4):

1. Explain a typical EMS system configuration with a neat sketch.
2. Explain about WAN.
3. Explain various switching techniques used in smart grid infrastructure.

Course Outcome 5 (CO5):

1. Write various substation configurations.
2. Demonstrate the modern concept of DAS in the distribution system for reducing the fault interruption time and energy loss with a simple case study.
3. A section of a distribution network is shown in Figure B3a. Daily load profiles of each load are given in Figure B3b. All loads are assumed to be unity power factor:

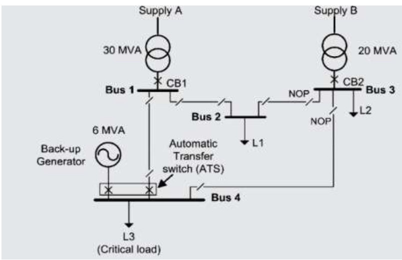


Fig.B3a

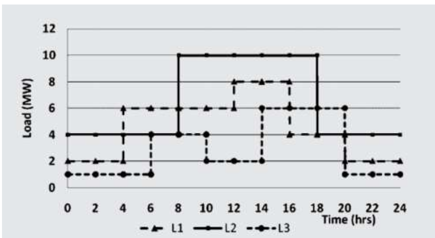


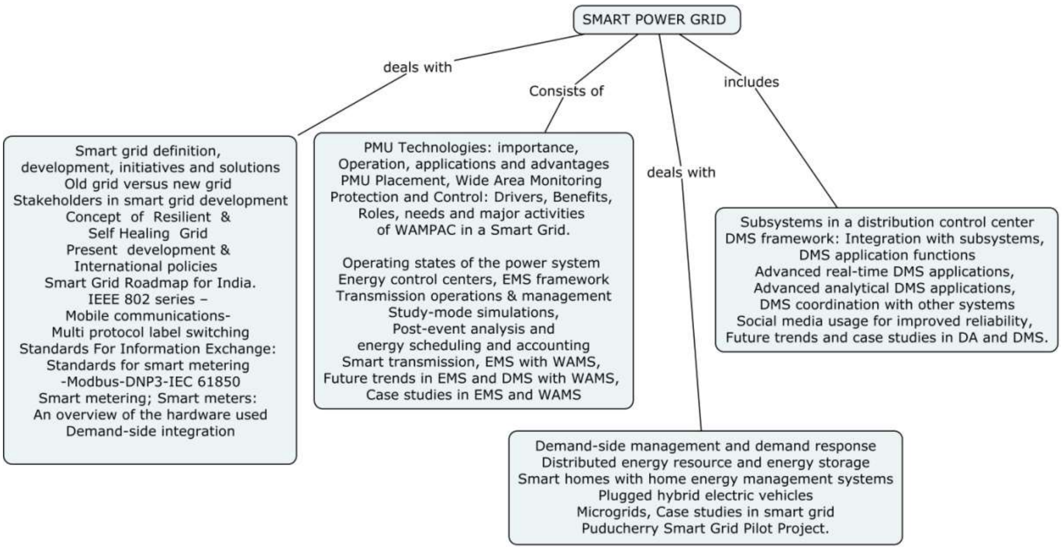
Fig.B3b

Discuss the consequence of loss of Supply A when there is no automation. Also, discuss a possible automatic restoration scheme which employs an Agent and re-closers with remote terminal units that provide minimum interruption to all the loads.

Course Outcome 6 (CO6):

1. Explain the functional block diagram of a smart meter with a neat sketch?
2. What are the services provided by DSI and explain in detail with a neat sketch?
3. Describe examples of functionality implemented at Pudhucherry.

Concept Map



Syllabus

INTRODUCTION TO SMART GRID

Smart grid definition, development, initiatives and solutions; Old grid versus new grid, Stakeholders in smart grid development, Concept of Resilient & Self Healing Grid, Present development & International policies in Smart Grid, Smart Grid Roadmap for India.

COMMUNICATION TECHNOLOGIES

Communication Technologies: IEEE 802 series – Mobile communications- Multi protocol label switching; Standards For Information Exchange: Standards for smart metering -Modbus-DNP3-IEC 61850, IS 1644 (2015), IS 15959-I-2011, IS15959-II-2016, Smart metering; Smart meters: An overview of the hardware used; Communications infrastructure and protocols for smart metering; Demand-side integration.

PMU TECHNOLOGIES

PMU Technologies: importance, Operation, applications and advantages, Algorithms for PMU Placement, Wide Area Monitoring, Protection and Control: Drivers, Benefits Roles, needs and major activities of WAMPAC in a Smart Grid.

SMART TRANSMISSION SYSTEM

Operating states of the power system and sources of grid vulnerability, Energy control centers, EMS framework, Transmission operations and management, Study-mode simulations, Post-event analysis and energy scheduling and accounting, Smart transmission, EMS with WAMS, Future trends in EMS and DMS with WAMS, Case studies in EMS and WAMS, Dynamic line rating, Virtual Power demand

SMART DISTRIBUTION SYSTEM

Subsystems in a distribution control center, DMS framework: Integration with subsystems, DMS application functions, Advanced real-time DMS applications, Advanced analytical DMS applications, DMS coordination with other systems, Social media usage for improved reliability, Future trends and case studies in DA and DMS, LVDC System, Concepts on Digital Substation (TIPS-Transformerless Intelligent Power Substation).

DEMAND-SIDE MANAGEMENT

Demand-side management and demand response, Distributed energy resource and energy storage, Smart homes with home energy management systems, Plugged hybrid electric vehicles, Microgrids, Case studies in smart grid, Indian Smart Grid Pilot Projects.

Reference Books

1. Thomas, Mini S., and John Douglas McDonald. Power System SCADA and smart grids. CRC press, 2015.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, “Smart Grid: Technology and Applications”, Wiley & Sons Ltd., February 2012.
3. “Smart Grid primer”, Published by Power grid Corporation of India limited, September 2013
4. Stuart Borlase, “Smart Grid: Infrastructure, Technology and Solutions”, CRC Press 2012.
5. James Momoh, “Smart Grid Fundamentals of Design and Analysis”, IEEE Press, 2012.
6. Tony Flick, Justin more house, “Securing the smart grid: Next generation power grid security”, Elsevier, 2010.
7. K S K Weranga, D P Chandima, "Smart Meter Design and Application", Springer, 2014.
8. MOOCs course link: https://www.edx.org/course/smart-grids-electricity-future-ieeex-smartgrid-x-0
9. IEEE Transaction on smart grid.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**INTRODUCTION TO SMART GRID**	
1.1	Smart grid definition, development, initiatives and solutions	**2**
1.2	Old grid versus new grid	**1**
1.3	Stakeholders in smart grid development	**1**
1.4	Concept of Resilient & Self Healing Grid	**2**
1.5	Present development & International policies in Smart Grid	**1**
1.6	Smart Grid Roadmap for India.	**1**
2	**COMMUNICATION TECHNOLOGIES**	
2.1	IEEE 802 series – Mobile communications- Multi protocol label switching	**1**
2.2	Standards For Information Exchange: Standards for smart metering -Modbus-DNP3-IEC 61850, IS 1644 (2015), IS 15959-I-2011, IS15959-II-2016,	**1**
2.3	Smart metering; Smart meters: An overview of the hardware used	**2**
2.4	Demand-side integration	**1**
3	**PMU TECHNOLOGIES**	
3.1	PMU Technologies: importance, Operation, applications and advantages	**2**
3.2	Algorithms for PMU Placement, Wide Area Monitoring	**2**
3.3	Protection and Control: Drivers, Benefits, Roles, needs and major activities of WAMPAC in a Smart Grid.	**1**
4	**SMART TRANSMISSION SYSTEM**	
4.1	Operating states of the power system and sources of grid vulnerability	**1**
4.2	Energy control centers, EMS framework	**1**
4.3	Transmission operations and management	**1**
4.4	Study-mode simulations, Post-event analysis and energy scheduling and accounting, Smart transmission, EMS with WAMS	**1**
4.5	Future trends in EMS and DMS with WAMS, Case studies in EMS and WAMS, Dynamic line rating, Virtual Power demand	**1**
5	**SMART DISTRIBUTION SYSTEM**	
5.1	Subsystems in a distribution control center	**1**

Module No.	Topic	No. of Lectures
5.2	DMS framework: Integration with subsystems, DMS application functions	**2**
5.3	Advanced real-time DMS applications, Advanced analytical DMS applications, DMS coordination with other systems	**2**
5.4	Social media usage for improved reliability, Future trends and case studies in DA and DMS, LVDC System, Concepts on Digital Substation, TIPS.	**2**
6	**DEMAND-SIDE MANAGEMENT**	
6.1	Demand-side management and demand response	**1**
6.2	Distributed energy resource and energy storage	**1**
6.3	Smart homes with home energy management systems	**1**
6.4	Plugged hybrid electric vehicles	**1**
6.5	Microgrids, Case studies in smart grid	**1**
6.6	Indian Smart Grid Pilot Projects.	**1**
	Total	**36**

Course Designers:

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18PSPC0	POWER CONVERTERS FOR POWER SYSTEM APPLICATIONS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Power electronic converters are used for various applications in power system such as HVDC transmission, renewable energy systems such as solar power system, wind power system, FACTS and custom power devices etc. Power converters have higher power conversion efficiency and are used to extract maximum power from the renewable sources. Power converters are also used to solve the power system operational issues related to grid synchronization, real and reactive power control, etc. while integrating renewable sources with the grid.

Course Outcomes

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

CO No.	Course outcomes	Blooms Level
CO1.	Explain the concept, application and types of HVDC transmission systems	Understand
CO2.	Analyze the performance of HVDC converters	Analyze
CO3.	Explain different types of Solar PV systems and their components	Understand
CO4.	Design power converters for Solar PV systems	Apply
CO5.	Explain different types of Wind Energy systems and their components	Understand
CO6.	Design power converters for Wind Energy systems	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M	M		L						
CO2.	S	S	S		S						
CO3	S	M	M		L						
CO4	S	M	S		L						
CO5	S	M	M		L						
CO6	S	M	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	30	30	30	30
Apply	30	50	40	40
Analyse	20	0	10	10
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 in transmission of electric power?. 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. Derive the expression for output voltage in a 6-pulse current source converter when there exists overlap during the commutation of thyristors.
5. Deduce the expression for dc current flow in a HVDC system using the equivalent circuit of rectifier and inverter.

Course Outcome 2 (CO2):

1. The maximum value of phase voltage applied to a 3-phase current source converter (CSC) in a HVDC system is 60.43 kV and the system frequency is 50 Hz. The value of leakage reactance per phase of the transformer feeding the CSC is 5 mH and the overlap angle is 5^0. Calculate the output dc current and output dc voltage of the converter if the firing angle is 20^0 and 120^0. Compare the performance of the converter in both cases.
2. Simulate a 6-pulse and a 12-pulse current source converter using Matlab-Simulink and analyze the output voltage and output current waveforms of the converters for different firing angles.
3. Simulate a sample monopolar and bipolar HVDC systems having 12-pulse converters using Matlab-Simulink and analyze the output voltage, output current of the converters and power flow in the system when the converters in station-I operates in rectifier mode and the converters in station-II operates in inverter mode and Vice-versa.

Course Outcome 3 (CO3):

1. Explain the different types of PV energy conversion systems.
2. Explain the state space analysis of boost converter.
3. Describe the P & O MPPT technique for a PV system which uses a boost converter with neat flowchart.
4. Explain the sine PWM and SVPWM techniques used in inverter in detail with neat diagrams.
5. Describe the parameters to be considered for the selection of inverter and the need for filter at the output of inverter in a solar PV system.
6. Define the terms: Voltage THD, Current THD, distortion factor and displacement power factor

Course Outcome 4 (CO4):

1. In a buck-boost converter operating at 20KHz, L=0.05 mH. The output capacitor C is sufficiently large and Vin=158V.The output is to be regulated at 10V and the converter is supplying a load of 10W.Calculate the duty ratio D.
2. Calculate the duty cycle to be applied to the boost converter when a PV panel having the following V-I characteristics is connected to a load resistance of 30 ohm through a boost converter in the following cases: i)To have 28V at the output of PV panel. ii) To extract maximum power from the PV panel.

V_{PV} (V)	26	27	28	29	30
I_{PV} (A)	1.7	1.6	1.5	1.4	1.1

3. Select suitable number of 12V & 100 Ah batteries and 100W (20V, 5A) PV panels to meet the following load demand in an office by a standalone PV system. A dc-dc converter is used for MPPT in the system. Design for one day of autonomy and there is good sunshine for 6 hours per day. Select system operating voltage as 24V. The efficiency of battery, dc-dc converter and inverter are 85%, 87% and 90% respectively. The depth of discharge of battery is 70%.

Device	Power Consumed per device(W)	Operating hours/ day	No. of Devices
FAN	50	8	3
CFL	15	6	5
TV	200	10	1

PC	100	6	1

4. A boost converter is required to have an output voltage of 8 V and supply a load current of 1 A. The input voltage varies from 2.7 to 4.2 V. A control circuit adjusts the duty ratio to keep the output voltage constant. Select the switching frequency. Determine a value for the inductor such that the variation in inductor current is no more than 40 percent of the average inductor current for all operating conditions. Determine a value of an ideal capacitor such that the output voltage ripple is not more than 2 percent. Determine the maximum capacitor equivalent series resistance for a 2 percent ripple.

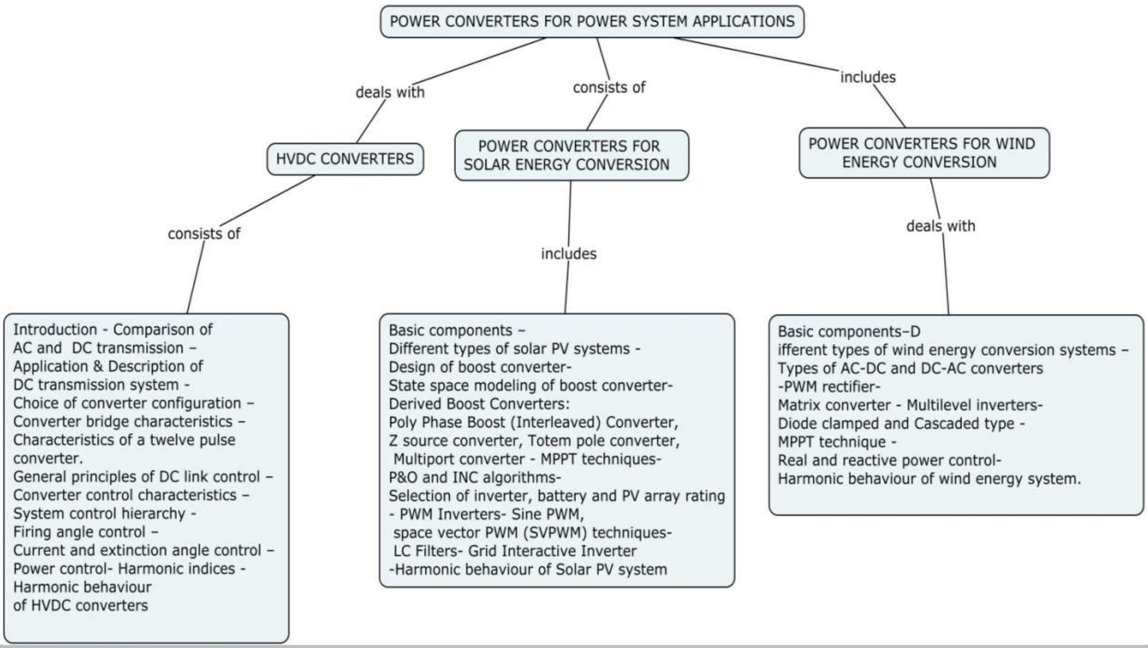
Course Outcome 5 (CO5):

1. Explain the working principle of constant speed wind power generating system with neat sketch.
2. List the different types of generators used in wind energy system along with their features.
3. Write the expression for tip speed ratio and power coefficient of wind turbine.
4. What are the different methods used to control the speed of wind turbine.
5. Explain the working principle of single phase 7-level cascaded multilevel inverter with neat diagram.
6. Describe the basic principle of operation of three phase to three phase matrix converter with necessary diagram.

Course Outcome 6 (CO6):

1. In a three phase voltage source inverter which uses sine PWM technique, the value of dc link input voltage is 600V. Find the rms value of fundamental line to line output voltage if the modulation index is 0.5 and 0.9.
2. Determine the value of fundamental line to line output voltage in a three phase voltage source inverter which uses SVPWM technique if the dc input voltage is 500V and the modulation index is 1.
3. What is the value of the modulation index in a three phase voltage source inverter which uses SVPWM technique to operate it in overmodulation region and in six step mode?
4. In a three phase uncontrolled rectifier which uses LC filter at the output, determine the output dc voltage and the minimum inductance value to make the output current continuous if the line to line input voltage is 415V, 50Hz and the average output current value is 100A.
5. A 440V,250A,120 pole,50Hz, 3-phase permanent magnet synchronous generator has a reactance of 0.3 ohm per phase. The generated emf per phase is given by Eg=1.05ω where ω is the angular frequency of the rotor. The generator is driven by a wind turbine whose optimum power as a function of speed of rotation (in rpm) is given by $P_{opt} = 1.38N^3$. The generator feeds power to a dc link through a diode bridge rectifier. Find the optimal dc link current and voltage for a rotation speed of 50 rpm. Ignore transmission losses.

Concept Map



Syllabus

Power converters for HVDC transmission

Introduction - Comparison of AC and DC transmission – Application & Description of HVDC transmission system - Choice of converter configuration – Converter bridge characteristics – Characteristics of twelve pulse converter- Simulation of HVDC converters- General principles of DC link control – Converter control characteristics – System control hierarchy - Firing angle control – Current and extinction angle control – Power control- Harmonic indices - Harmonic behaviour of HVDC converters

Power converters for solar energy conversion

Basic components –Different types of solar PV systems - Design of boost converter- State space modeling of boost converter- Derived Boost Converters: Poly Phase Boost (Interleaved) Converter, Z source converter, Totem pole converter, Multiport converter - MPPT techniques- P&O and INC algorithms- Selection of inverter, battery and PV array rating- PWM Inverters- Sine PWM, space vector PWM (SVPWM) techniques- LC Filters- Grid Interactive Inverter - Harmonic behaviour of Solar PV system

Power converters for wind energy conversion

Basic components–Different types of wind energy conversion systems – Types of AC-DC and DC-AC converters-PWM rectifier- Matrix converter - Multilevel inverters-Diode clamped and Cascaded type - MPPT technique - Real and reactive power control- Harmonic behaviour of wind energy system.

Reference Books

1. K.R.Padiyar, HVDC Power Transmission Systems, New Age International (P) Ltd., New Delhi, 2017.
2. Ned Mohan, Tore Undeland & William Robbins, Power Electronics: Converters Applications and Design-John Willey and sons 2003.
3. Muhammad H.Rashid, Power electronics Handbook, Third edition, Elsevier Inc., 2011.
4. Muhammad H.Rashid, Power electronics – Circuits, devices and applications, Third edition, Pearson Education., 2009.
5. S.N.Bhadra, D.Kastha & S.Banerjee,Wind electrical systems, Oxford university press, 2010.
6. D.Grahame Holmes & Thomas Lipo, Pulse width modulation for power converters, Wiley-Interscience, 2003.
7. Ali Keyhani, M.N.Marwali & Min Dai, Integration of green and renewable energy in electrical power systems, Wiley and sons, 2010.
8. Felix A.Farret & M.G.Simoes, Integration of alternative sources of energy, Wiley-IEEE press, 2007.

7. Arindam Ghosh & Gerald Ledwich, Power quality enhancement using custom power devices, Kluwer Academic Publishers, 2002.

Course Contents and Lecture Schedule

S.No	Topics	No. of Periods
1.	**HVDC CONVERTERS**	
1.1	Introduction , Comparison of AC and DC transmission	1
1.2	Application & Description of HVDC transmission system	1
1.3	Choice of converter configuration & Converter bridge characteristics	2
1.4	Characteristics of twelve pulse converter, Simulation of HVDC converters	2
1.5	General principles of DC link control	2
1.6	Converter control characteristics, System control hierarchy	2
1.7	Firing angle control, Current and extinction angle control, Power control	
1.8	Harmonic indices - Harmonic behaviour of HVDC converters	2
2.	**POWER CONVERTERS FOR SOLAR ENERGY CONVERSION**	
2.1	Basic components, Different types of PV systems	2
2.2	Design of boost converter	1
2.3	State space modeling of boost converter	1
2.4	Derived Boost Converters: Poly Phase Boost (Interleaved) Converter, Z source converter, Totem pole converter, Multiport converter	2
2.5	MPPT techniques- P&O and INC algorithms	2
2.6	Selection of inverter rating, battery rating and PV array rating	2
2.7	PWM Inverters- Sine PWM, space vector PWM (SVPWM) techniques	2
2.8	LC Filters, Grid Interactive Inverter	1
2.9	Harmonic behaviour of Solar PV system	1
3.	**POWER CONVERTERS FOR WIND ENERGY CONVERSION**	
3.1	Basic components	1
3.2	Different types of wind energy conversion systems	1
3.3	Types of AC-DC and DC-AC converters	1
3.4	PWM rectifier, Matrix converter	
3.5	Multilevel inverters: Diode clamped and Cascaded type	
3.6	MPPT technique	1
3.7	Real and reactive power control	1
3.8	Harmonic behaviour of Wind Energy system	1

Course Designers:

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	Category	L	T	P	Credit
18CI120/18PSPA0 SYSTEMS THEORY	PC/PE	2	1	0	3

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

Course Outcomes

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

CO	Course Outcomes	Blooms level
1	Analyze the characteristics of the developed state space model for the given electrical (or) electromechanical system	Analyze
2	Design a pole placement controller with or without observer for the given system to achieve desired specifications	Apply
3	Design an optimal state regulator / stochastic optimal regulator for the given system	Apply
4	Explain the characteristics of MIMO system	Understand
5	Develop the phase plane trajectories of the given nonlinear system	Apply
6	Analyze the stability of the given nonlinear system using describing function method	Analyze
7	Analyze the stability of the given linear and nonlinear system using Lyapunov stability theory	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**S**	**S**	**M**	**M**							**M**
CO2	**S**	**M**	**M**	**M**							**M**
CO3	**S**	**M**	**M**								
CO4	**M**	**L**	**L**								
CO5	**S**	**M**	**M**	**M**							**M**
CO6	**S**	**S**	**M**	**M**							**M**
CO7	**S**	**S**	**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	10	10
Understand	20	20	20	20
Apply	40	40	50	50
Analyze	20	20	20	20

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.

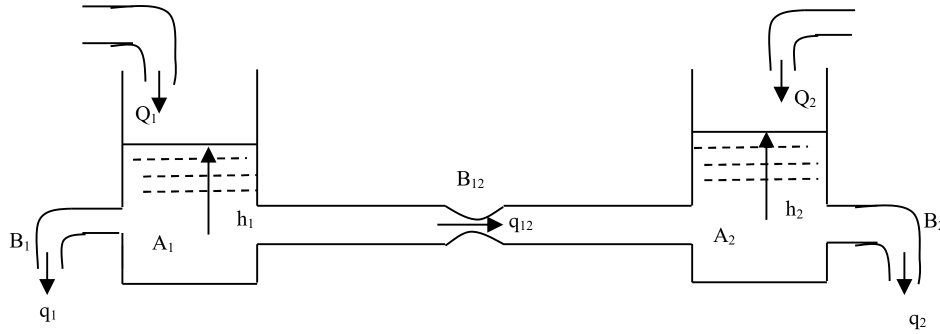


fig.1

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

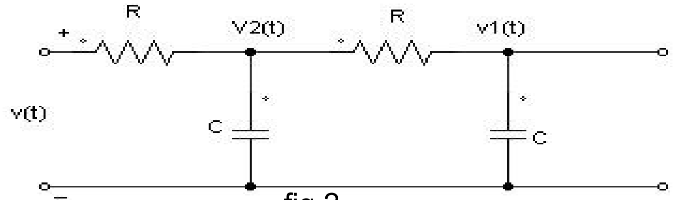


fig.2

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

$$\dot{X} = \begin{bmatrix} -1 & -2 & -2 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix} X(t) + \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix} u(t)$$
$$Y(t) = [1 \quad 1 \quad 0]\, X(t)$$

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:

$$J = 1/2 \int_0^{\infty} (x^T Q x + 2u^2) dt; \quad Q = \begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$$

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 $\ddot{y} + 2\zeta\omega_n\dot{y} + {\omega_n}^2 y = {\omega_n}^2$, where ωn = 1, y(0)=2, 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$\dot{y}$+7y=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.
4. Consider the system shown figure 3. 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.

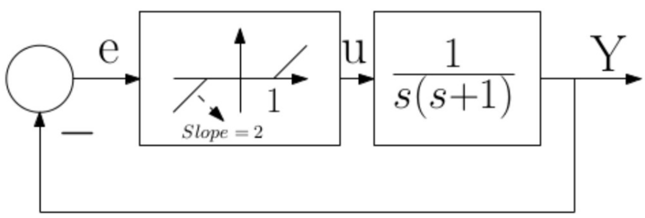


fig.3

5.Explain the stability analysis of non linear system by describing function method.
6.Investigate the stability of a relay controlled system shown in figure 4.

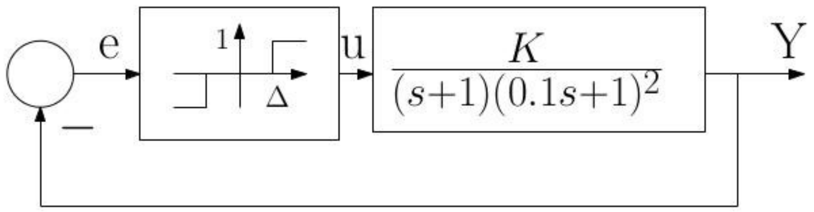


fig.4

Course Outcome 7 (CO7):

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 equilibrium state

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

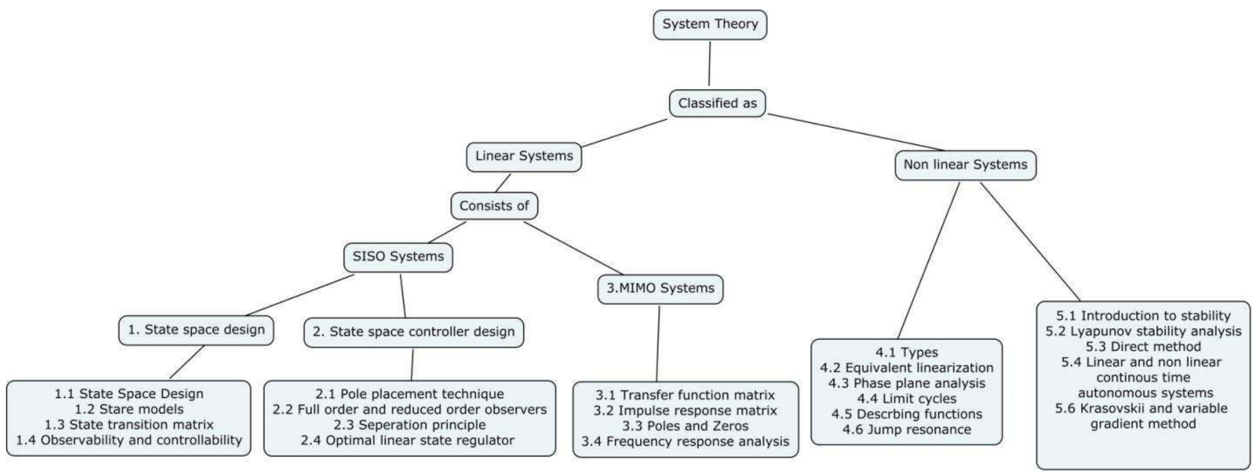
$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = -x_1 - {x_1}^2 x_2$$

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

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 – Lashalle Invariance principle, Barbalat Lemma, 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	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	1
2.4	Separation principle	1
2.5	Optimal linear state regulator	1
2.6	Stochastic optimal linear estimator	1
3.0	**MIMO Systems**	
3.1	Properties of transfer functions Matrix	1
3.2	Impulse response matrices	1
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	1
3.6	Singular value analysis	1
4.0	**Non-Linear Systems**	

4.1	Types of non-linearity – Typical examples	1
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	1
5.3	Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems	1
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 Lashalle Invariance principle, Barbalat Lemma	2
5.6	Krasovskii and Variable-Gradient Method	2
	Total	**36**

Course Designers:

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18PSPD0	POWER SYSTEM VOLTAGE STABILITY	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

At any point of time, a power system operating condition should be stable, meeting various operational criteria, and it should also be secure in the event of any credible contingency. Present day power systems are being operated closer to their stability limits due to economic and environmental constraints. Maintaining a stable and secure operation of a power system is therefore a very important and challenging issue. Voltage instability has been given much attention by power system researchers and planners in recent years, and is being regarded as one of the major sources of power system insecurity. Voltage instability phenomena are the ones in which the receiving end voltage decreases well below its normal value and does not come back even after setting restoring mechanisms such as VAR compensators, or continues to oscillate for lack of damping against the disturbances. The aim of the course is to develop an understanding of the basic concepts of understanding voltage stability and its solution methodologies.

Prerequisite

18PS120 Power System Dynamics and Stability

Course Outcomes

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

Course Outcome NO.	Course Outcomes	Blooms level
CO1	Explain physical phenomenon of voltage stability	Understand
CO2	Derive maximum deliverable power on SLIB system for various condition	Understand
CO3	Explain transmission system aspects on voltage stability	Understand
CO4	Explain generation and load aspects on voltage stability	Understand
CO5	Assessment of power system voltage stability	Apply
CO6	Simulation of power system for voltage stability assessment	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	L						M		M	
CO2.	M	L						M		M	
CO3.	M	L						M		M	
CO4.	M	L						M		M	
CO5.	S	M	L	L				M		M	
CO6.	S	M	L	L				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	80	60	60	60
Apply	0	20	20	20
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

CO6 evaluation is based on Assignment or Project.

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. 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 4 (CO4):

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

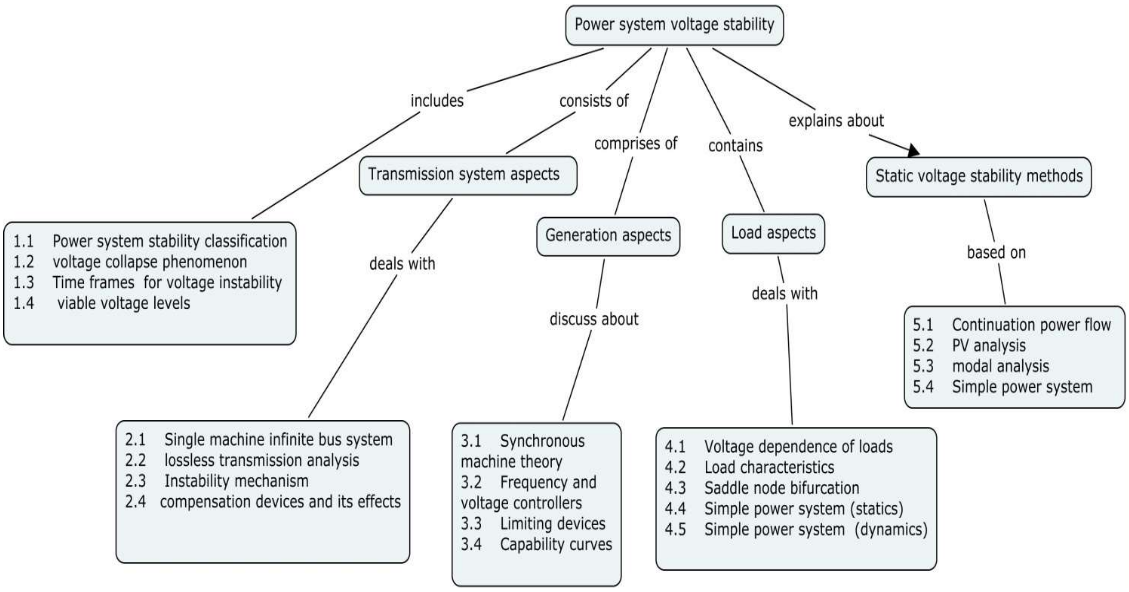
Course Outcome 5 (CO5):

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.
5. Apply continuation power flow method to assess the voltage stability assessment of a two bus system.

Course Outcome 6 (CO6):

Simulate a simple power system for voltage stability assessment.

Concept Map



Syllabus

Introduction: Voltage stability– power system stability classification – physical phenomenon of voltage collapse – description – time scales – reactive power, system changes and voltage collapse – maintaining viable voltage levels.
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.
Generation aspects: Synchronous machine theory - Frequency and voltage controllers - voltage regulators – Limiting devices affecting voltage stability – over excitation limiters – description – field current, armature current limiters – 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, modal analysis. Simple power system example.

Reference:

1. T.Van Cutsem and C.Vournas, Voltage stability of electric power systems, Kluwer academic publishers 1998.
2. P.Kundur, Power system stability and control, McGraw-Hill, Inc., 1995.
3. IEEE Working Group on Voltage Stability. Voltage Stability Assessment: Concepts, Practices and Tools, 2002.
4. V.Ajjarapu, Computational techniques for voltage stability assessment and control, Springer, 2007.
5. Chiang HD, Fluek AJ, Shah KS, Balu N (1995) CPFLOW: A practical tool for tracing power system steady state stationary behavior due to load and generation variation. IEEE Trans. on Power Systems 10(2): 623-633

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	01
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	01
2.2	Maximum deliverable power, lossless transmission	01
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	02
3.0	**Generation aspects**	
3.1	A review of Synchronous machine theory	01
3.2	Frequency and voltage controllers	01
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	01
4.2	Load characteristics, exponential load, polynomial load	01
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	02
5.2	PV analysis, VQ analysis	02
5.3	Time domain analysis, modal analysis	02
5.4	Simple power system example	02
	Total	**36**

Course Designers:

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18PSPE0	ELECTRICAL TRANSIENTS IN POWER SYSTEM	Category	L	T	P	Credit
		PE	3	0	0	3

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

NIL

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.	Draw and analyses Travelling waves using Lattice Diagram	Apply
CO4.	Apply the EMTP software for transient studies.	Apply
CO5.	Model power apparatus under transient conditions	Apply
CO6.	Apply insulation co-ordination principles.	Apply

Mapping with Programme Outcomes

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

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. For the given transmission line model obtain the reflected and refracted waves using Bewley's lattice diagram

2. An Overhead line A with a surge impedance of 450Ohm is connected to three other lines - B & C with surge impedances of 600Ohm each and a cable D with a surge impedance of 60 Ohm at the junction J. A travelling wave of vertical front of magnitude 25kV and very long tail travels on A towards the junction J. Calculate the magnitude of the voltage and current waves which are transmitted and reflected at the junction. Neglect the attenuation of the line.

Course Outcome 4 (CO4):
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?

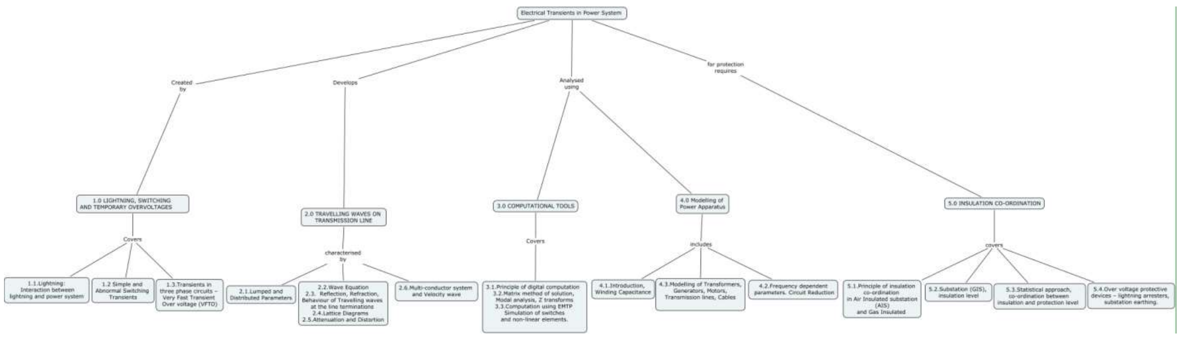
Course Outcome 5 (CO5):
1. Discuss the application of
   - Ground wires
   - Surge Diverters
   - For the protection of a line against surge voltages.
2. A transmission line is 300km long and open at far end. The attenuation of surge is 0.9 over one length of travel at light velocity. It is energised 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 6 (CO6):

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", 2nd 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	2
1.3.	Transients in three phase circuits – Very Fast Transient Over voltage (VFTO) - IEC standards and wave models.	2
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	2
3.3.	Computation using EMTP – Simulation of switches and non-linear elements.	2
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	2
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	**36**

Course Designer:

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18PSPF0	DESIGN OF POWER DISTRIBUTION SYSTEMS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The electric utility industry grew very rapidly, and generation stations and transmission and distribution networks spread across the entire world. The economic importance of the distribution system is very high, and the amount of investment involved dictates careful planning, design, construction, and operation. The Design of electric power distribution systems of this course includes distribution transformer usage, design of subtransmission lines, distribution substations, primary and secondary networks design Voltage-drop and Power-loss calculations, Application of capacitors and voltage regulation of distribution substations and overhead/underground distribution systems are also included,

Prerequisite

- 18PS160 : Analysis of modern power systems

Course Outcomes

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

Course Outcome NO.	Course Outcomes	Blooms level
CO1	Describe the selection of Distribution transformer for the given condition.	Understand
CO2	Specify the arrangements of substation with primary and secondary feeders.	Apply
CO3	Design the primary distribution system for a given condition.	Apply
CO4	Describe the Secondary distribution system networks.	Understand
CO5	Select and locate the capacitor for a given application.	Apply
CO6	Calculate voltage regulation of the given feeder.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	L						M		M	
CO2.	S	M	L	L				M		M	
CO3.	S	M	L	L				M		M	
CO4.	M	L						M		M	
CO5.	S	M	L	L				M		M	
CO6.	M	L						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. Explain the need of loading guides for a distribution transformer.
2. Describe the use of equivalent circuit of a single phase distribution transformer and explain its use.
3. Assume that a 250-kVA distribution transformer is used for single-phase pole mounting. The transformer is connected phase-to-neutral 7200 V on the primary and 2520 V phase-to-neutral on the secondary side. The leakage impedance of the transformer is 3.5%. Assume that the transformer has 0.7 p.u A in the high-voltage winding. Find the actual current values in the high and low-voltage windings.

Course Outcome 2 (CO2):

1. List out the various components of the distribution system.
2. Draw and explain the Grid- or network-type subtransmission.
3. Consider a typical substation which might be fed by two incoming 138-kV lines feeding two 32-MVA, 138-kV/12.47-kV transformers, each with a low-voltage bus. Each bus has four outgoing distribution feeders of 9 MVA peak capacity each. The total site cost of the substation is $600,000. The total transmission cost including high-side bus circuit breakers, is estimated to be $900,000. The feeder buswork/getaway cost is $400,000. Determine the total cost of this substation.

Course Outcome 3 (CO3):

1. What are the factors affecting the selection of primary-feeder rating?
2. Draw and explain the various arrangements of Radial-type primary feeders.
3. A three-phase radial express feeder has a line-to-line voltage of 22.9 kV at the receiving end, a total impedance of 5.25 + j 10.95 ohm per phase, and a load of 5 MW with a lagging power factor of 0.9. Determine the line-to-neutral and line-to-line voltages at the sending end.

Course Outcome 4 (CO4):

1. Explain the present design practice of secondary systems.
2. Describe the two different methods of banking secondaries.

3. What are spot networks?

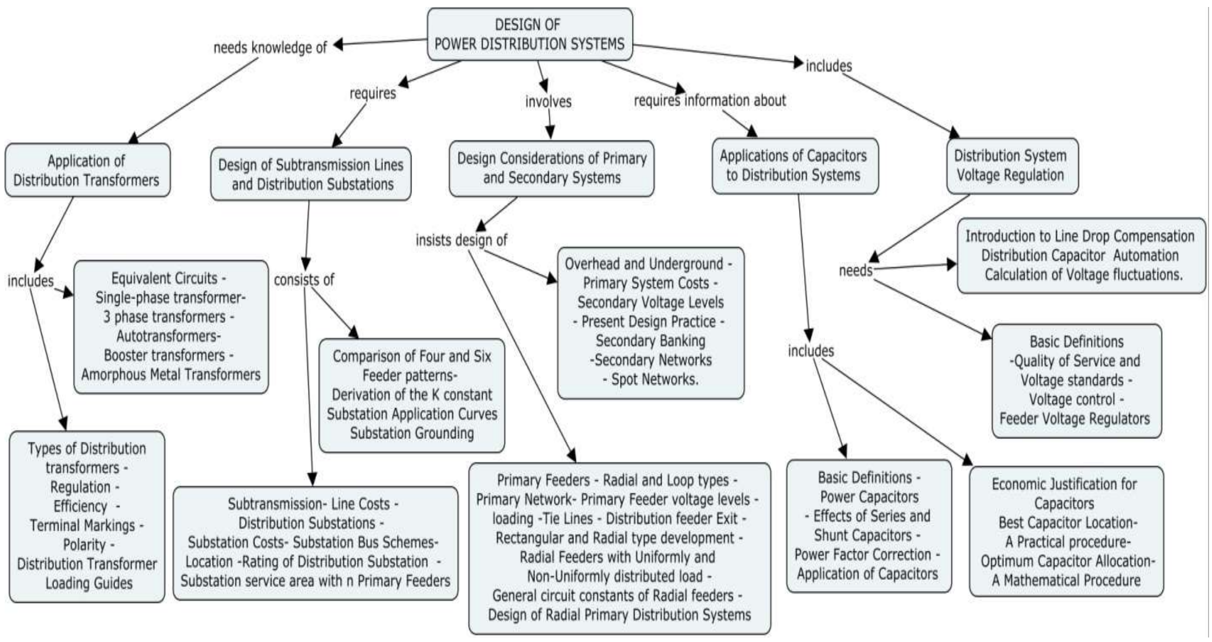
Course Outcome 5 (CO5):

1. Explain the effects of shunt capacitors in a feeder.
2. Describe the practical procedure to determine the best location of capacitor.
3. Explain the capacitor allocation by loss reduction technique.

Course Outcome 6 (CO6):

1. Describe the function of feeder voltage regulators.
2. Explain the concept of Distribution capacitor automation.
3. List out the ways to improve the voltage regulation of distribution system.

Concept Map



Syllabus

Application of Distribution Transformers

Types of Distribution transformers - Regulation - Efficiency -Terminal Markings - Polarity - Distribution Transformer Loading Guides - Equivalent Circuits - Single-phase transformer-3 phase transformers - Autotransformers- Booster transformers - Amorphous Metal, Energy efficient transformers.

Design of Subtransmission Lines and Distribution Substations

Subtransmission- Line Costs - Distribution Substations - Substation Costs- Substation Bus Schemes- Location -Rating of Distribution Substation - Substation service area with n Primary

Feeders -Comparison of Four and Six-Feeder patterns- Derivation of the K constant - Substation Application Curves -Substation Grounding.

Design Considerations of Primary and Secondary Systems
Primary System – Primary Feeders - Radial and Loop types - Primary Network- Primary Feeder voltage levels - loading -Tie Lines - Distribution feeder Exit -Rectangular and Radial type development -Radial Feeders with Uniformly and Non-Uniformly distributed load -General circuit constants of Radial feeders - Design of Radial Primary Distribution Systems -Overhead and Underground - Primary System Costs – **Secondary System**-Secondary Voltage Levels - Present Design Practice - Secondary Banking -Secondary Networks - Spot Networks.

Applications of Capacitors to Distribution Systems
Power Capacitors - Effects of Series and Shunt Capacitors - Power Factor Correction - Application of Capacitors - Economic Justification for Capacitors - Best Capacitor Location- A Practical procedure- Optimum Capacitor Allocation-A Mathematical Procedure.

Distribution System Voltage Regulation
Quality of Service and Voltage standards - Voltage control - Feeder Voltage Regulators - Introduction to Line Drop Compensation - Distribution Capacitor Automation - Calculation of Voltage fluctuations.

Reference Books

1. Electric Power Distribution System Engineering, Second Edition, Turan Gonen, CRC Press, Taylor&Francis Group, Boca Raton, 2008 ISBN: 13:978-1-4200-6200-7

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Application of Distribution Transformers**	
1.1	Types of Distribution transformers - Regulation - Efficiency	1
1.2	Terminal Markings - Polarity -Distribution Transformer Loading Guides - Equivalent Circuits	1
1.3	Single-phase transformer-3 phase transformers	2
1.4	Autotransformers- Booster transformers - Amorphous Metal, Energy efficient transformers.	2
2.0	**Design of Subtransmission Lines and Distribution Substations**	
2.1	Subtransmission- Line Costs - Distribution Substations - Substation Costs	2
2.2	Substation Bus Schemes- Location -Rating of Distribution Substation	2
2.3	Substation service area with n Primary Feeders -Comparison of Four and Six-Feeder patterns	2
2.4	Derivation of the K constant - Substation Application Curves	1
2.5	Substation Grounding.	1
3.0	**Design Considerations of Primary and Secondary Systems**	
3.1	**Primary Feeders** - Radial and Loop types - Primary Network- Primary Feeder voltage levels - loading	2
3.2	Tie Lines - Distribution feeder Exit	1

3.3	Rectangular and Radial type development -Radial Feeders with Uniformly and Non-Uniformly distributed load, General circuit constants of Radial feeders	2
3.4	Design of Radial Primary Distribution Systems -Overhead and Underground- Primary System Costs	2
3.5	**Secondary Feeders** -Secondary Voltage Levels - Present Design Practice	1
3.6	Secondary Banking -Secondary Networks - Spot Networks	1
4.0	**Applications of Capacitors to Distribution Systems**	
4.1	Effects of Series and Shunt Capacitors - Power Factor Correction	2
4.2	Application of Capacitors	1
4.3	Economic Justification for Capacitors - Best Capacitor Location	2
4.4	A Practical procedure- Optimum Capacitor Allocation-A Mathematical Procedure	2
5.0	**Distribution System Voltage Regulation**	
5.1	Quality of Service and Voltage standards	1
5.2	Voltage control - Feeder Voltage Regulators	1
5.3	Introduction to Line Drop Compensation	2
5.4	Distribution Capacitor Automation - Calculation of Voltage fluctuations.	2
	Total	36

Course Designers:

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

18PSPG0	**DISTRIBUTED GENERATION SYSTEMS**	Category	L	T	P	Credit
		PE	2	1	0	3

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 centres, 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 with Wind and Photovoltaic Systems, Major issues of connecting DG into the system and State of the art of hybrid systems.

Prerequisite

- 18PS160 : Analysis of Modern Power Systems
- 18PS130: Design of Renewable Energy System

Course Outcomes

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

Course Outcome NO.	**Course Outcomes**	**Blooms level**
CO1	Explain the use of Diesel Generator, Solar, PV, Wind, Microturbine, Micro-hydro, Biomass and Fuel cell and their options.	Understand
CO2	Calculate the power and energy from Micro-hydro, Wind and Solar plants.	Apply
CO3	Calculate the various economical factors of the energy for a given distributed resource.	Apply
CO4	Describe the modelling of Wind and Solar and various issues of Distributed Generation systems.	Understand
CO5	Analyze the effects of Distributed Generation in power system.	Analyze
CO6	Describe the components and control techniques of hybrid systems.	Understand

Mapping with Programme Outcomes

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

CO4.	M	L						M		M	
CO5.	S	S	M	M				M		M	
CO6.	M	L						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	50	40	40	40
Apply	30	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 operation of Micro turbine with neat diagram.
2. Draw and explain the functional diagram of Concentrating Solar power plants.
3. Describe the function of Micro-Hydropower Systems.

Course Outcome 2 (CO2):

1. Suppose a 4-in.-diameter penstock delivers 150 gpm of water through an elevation change of 100 feet. The pressure in the pipe is 27 psi when it reaches the power house. What fraction of the available head is lost in the pipe? What power is available for the turbine?

2. A wind turbine maintains a tip-speed ratio of 8 at all wind speeds. At which wind speed will the blade tip exceed the speed of sound?

3. Describe the use of histogram to determine the energy in a wind turbine.

Course Outcome 3 (CO3):

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 the energy efficiency measurement of a CHP plant.

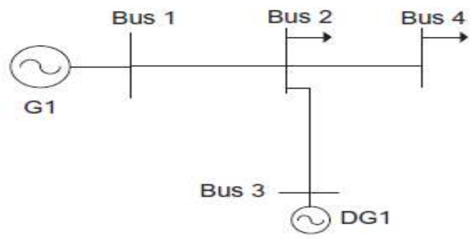
Course Outcome 4 (CO4):

1. Explain the modelling of doubly fed induction generator.
2. Compare the modelling of Linear and Non-linear solar energy models.
3. State the types of generators used in wind tubines.

Course Outcome 5 (CO5):

1. A large generator, G1, is connected to Bus 1 of the following Fig. and maintains the voltage of that bus at $1.1\angle 0°$. Two loads connected to Bus 2 and 4 are 1 + j0.5 and 0.5 + j 0.25 p.u. respectively. DG1 generates active power of 0.5 p.u and absorbs reactive power 0.2 p.u. All the per unit quantities are on a 10 MVA base. Use the Gauss-Seidel

method to determine the busbar voltages. If two identical DGs of are connected at Bus 3, analyze the effect.



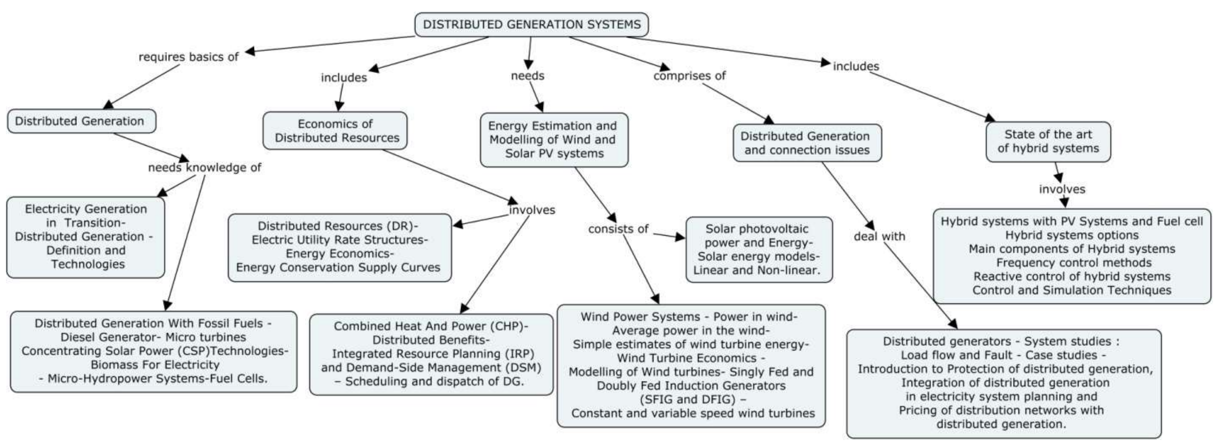
From bus	To bus	R (pu)	X (pu)
1	2	0.02	0.04
2	4	0.01	0.02
2	3	0.01	0.02

2. Describe the impact of Distributed Generation on network design.
3. Explain the primary objectives of network pricing in a distribution system with distributed generation.

Course Outcome 6 (CO6):

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.

Concept Map



Syllabus

Distributed Generation

Electricity Generation in Transition- Distributed Generation - Definition and Technologies - Distributed Generation With Fossil Fuels - Diesel Generator- Micro turbines –- 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.

Energy Estimation and Modelling of Wind and Solar PV systems
Wind Power Systems - Power in wind- Average power in the wind- Simple estimates of wind turbine energy- Wind Turbine Economics - Modelling of Wind turbines- Singly Fed and Doubly Fed Induction Generators (SFIG and DFIG) – Constant and variable speed wind turbines- Solar photovoltaic power and Energy- Solar energy models- Linear and Non-linear.

Distributed Generation and their connection to the System
Integration of Distributed Generators with Grid - Issues - System studies : Load flow and Fault - Case studies - Introduction to Protection of distributed generation, Integration of distributed generation in electricity system planning and Pricing of distribution networks with distributed generation - IEEE 1547 and 2030 standards for DG integration.

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.

Reference Books

1. Gilbert M.Masters, “Renewable and Efficient Electric Power Systems”, John Wiley & Sons,Inc.,Hoboken,New Jersey,2004.
2. N. Jenkins, J.B. Ekanayake and G. Strbac, "Distributed Generation", IET RENEWABLE ENERGY SERIES 1, The Institution of Engineering and Technology, 2010.
3. Bansal.R, Bhatti.T.S, “ Small signal Analysis of isolated Hybrid power systems”, Narosa Publishing House Pvt.Ltd.New Delhi,2008.
4. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright,Mike Hughes, “Wind Energy Generation Modelling and Control” John Wiley & Sons, Ltd,2009.
5. Zekai Sen “Solar Energy Fundamentals and Modeling Techniques” Springer-Verlag London Limited, 2008.
6. Tomas Petru and Torbjorn Thiringer, “Modeling of Wind Turbines for Power System Studies” IEEE Transactions on Power Systems, vol. 17, No.4, November 2002.
7. Paul Breeze, “Power Generation Technologies”, Newnes, An imprint of Elsevier, Linacre House, Jordan Hill, Oxford OX2 8DP,2005.
8. Thomas Ackermann, Goran Andersson, and Lennart Soder: “Distributed generation: a definition”, Electric Power System Research, 51, 2001, pp.195-204.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Distributed Generation**	
1.1	Electricity Generation in Transition- Distributed Generation - Definition and Technologies	1
1.2	Distributed Generation With Fossil Fuels - Diesel Generator- Micro turbines	2

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	1
2.2	Energy Economics- Energy Conservation Supply Curves	2
2.3	Combined Heat And Power (CHP)	1
2.4	Distributed Benefits	1
2.5	Integrated Resource Planning (IRP) and Demand-Side Management (DSM) - Scheduling and dispatch of DG	2
3.0	**Energy Estimation and Modelling of Wind and Solar PV systems**	
3.1	Wind Power Systems - Power in wind- Average power in the wind- Simple estimates of wind turbine energy- Wind Turbine Economics	3
3.2	Modelling of Wind turbines- Singly Fed and Doubly Fed Induction Generators (SFIG and DFIG)	1
3.3	Constant and variable speed wind turbines	1
3.4	Solar photovoltaic power and Energy	2
3.5	Solar energy models- Linear and Non-linear	1
4.0	**Distributed Generation and their connection to the System**	
4.1	Integration of Distributed Generators with Grid - Issues	**1**
4.2	System studies : Load flow and Fault - Case studies	1
4.3	Introduction to Protection of distributed generation	1
4.4	Integration of distributed generation in electricity system planning	1
4.5	Pricing of distribution networks with distributed generation.	1
4.6	IEEE 1547 and 2030 standards for DG integration	1
5.0	**State of the art of hybrid systems**	
5.1	Hybrid Systems with PV Systems and Fuel cell	1
5.2	Hybrid Systems options-Main components of Hybrid systems	2
5.3	Frequency control methods	2
5.4	Reactive control of hybrid systems, Control and Simulation Techniques	2
	Total	36

Course Designers:

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18PSPH0	FLEXIBLE AC TRANSMISSION SYSTEMS	Category	L	T	P	Credit
		PE	3	0	0	3

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

NIL

Course Outcomes

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

CO1.	Explain the basic principles, characteristics of Series FACTS controllers.	Understand
CO2.	Explain the basic principles, characteristics of Shunt FACTS controllers.	Understand
CO3.	Explain the operation and transmission control capabilities of Phase angle regulator and UPFC	Understand
CO4.	Calculate the performance parameters of various FACTS controllers.	Apply
CO5.	Model FACTS controller for power flow and stability applications.	Apply
CO6.	Design a suitable FACTS controller for a given specification based on the performance	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	L						M		M	
CO2.	M	L						M		M	
CO3.	M	L						M		M	
CO4.	S	M	L	L				M		M	
CO5.	S	M	L	L				M		M	
CO6.	S	M	L	L				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. Explain the working of TCR.
2. Explain the characteristics of TCSC.
3. Explain the working of UPFC.

Course Outcome 2 (CO2):
1. Discuss the application of STATCOM in Power System Damping.
2. Explain the VSC based STATCOM
3. List the different types of shunt compensators

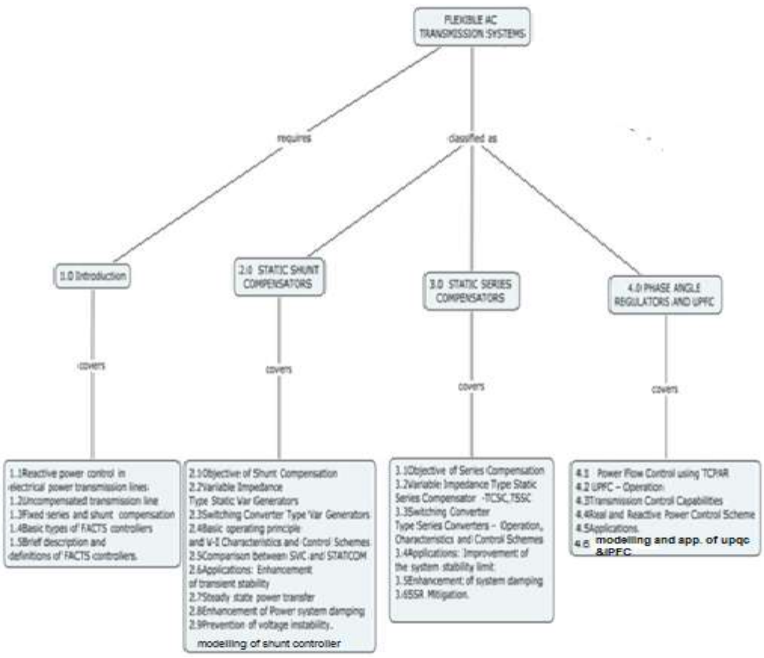
Course Outcome 3 (CO3):
1. How TCSC is used to mitigate SSR?
2. Draw the UPFC model used for power flow studies.
3. Draw the phasor diagram for UPFC.
4. Discuss the application of STATCOM in Power System Damping.
5. Explain the application of UPFC in power flow control
6. Explain the application of TCSC in stability studies

Course Outcome 4 (CO4):
1. Compare SVC and STATCOM.
2. Compare SSSC and TCSC.
3. Compare TSSC and TCSC.

Course Outcome 5 (CO5):
1. Compare the performance of series and shunt compensators for transient stability applications
2. Compare the performance of UPFC and UPQC

Course Outcome 6 (CO6):
1. Select a suitable controller in improving the voltage profile at a bus.
2. Select a suitable controller in improving the transient stability 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-Modelling of Shunt controllers.

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 - Modelling of UPFC -Applications. UPQC & IPFC

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- Modelling of Shunt controllers	2
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	Modelling of UPFC -Applications. UPQC & IPFC	2
	Total	**36**

Course Designers:

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18PSPJ0	ENERGY CONSERVATION AND MANAGEMENT	Category	L	T	P	Credit
			3	0	0	3

Preamble

Energy resource scarcity becomes one of the biggest issues in the world and leading to rise in cost. Effective utilization of Electrical energy is one of the key issues to minimize the rising cost of energy and to minimize the global warming. This course will educate the power system engineers on the aspect of energy conservation in electrical equipment and Electrical Installations. It will helpful to select an energy efficient electrical system for an establishment.

Prerequisite

NIL

Course Outcomes

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

	Course Outcomes	Bloom's Level
CO1.	Describe the principles of Energy Audit, Management and Conservation	Understand
CO2	Estimate the Energy & Financial performance of Electrical System	Apply
CO3	Estimate the energy performance of Electrical Motors	Apply
CO4	Estimate the energy performance of Lighting System	Apply
CO5	Selection and Operation aspects of DG Set for Energy Efficiency	Apply
CO6	Identify the Energy Efficient gadgets for domestic, commercial and industrial applications	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	M	L						M		M		
CO2	S	M	L	L				M		M		
CO3	S	M	L	L				M		M		
CO4	S	M	L	L				M		M		
CO5	S	M	L	L				M		M		
CO6	M	L						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	50	50	30	30
Apply	30	30	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. Mention the types of Energy audit.
2. List down the objective of energy management
3. Explain the implications of part load operation of energy equipment with examples.

Course Outcome 2 (CO2):

1. Define contracted demand and billing demand.
2. What are the factors affecting financial analysis while computing NPV and IRR.
3. A textile mill operates with a load of 1800kVA demand at 0.85 power factor lagging. If the power factor is improved from 0.85 to 0.95 lagging by adding additional capacitors, calculate the reduction in demand. The demand charge is Rs.300 per kVA demand per month. Calculate the demand cost saving per year due to the power factor improvement.
4. The energy and demand savings analysis for retrofit LED exit signs is given in table below.

Retrofit cost	Energy & demand savings	Maintenance savings
Rs. 32,500	6000 kWh/month & Rs.3800/year as demand charges	Annual maintenance savings will be Rs. 2000/-.

The key data is given below:
• Energy savings are based on Rs3.00/kWh
• No changes in energy rates for 10 years
• LED exit signs have 10 year life period
a) Estimate savings in maintenance costs at the end of life of LED signs.
b) Prepare cash-flow analysis for the upgrade option.
c) Calculate NPV against 12% interest rate.

5. In a sub-station 2Nos. of identical 5000kVA 33kV / 11kV Transformers are operated parallel to meet a domestic load. The iron and full load copper loss of the above Transformer is 9.2 kW and 32.5kW respectively. Initially the two transformers are operated in parallel to meet the load. The load pattern of the domestic load is as follows:

Load in kW	6000	3500	3000	8000	1500
Power factor	0.8 Lagging	0.78 Lagging	0.75 Lagging	0.9 Lagging	0.7 Lagging
Time in	6.00 A.M to	9.00 A.M to	12 Noon to	6.00 P.M to	10.00 P.M to

24 Hours	9.00 A.M	12 Noon	6.00 P.M	10.00 P.M	6.00 A.M

Suggest the best operating practice for the sub-station to minimize the transformer loss and also quantify the transformer loss minimized due to the best transformer operating practice.

Course Outcome 3 (CO3).

1. Name three types of motors in industrial practice.
2. Estimate the percentage loading of the induction motor with following data using input power method, line current method and slip method. Name plate details: Rated kW of Motor = 30 kW, Rated Amps = 55 A, Rated voltage = 415 V, Name plate efficiency = 92%,Name plate speed = 1440 rpm, No. of poles = 4, Frequency = 50 Hz.

   Operating Data: Measured speed = 1460 rpm, Input load current = 45 A, Operating voltage = 425 V & Input power = 20 kW
3. An 89% efficient 30HP Size standard efficiency induction motor was replaced with a 93% efficient 30HP size Premium efficiency induction motor to improve energy efficiency. Calculate the Annual energy saving potential and payback period for the above proposal, using the following data given for the above applications.

   Load factor - 90%
   Operating Hours per year - 8000 Hours
   Cost per kWh of Energy - Rs.5
   Cost of Premium efficiency induction motor - Rs.60000/-
   Scrap value of old standard efficiency induction motor - Rs.20000/-
   Assume the operating efficiency is as that of designed efficiency at 90% load factor condition.

Course Outcome 4 (CO4)

1. List the types of commonly used lamps.
2. Describe the methodology of lightning energy audit in an industrial facility.
3. The exterior areas of a Compressor House are illuminated by twenty wall-mounted 1000W Tungsten Halogen, single lamp, luminaries. The lamps burn 12 hours a day, throughout the year. The energy and cost savings that could be realized by changing to a more efficient light source were investigated.

   With reference to data given below suggest the suitable retrofit for annual energy saving and the simple payback period.

Luminaries	Lumens	Efficacy	Cost /lamp
1000 W Halogen lamp	22,700	22.70	Rs. 5000
250 W HPSV lamp	24,600	98.40	Rs. 5500
400 W Metal halide lamp	27,000	67.50	Rs. 6500

   Plant Operating Hours: 12 hours per day, 365 days per year. Electricity Costs: Rs 3.00/kWh
4. Look at two purely fictitious lighting systems, A and B. Lighting System A is the existing system and Lighting System B is a proposed retrofit system which simply includes more-energy-efficient lamps and ballasts. They produce comparable light output.

	Lighting System A	Lighting System B (proposed)
No. of fixtures	100	100
Input Watts/Fixture	175	100

Hours of Operation/Year	3,000	3,000
Energy Consumption/Year (kWh)	525 / fixture	300 / fixture
Utility Cost/kWh	Rs 1.0	Rs 1.0
Cost of implementation		Rs 700/fixture

Define the following for above case study and also calculate: a) Simple payback b) Five-year cash flow c) Simple return on Investment

5. Two main areas of an industrial plant have the following lighting systems:
   Area A: 50 x 400W High Pressure Sodium (HPSV) single lamp luminaries.
   Area B: 35 x 400W Mercury Vapour (HPMV) single lamp luminaries.
   In Area A and Area B, the measured Illuminance during daylight hours (12 hours) without artificial light was found to be adequate. In Area B it was noted that 8 of the MV fixtures are redundant. Plant Operating Hours: 24 hours per day, 365 days per year. Electricity Energy costs: Rs 3.00/kWh Calculate the annual potential energy cost savings from switching off unnecessary lights and from disconnecting redundant luminaries?
   Note: Ignore the ballast energy consumption.

Course Outcome 5 (CO5)

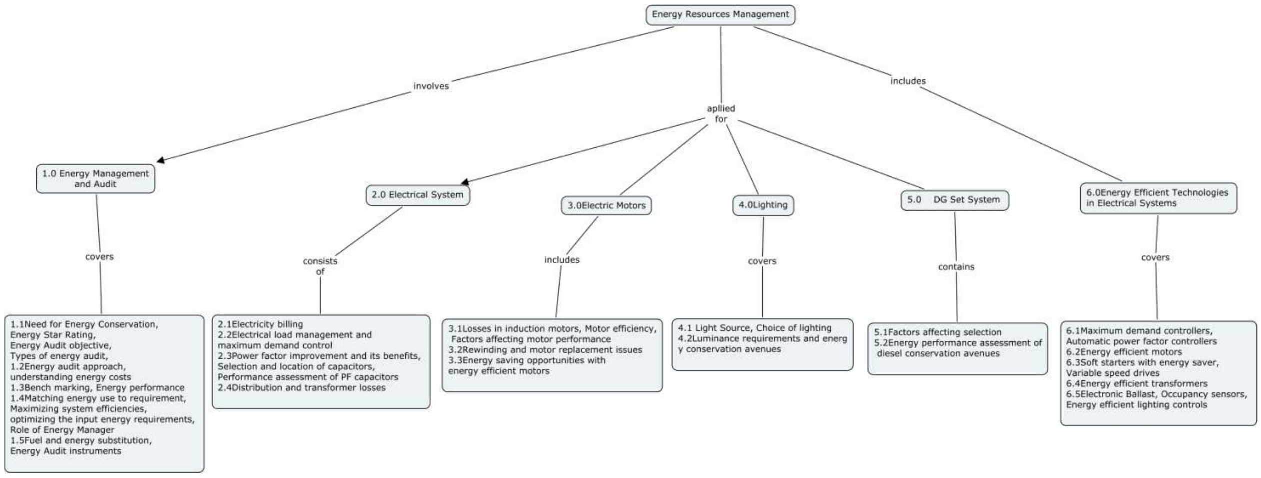
1. Specify the role of Turbo chargers.
2. List the energy savings opportunities in an industrial DG Set plant.
3. The Specific Fuel Consumption of a 500KVA Diesel Generating Set is 3.2kWh per litre of Diesel at 40% Load Factor. If the Load Factor is improved from 40% to 70%, the Specific Fuel Consumption is 3.8kWh per litre of Diesel. Calculate the fuel saving per day because of the load factor improvement.

Course Outcome 6 (CO6)

1. Specify the advantages of energy efficient motors.
2. Explain why centrifugal machines offer the greatest savings, when operating with Variable speed drives.
3. Mention the role of demand controller in industrial plants.
4. What is the function of Automatic Power factor controller?
5. A 500KVA 11KV/415V Transformer was proposed to buy for an Industrial application. The conventional Core Transformer Cost Rs. 2,50,000/-, whereas the Energy Efficient Amorphous core Transformer cost Rs.2,90,000/-. The Iron losses of Conventional and Amorphous core Transformers are 2200 Watts and 800Watts respectively. The copper losses for the both the transformers are same. Calculate the payback period for the excess investment paid for the Energy efficient Amorphous core transformer, when compared to conventional core Transformer. The cost of Electrical Energy is Rs.5 per kWh and the Transformer proposed to operate for 8760 Hours in a year.
6. A Chemical industry planned to install a Maximum Demand Controller and an Automatic Power Factor Controller to minimize the Demand Cost. The existing Contracted Demand is 4500KVA and actual demand is 4375KVA. The electricity board billing is based on 90% of contracted demand or Actual demand reached, whichever is higher. The demand charge is Rs.400 per KVA per month. The existing power factor is 0.92 lagging. After installing the Maximum Demand Controller and Automatic Power factor controller, the

Actual Maximum Demand reached is 3900KVA. The investment incurred in the Demand Saving measure is Rs. 9,00,000/-. Calculate the Demand Cost saving per year and Payback period for the above Encon proposal.

Concept Map



Syllabus

Energy Management and Audit –Need of Energy Conservation, Energy Star Rating/Green Labeling, Energy Audit objective, Types of energy audit, Energy audit approach, understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, optimizing the input energy requirements, Fuel and energy substitution, Energy Audit instruments, Role of Energy Manager

Electrical System – Electricity billing, Electrical load management and maximum demand control, Power factor improvement and its benefits, Selection and location of capacitors, Performance assessment of PF capacitors, Distribution and transformer losses. (Case Studies)
Financial Management: Interest Charges, Simple Payback calculation, Discounted Cash Flow Methods- Net Present Value Method & Internal rate of return method

Electric Motors – Types, Losses in induction motors, Motor efficiency, Factors affecting motor performance, Rewinding and motor replacement issues, Energy saving opportunities with energy efficient motors. (Case Studies)

Lighting – Light Source, Choice of lighting, LED Lighting, Induction Lighting, Luminance requirements and energy conservation avenues. (Case Studies)

DG Set System – Factors affecting selection, Energy performance assessment of diesel conservation avenues. (Case Studies)

Energy Efficient Technologies in Electrical Systems – Maximum demand controllers, Automatic power factor controllers, Energy efficient motors, Soft starters with energy saver, Variable speed drives, Energy efficient transformers, Electronic Ballast, Occupancy sensors, Energy efficient lighting controls. Checklist & Tips for Energy Efficiency in Electrical System.

Reference Books

1. Book I - General aspect of energy management and energy audit, Second Edition 2005, By Bureau of Energy Efficiency, Ministry of Power, India.
2. Book III - Energy efficiency in electrical utilities, Second Edition 2005, By Bureau of Energy Efficiency, Ministry of Power, India.

3. Book IV - Energy Performance Assessment for Equipment and Utility systems, Second Edition 2005, By Bureau of Energy Efficiency, Ministry of Power, India.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Energy Management and Audit**	
1.1	Need for Energy Conservation, Energy Star Rating, Energy Audit objective, Types of energy audit,	2
1.2	Energy audit approach, understanding energy costs	2
1.3	Bench marking, Energy performance	1
1.4	Matching energy use to requirement, Maximizing system efficiencies, optimizing the input energy requirements, Role of Energy Manager	2
1.5	Fuel and energy substitution, Energy Audit instruments	1
2.0	**Electrical System**	
2.1	Electricity billing	1
2.2	Electrical load management and maximum demand control	1
2.3	Power factor improvement and its benefits, Selection and location of capacitors, Performance assessment of PF capacitors	2
2.4	Distribution and transformer losses	1
2.5	***Financial Management*** :Interest Charges, Simple Payback calculation	1
2.6	Discounted Cash Flow Methods- Net Present Value Method	1
2.7	Internal rate of return method	1
3.0	**Electric Motors**	
3.1	Losses in induction motors, efficiency, Factors affecting motor performance	2
3.2	Rewinding and motor replacement issues	2
3.3	Energy saving opportunities with energy efficient motors	1
4.0	**Lighting**	
4.1	Light Source, Choice of lighting, LED Lighting, Induction Lighting	2
4.2	Luminance requirements and energy conservation avenues	2
5.0	**DG Set System**	
5.1	Factors affecting selection	1
5.2	Energy performance assessment of diesel conservation avenues	1
6.0	**Energy Efficient Technologies in Electrical Systems**	
6.1	Maximum demand controllers, Automatic power factor controllers	2
6.2	Energy efficient motors	2
6.3	Soft starters with energy saver, Variable speed drives	1
6.4	Energy efficient transformers	2
6.5	Electronic Ballast, Occupancy sensors, Energy efficient lighting controls	1
6.6	Checklist & Tips for Energy Efficiency in Electrical System.	1
	Total	**36**

Course Designers:

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18PSPK0	POWER QUALITY	Category	L	T	P	Credit
		PE	2	1	0	3

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 power conditioners

Prerequisite

NIL

Course Outcomes

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

CO1	Classify various electrical power quality issues in power systems	Understand
CO2	Describe causes and effects of power quality problems	Understand
CO3	Analyze various PQ problems	Analyze
CO4	Explain the mitigation methods for PQ issues	Understand
CO5	Construct harmonic filters for given specifications	Apply
CO6	Choose suitable custom power devices for mitigating power quality problems	Apply
CO7	Measure various PQ events	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	L						M		M	
CO2.	M	L						M		M	
CO3.	S	S	M	M				M	M	M	
CO4.	M	L						M		M	
CO5.	S	M	L	L				M		M	
CO6.	S	M	L	L				M		M	
CO7.	S	S	M	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	20	20	20	20
Understand	40	40	40	40
Apply	20	20	20	20
Analyse	20	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

* CO7 only for Assignment

Course Level Assessment Questions

Course Outcome 1 (CO1)

1. Distinguish voltage sag and voltage fluctuations.
2. Describe the need for PQ standards.
3. Explain the different types of transient over voltages.

Course Outcome 2 (CO2)

1. Describe the effects of loads on the quality of power.
2. What are the causes for voltage sag?
3. What are the effects of harmonics on transformers?

Course Outcome 3 (CO3)

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. Chose suitable mathematical tool for the extraction of fundamental sequence components from the samples of distorted voltage waveform.
3. 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 4 (CO4)

1. Differentiate active and passive filters.
2. Explain the working of UPS.
3. Describe the mitigation of PQ issues using constant voltage transformers.

Course Outcome 5 (CO5)

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. Design a suitable shunt active filter for the elimination of harmonics produced by 6-pulse power converter. Make suitable assumptions.

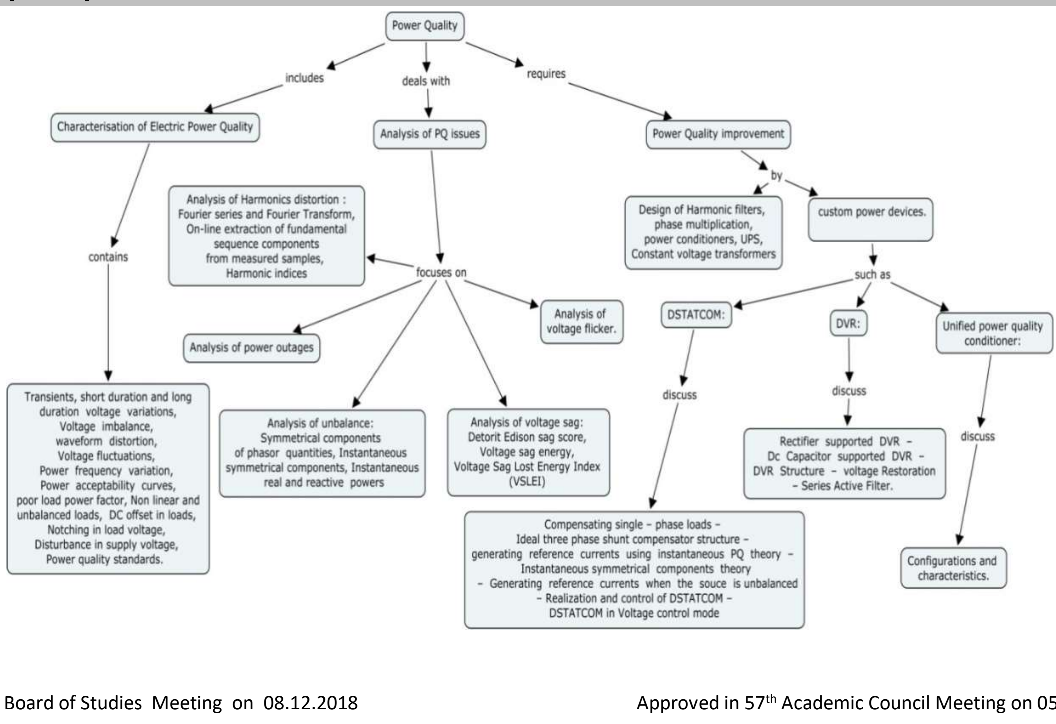
Course Outcome 6 (CO6)

1. Identify the role of shunt compensation devices and explain how Instantaneous pq theory is adapted to solve the load compensation issues.
2. Discuss how DVR is used to mitigate power quality problems.
3. Consider a distribution system which has large number of unbalanced non linear loads which highly affects the voltage quality of the distribution system. Identify suitable compensation device and explain how the issues related to voltage quality are mitigated.

Course Outcome 7 (CO7)

1. Classify PQ events measured using power quality analyzer in the power converter fed induction motor drive system.
2. Measure and analyze harmonic distortion in the electrical sub-station.
3. Indentify various power quality issues associated with non-linear loads using PQ analyzer.

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, Cable capacitance mitigation.

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, Static power balancer techniques.

DVR: Rectifier supported DVR, DC capacitor supported DVR, Series compensation and applications. **UPQC:** Configurations and applications.

PQ Monitoring – PQ Analyzer and Case Studies.

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(2nd 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

Module No.	Topic	No. of Lecture Hours
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)	2
2.5	Analysis of voltage flicker	1
3	**Power Quality Improvement**	
3.1	Passive filters	1
3.2	Shunt active filter	1
3.3	Phase multiplication, power conditioners	1
3.4	UPS, Constant voltage transformers	1
3.5	Cable capacitance mitigation	1
4	**DSTATCOM**	
4.1	Compensating single – phase loads	1
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	1
4.4	Realization and control of DSTATCOM	2
4.5	Static power balancer techniques	1
5	**DVR**	
5.1	Rectifier supported DVR	1
5.2	DC Capacitor supported DVR	1
5.3	Series Active Filter	2
5.4	Voltage Restoration	1
6	**Unified Power Quality Conditioner**	
6.1	Configurations and applications	2
7	**PQ Monitoring**	
7.1	Case Studies using Power Quality Analyzers	3
	Total	**36**

Course Designers:

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18PSPL0/ 18CIPS0	POWER PLANT INSTRUMENTATION AND CONTROL	Category	L T P	Credit
		PE	3 0 0	3

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

NIL

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.	Describe 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.	Select from currently commercially available power plant instrumentation and control systems for a given application.	Apply
CO5.	Explain the control equipment Practices in power plant.	Understand
CO6.	Suggest suitable instrumentation system for Turbine- Monitoring and control in a power plant.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	L						M		M	
CO2.	M	L						M		M	
CO3.	S	M	L	L				M		M	
CO4.	S	M	L	L				M		M	
CO5.	M	L						M		M	
CO6.	S	M	L	L				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	50	50	50	50
Apply	30	30	30	30
Analyze	0	0	0	0

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 role of instrumentation and control in power plants.
3. Explain the basic principles of power system control.
4. Draw and explain the Piping and Instrumentation (P & I) diagram for steam flow control in a boiler.

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.
1. Discuss briefly about waste to energy plants.
2. Explain how temperature is controlled with tilting burners.
3. List any two types of attemperator.
4. Compare the operation of two element and three element control used for feed water pumping.

Course Outcome 4 (CO4):

1. Organize the steps involved in compression control.
2. Compare and contrast between an oxygen analyzer and a flue gas analyzer.
3. Name three different drafts used in connection with boilers.
4. State any two advantages of electrical actuators.

Course Outcome 5 (CO5):

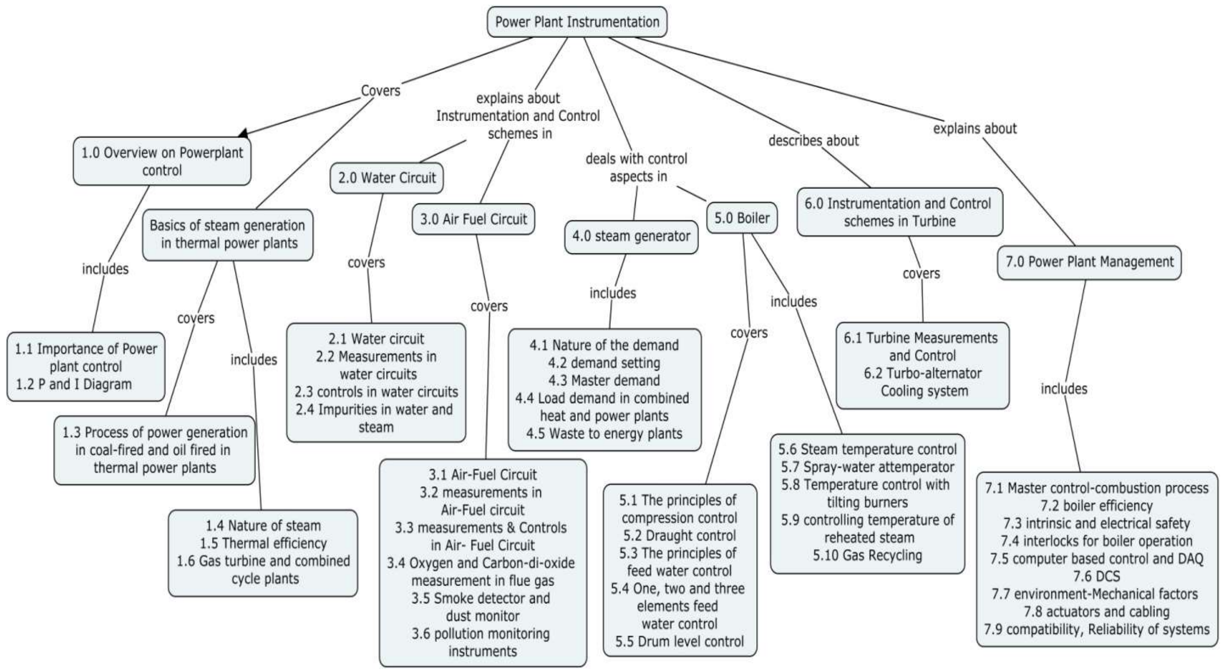
1. How system reliability is enhanced through redundancy in DCS?
2. List out basic safety interlocks used in boilers.
3. Describe how the functions of DDC and PLC combined in a DCS system.
4. Name various approaches for protection of explosion.

Course Outcome 6 (CO6):

1. Compare the technical features of safety control system and process control system in a turbine.
2. Explain how the speed and vibration of a steam turbine monitored.
3. Enumerate the essential steam turbine parameters to be monitored and controlled.
4. Select the suitable method for temperature measurements with suitable ranges, suitable sensors protection devices etc. for the following:

a. Shell temperature measurements
b. Bearing temperature measurements
c. Stem inlet temperature measurements
d. Lube oil temperature measurements

Concept Map



Syllabus

Introduction: Importance of instrumentation and control in Power plants-Piping and Instrumentation Diagram (P and I diagram).

Basics of steam generation process 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.

Instrumentation and Control schemes in Water Circuit: Water circuit-Measurements in water circuits-controls in water circuits-impurities in water and steam.

Instrumentation and Control schemes in Air- Fuel Circuit: Air-Fuel Circuit-measurements in Air-Fuel circuit – Controls in Air- Fuel Circuit-Analytical Measurements- Oxygen measurement in flue gas- Carbon-di-oxide measurement in flue gas-Infra red flue gas analysis-Smoke detector-dust monitor-chromatography-pollution monitoring instruments

Control aspects in 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

Control aspects in Boiler: 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 attemperator-Temperature control with tilting burners-controlling temperature of reheated steam-Gas Recycling

Instrumentation and Control schemes in Turbine:
Turbine steam Inlet System- Turbine Measurements-Turbine Control system- Turbo-alternator Cooling system.

Power Plant Management: Introduction-Master control-combustion process-boiler efficiency-maintenance of measuring instruments-intrinsic and electrical safety-interlocks for boiler operation-computer based control and data acquisition system-distributed control system (DCS)-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 Operations, McGraw Hill, New Delhi, 1994.
4. R.K.Jain, Mechanical and Industrial Measurements, Khanna Publishers, New Delhi, 1995.
5. P.K.Nag, "Power Plant Engineering" Tata McGraw-Hill, New Delhi, 2005.
6. A.K.Mahalanbias-"Power System Instrumentation"-Tata McGraw Hill.
7. K.Krishnaswamy and M.Ponni Bala-"Power Plant Instrumentation-" – PHI Learning Pvt. Ltd., New delhi, 2015.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Introduction**	
1.1	Importance of instrumentation and control in Power plants-	1
1.2	Piping and Instrumentation Diagram (P and I diagram).	1
	Basics of steam generation in thermal power plants	
1.3	Process of power generation in coal-fired and oil fired in thermal power plants	1
1.4	Nature of steam	1
1.5	Thermal efficiency	1
1.6.	Gas turbine and combined cycle plants	1
2.0	**Instrumentation and Control schemes in Water Circuit:**	
2.1	Water circuit-	1
2.2	Measurement and control in water circuits	1
2.3	Impurities in water and steam.	1
3.0	**Instrumentation and Control schemes Air- Fuel Circuit**	
3.1	Air-Fuel Circuit	1
3.2	Measurement and control in Air-Fuel circuit	1
3.3	Oxygen measurement in flue gas- Carbon-di-oxide measurement in flue gas	1
3.4	Infra red flue gas analysis-Smoke detector-dust monitor	1
3.5	chromatography-pollution monitoring instruments	1
4.0	**Control aspects in 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
4.4	Load demand in combined heat and power plants	1
4.5	Waste to energy plants	1

5.0	**Control aspects in Boiler**	
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	1
5.6	Steam temperature control	1
5.7	Spray-water attemperator	1
5.8	Temperature control with tilting burners, controlling temperature of reheated steam	1
5.9	Gas Recycling	1
6.0	**Instrumentation and Control schemes in Turbine**	
6.1	Turbine steam Inlet System-Turbine Measurements	1
6.2	Turbine Control system- Turbo-alternator Cooling system	1
7.0	**Power Plant Management**	
7.1	Master control-combustion process	1
7.2	boiler efficiency-maintenance of measuring instruments	1
7.3	intrinsic and electrical safety, interlocks for boiler operation	1
7.4	computer based control and data acquisition system	1
7.5	DCS-A Typical DCS configuration-Interconnections between systems	1
7.6	Equipment selection and environment-Mechanical factors and ergonomics	1
7.7	Electrical actuators-Hydraulic actuators-Cabling	1
7.8	Electromagnetic compatibility, Reliability of systems	1
	Total	**36**

Course Designers:

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18PSPM0	POWER SYSTEM RELIABILITY	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The basic function of a power system is to supply electrical energy to both large and small customers as economically as possible, and with an acceptable degree of reliability and quality. Reliability and quality are two essential measures and important components of all power system planning and operation procedures. Reliability is one of the key design factors when designing complex, critical and expensive systems. The reliability of electric power supply system has been defined as the probability of providing the users with continuous service of satisfactory quality. This course will cover key aspects of power system reliability. Starting from the basic concepts of reliability, in depth discussions on reliability in generation systems, transmission systems and distribution systems will be carried out.

Prerequisite

- 18PS110 - Optimization & Applied Mathematics
- 18PS160 - Analysis of modern power systems

Course Outcomes

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

Course Outcome No.	Course Outcomes	Blooms level
CO1.	Explain the basic reliability concepts and measures.	Understand
CO2.	Apply different types of reliability indices evaluation methods for the calculation of generating systems reliability	Apply
CO3.	Compare different types of reliability indices evaluation methods for transmission systems	Apply
CO4.	Apply the different types of reliability indices evaluation methods used in composite systems and interconnected systems.	Apply
CO5.	Compare different types of reliability indices evaluation methods for Distribution systems.	Apply
CO6.	Explain Reliability analysis of Combined DG and T&D Systems	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	L						M		M	
CO2.	S	M	L	L				M		M	
CO3	S	M	L	L				M		M	
CO4	S	M	L	L				M		M	
CO5	S	M	L	L				M		M	
CO6	M	L						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	**30**	**30**	**30**	**30**
Apply	**50**	**50**	**50**	**50**
Analyse	**-**	**-**	**-**	**-**
Evaluate	**-**	**-**	**-**	**-**
Create	**-**	**-**	**-**	**-**

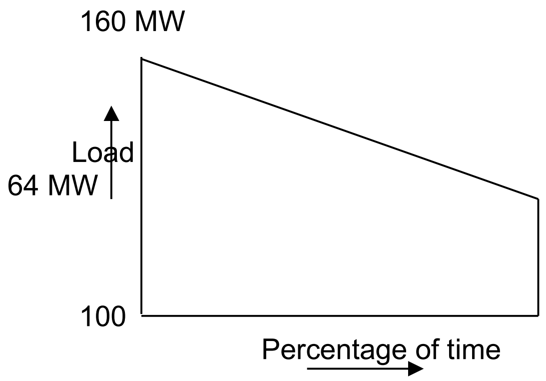
Course Level Assessment Questions

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):

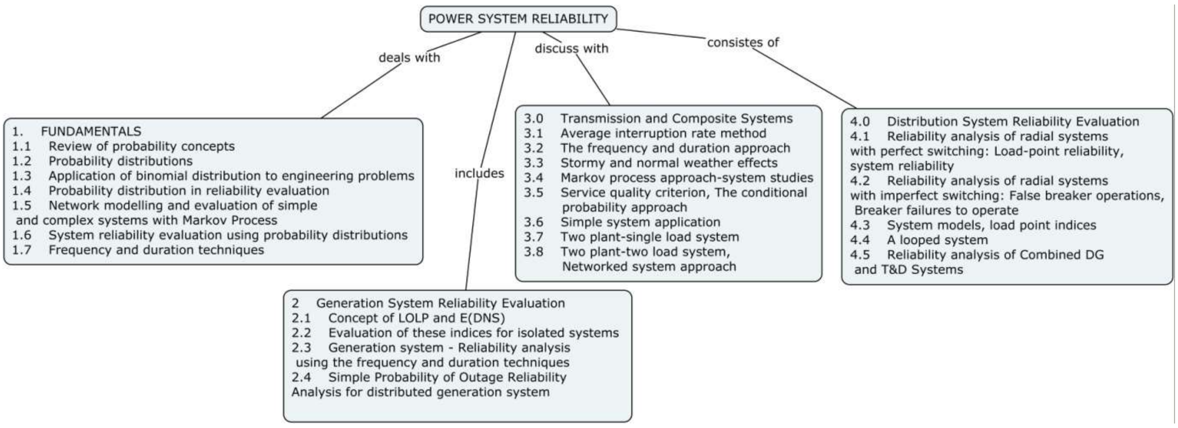
1. Write about load point reliability.
2. Find overall system reliability indices for a sample radial distribution system.
3. Derive the system reliability indices for the radial systems with perfect switching.

Course Outcome 6 (CO6):

1. Write about false breaker operations.

2. Discuss about breaker failures to operate for load point indices.
3. Find the mean duration of interruptions for a sample looped system with imperfect switching.

Concept Map



Syllabus

Fundamentals: Review of probability concepts - Probability distributions - Application of binomial distribution to engineering problems - Probability distribution in reliability evaluation - Network modelling and evaluation of simple and complex systems with Markov Process - System reliability evaluation using probability distributions - Frequency and duration techniques.

Generation System Reliability Evaluation: Concept of LOLP and E(DNS) - Evaluation of these indices for isolated systems - Generation system - Reliability analysis using the frequency and duration techniques - Simple Probability of Outage Reliability Analysis for distributed generation system.

Transmission and Composite Systems Reliability Evaluation: 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.

Distribution System Reliability Evaluation: Reliability analysis of radial systems with perfect switching: Load-point reliability, system reliability - Reliability analysis of radial systems with imperfect switching: False breaker operations, Breaker failures to operate – system models, load point indices – A looped system - Reliability analysis of Combined DG and T&D Systems.

Reference Books

1. Roy Billinton, Ronald N.Allan, “Reliability Evaluation of Engineering Systems”, Pitman Books Limited, London, second edition 1992.
2. J.Endrenyi, “Reliability modelling in Electric Power System”, John Wiley & Sons, New York, 1978
3. Roy Billinton, “Power System Reliability Evaluation”, Gordon and Breach Science Publishers, New York, Seventh printing, 1982.
4. Roy Billinton and R.N.Allan, “Reliability Evaluation of Power Systems, Pitman”, London, 1984 Edition.
5. U.G.Knight, “Power System Engineering Mathematics”, Pergamon Press – Gofard 1972
6. H. Lee Willis, Walter G Scott, “Distributed Power Generation: Planning and Evaluation Power Engineering”, CRC Press, 2000.
7. Rajesh Karki, Roy Billinton, Ajit Kumar Verma, “Reliability Modeling and Analysis of Smart Power Systems” Springer India, 2014.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	FUNDAMENTALS	
1.1	Review of probability concepts	2
1.2	Probability distributions	2
1.3	Application of binomial distribution to engineering problems	2
1.4	Probability distribution in reliability evaluation	2
1.5	Network modelling and evaluation of simple and complex systems with Markov Process	2
1.6	System reliability evaluation using probability distributions	2
1.7	Frequency and duration techniques	2
2	Generation System Reliability Evaluation	
2.1	Concept of LOLP and E(DNS)	1
2.2	Evaluation of these indices for isolated systems	2
2.3	Generation system - Reliability analysis using the frequency and duration techniques	2
2.4	Simple Probability of Outage Reliability Analysis for distributed generation system	2
3.0	Transmission and Composite Systems	
3.1	Average interruption rate method	1
3.2	The frequency and duration approach	1
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	Distribution System Reliability Evaluation	
4.1	Reliability analysis of radial systems with perfect switching: Load-point reliability, system reliability	**2**
4.2	Reliability analysis of radial systems with imperfect switching: False breaker operations, Breaker failures to operate	**1**
4.3	System models, load point indices	**1**
4.4	A looped system	**1**
4.5	Reliability analysis of Combined DG and T&D Systems	**2**
	Total	**36**

Course Designers:

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18PSPP0	HVDC TRANSMISSION	Category	L	T	P	Credit
		PE	3	0	0	3

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

NIL

Course Outcomes

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

CO1.	Explain the history, need and advantages of HVDC system	Understand
CO2.	Explain the modern technology used in HVDC.	Understand
CO3.	Explain the converters, choices and analyse using Graetz circuit	Understand
CO4.	Describe control strategies used in HVDC system with HVDC converters and multi terminal dc system .	Understand
CO5.	Apply suitable method for power flow analysis in AC/DC systems.	Apply
CO6.	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.	M	L						M		M	
CO2.	M	L						M		M	
CO3.	M	L			L			M		M	
CO4.	M	L			S			M		M	
CO5.	S	M	L	L	L			M		M	
CO6.	S	M	L	L	S			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	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. List the advantages of DC transmission.

Course Outcome 2 (CO2):
1. Explain modern trends in DC transmission system.
2. Explain the specifications and concepts used DC transmission system.

Course Outcome 3 (CO3):

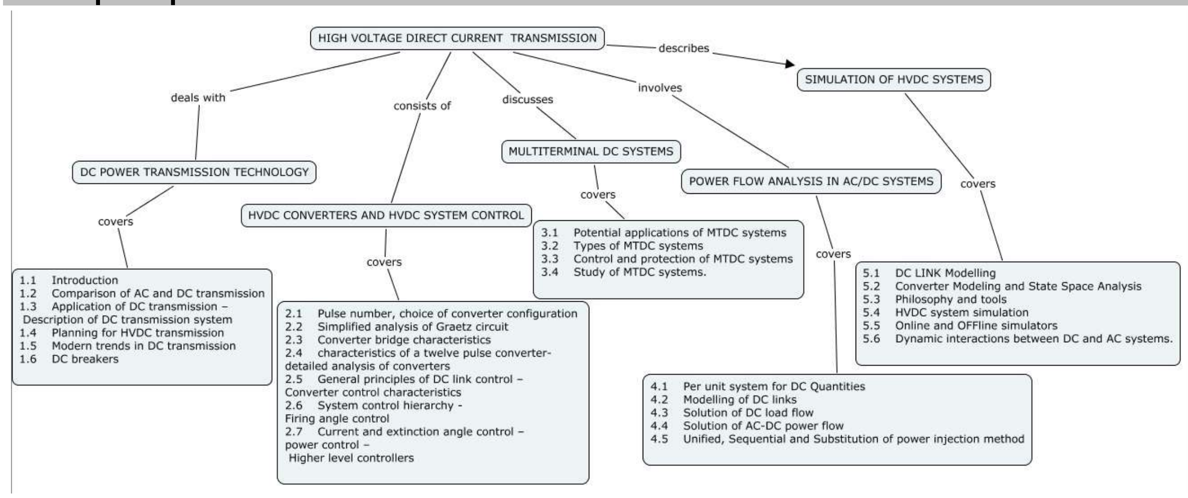
1. Define pulse number.
2. Explain the types of MTDC systems.
3. Explain the characteristics of a twelve pulse converter used in HVDC.

Course Outcome 4 (CO4):
1. Explain about current and extinction angle control
2. List the advantages of per unit quantities in DC system.

Course Outcome 5 (CO5):
1. Compare the solution of DC power flow over AC power flow in DC system.
2. Perform power flow analysis using substitution of power injection method.

Course Outcome 6 (CO6):
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	1
3.2	Types of MTDC systems	1
3.3	Control and protection of MTDC systems	1
3.4	Study of MTDC systems.	1
4.0 POWER FLOW ANALYSIS IN AC/DC SYSTEMS		
4.1	Per unit system for DC Quantities	1
4.2	Modelling of DC links	1
4.3	Solution of DC load flow	2
4.4	Solution of AC-DC power flow	1
4.5	Unified, Sequential and Substitution of power injection method	1
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	1
5.5	Online and OFF line simulators	1
5.6	Dynamic interactions between DC and AC systems.	1
	Total	**36**

Course Designer:

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18PSPQ0	**SOFT COMPUTING TECHNIQUES**	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

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

Prerequisite

18PS160 Analysis of modern power systems

Course Outcomes

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

CO1.	Describe soft computing techniques and their roles in building intelligent systems	Understand
CO2.	Identify the suitability of 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 and particle swarm optimization to power system economic load dispatch(ELD) problem	Apply
CO6.	Analyze the performance of Fuzzy logic and Neural network for mapping the given load forecasting and modelling using MATLAB	Analyze
CO7.	Analyze the performance of Genetic algorithm and particle swarm optimization algorithms for optimizing the given ELD problem using MATLAB	Analyze

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1.	M	L						M		M	
CO2.	S	M	L	L				M		M	
CO3.	S	M	L	L				M		M	
CO4.	S	M	L	L				M		M	
CO5.	S	M	L	L				M		M	
CO6.	S	S	M	M	S			M	M	M	**S**
CO7.	S	S	M	M	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	10	10	10	10
Understand	10	10	40	40

Apply	30	30	50	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

CO6 and CO7 are assessed by conducting practical examination.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the role of softcomputing tools in building intelligent systems.
2. Outline the use of softcomputing 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 softcomputing tools.
3. Contrast between conventional optimization and genetic algorithms.
4. Choose the appropriate softcomputing 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 softcomputing 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:

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

   Suppose a Cartesian product between $\tilde{T}$ and $\tilde{F}$ is formed that results in the following relation$\tilde{R}$

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

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 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 $f(x) = x^2$ $0 \leq x \leq 31$, 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. Evalute the performance of the fuzzy logic controller over PI controller for the given power system problem
2. Evalute 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

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 Seidel method. Take α=1.6.
Train the neural network for the load pattern suitably and obtain the load voltages

Course Outcome (CO7)
(For evaluating the attainment of CO6 , practical examination should be conducted)

1. Perform simple binary coded and real coded genetic algorithm to solve the following optimization problem.
   Maximize f(x) = |x| sin(x) $-5 \leq x \leq 5$, 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.

2. Evaluate the performance of the GA and PSO 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:

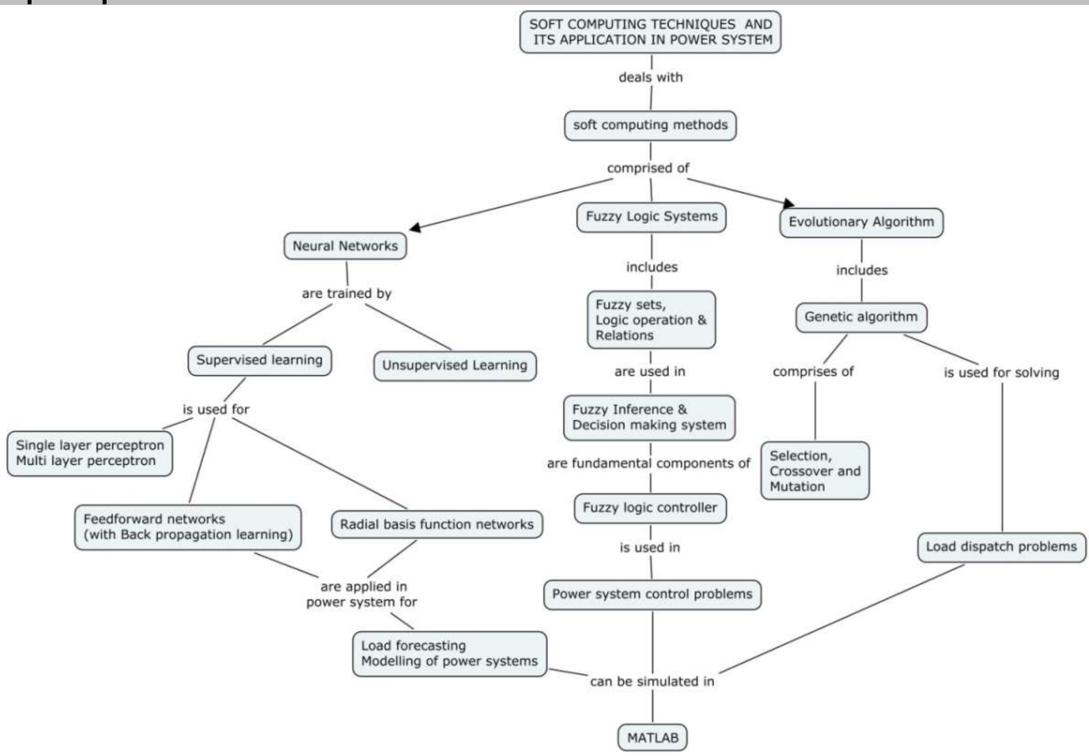
Fuel Cost($/h)	Minimum (MW)	Maximum (MW)
$F_1(P_1) = 0.00525P_1^2 + 8.66P_1 + 328$	50	250
$F_2(P_2) = 0.00608P_2^2 + 10.04P_2 + 137$	5	150
$F_3(P_3) = 0.00591P_3^2 + 9.76P_3 + 59$	15	100

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; Introduction to Deep learning, Application of neural network to load forecasting and modeling of power system

Introduction to genetic algorithms; genetic algorithm steps-Selection, Crossover and Mutation; introduction to swarm optimization, particle swarm optimization (PSO)-Velocity and position update equations. Application of GA and PSO to power system economic dispatch problem

Use of MATLAB, Fuzzy logic toolbox ,and Neural network toolbox to modeling, load forecasting and economic load dispatch problems

Reference Books

1. S.N.Sivanandam, and S.N.Deepa, Principles of Soft computing, Second Edition, Wiley India Pvt. Ltd,2013
2. George J.Klir and, Bo Yuan, Fuzzy sets and Fuzzy Logic, Second Edition, PHI,2006
3. J.M.Zurada, Introduction to artificial neural systems, Jaico Publishing House, 2006
4. D.E. Goldberg, Genetic algorithms in search, optimization, and machine learning, Addison-Wesley.1989.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	Introduction to soft computing and its role in building intelligent systems	1
2.	Need of soft computing tools , Merits and demerits	1
3.	Basics of Fuzzy logic, Neural network, and Genetic algorithms	3
4.	Fuzzy sets, logic operations, and relations	2
5.	Fuzzy decision-making and fuzzy inference systems	1
6.	Design steps in fuzzy logic controller	1
7.	Application of fuzzy logic controller in power system	2
8.	Neural networks: Basic concepts and major classes of neural networks,	2
9.	supervised and unsupervised learning,	1
10.	Single-layer perceptron, Multi-layer perceptron	2
11.	Back Propagation Neural network,	2
12.	Radial-basis function networks, introduction to Deep learning	1
13.	Application of neural network to load forecasting and modelling of power system	2
14.	Introduction to Evolutionary Algorithms and Swarm Optimization	1
15.	Genetic algorithm (GA) steps-Selection, Crossover and Mutation;	2

Module No.	Topic	No. of Lectures
16.	Particle Swarm optimization (PSO),Velocity and position update equations	2
17.	Application of GA and PSO to economic dispatch problem	2
18.	Use of MATLAB, Fuzzy logic toolbox , Neural network toolbox and to solve modeling ,forecasting and load dispatch problems	8
	Total	36

Course Designers:

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		Category	L	T	P	Credit
18PSPR0	**SUBSTATION AUTOMATION**	PE	3	0	0	3

Preamble

Substation automation is a rapidly increasing area of interest and benefit to utilities. Substation automation goes beyond traditional SCADA to provide added capability and information that can further improve operations and maintenance, increase system and staff efficiencies, and leverage and defer major capital investments. Substation Automation System provides protection, control, automation, monitoring, and communication capabilities as a part of a comprehensive substation control and monitoring solution. Substation automation is the cutting edge technology in electrical engineering. It means having an intelligent, interactive power distribution network.

Prerequisite

NIL

Course Outcomes

At the end of the course the student should be able to:

CO1	Explain the fundamental requirements and architecture of SCADA for Substation operation and its automation in electric power system.	Understand
CO2	Explain the features of RTU, interfaces and other functions of SCADA.	Understand
CO3	Discuss the operational and physical separation among station level, bay level and the process level.	Understand
CO4	Discuss the protection and interoperability standards of the power system	Understand
CO5	Select appropriate monitoring and control instruments to improve power system functionality and performance.	Apply
CO6	Design a complete SCADA equipped monitoring and control setup for substation automation.	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

S.No.	Bloom's Category	Test 1	Test 2	Test 3	End-semester examination
1	Remember	20	20	20	20
2	Understand	50	40	40	40
3	Apply	30	30	30	30
4	Analyze	0	0	0	0
5	Evaluate	0	0	0	0

6	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 2 (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 3 (CO3):

1. Draw the conceptual structure of Substation Automation.
2. What is meant by bay level in Substation Automation?
3. What is the role of local mode HMI?
4. Explain in detail about data exchange between station level and bay level.

Course outcome 4 (CO4)

1. Illustrate the power transformer protection and control monitoring with SA.
2. Discuss the communication standards and protocols for substation automation
3. Illustrate the interoperability features of SAS

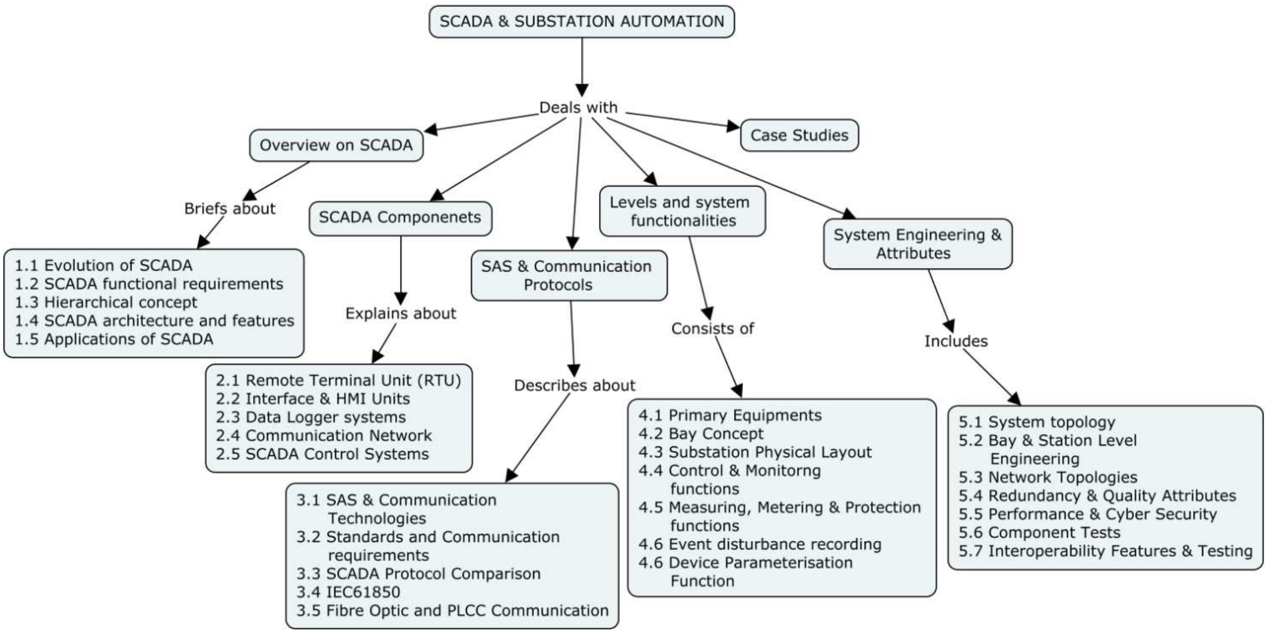
Course outcome 5 (CO5)

1. Illustrate the reliability improvement through substation automation.
2. Demonstrate the disturbance recording and power quality assessment done by SA.
3. Illustrate how the performance is improved in the operation of power system because of SA.
4. Demonstrate the substation automation methodology to counteract power system collapse.

Course outcome 6 (CO6)

1. List the SCADA software utilized for power system applications
2. Design an SCADA configuration for utility Substation automation
3. Develop SCADA architecture for enhance interoperability feature of distribution system.
4. Explain the role of SCADA in power system monitoring

Concept Map



Syllabus

UNIT I INTRODUCTION TO SCADA
Evolution of SCADA, SCADA definitions, SCADA Functional requirements and Components, SCADA Hierarchical concept, SCADA architecture, General features, SCADA Applications, Benefits

UNIT II SCADA SYSTEM COMPONENTS
Remote Terminal Unit (RTU), Interface units, Human- Machine Interface Units (HMI), Display Monitors/Data Logger Systems, Intelligent Electronic Devices (IED), Communication Network, SCADA Server, SCADA Control systems and Control panels

UNIT III INTRODUCTION TO SAS & COMMUNICATION PROTOCOLS
Evolution of SAS – Emerging Communication Technologies – IED's – Networking Mediums – Communication requirements – Standards - Structure of a SCADA Communications Protocol, Comparison of various communication protocols - IEC61850 based communication architecture, Communication media like Fiber optic & PLCC, Interface provision and communication extension, synchronization with NCC, DCC.

UNIT IV SWITCHYARD LEVEL EQUIPMENT LEVEL & SYSTEM FUNCTIONALITIES

Primary Equipments – Instrument Transformers – Power Transformers – Electrical Connections – Bay Concept - Substation Physical Layout – System Functionalities – Control Function – Monitoring Function – Measuring & Metering function – Protection Function –Event and Alarm- Event disturbance recording- Breaker Control- Report Generation & Device Parameterisation Function

UNIT V SAS SYSTEM ENGINEERING, ATTRIBUTES & TE

System General Concept – System Topology – Signal Lists – Bay Level Engineering – Station Engineering – Functionalities Level Engineering – Network Topologies – Redundancy Options – Quality Attributes – Performance Requirements – Cyber security Considerations – Tests on SAS Components-Interoperability features-system installation- testing and commissioning.

CASE STUDIES:
SAS Design for 220/132 kV or 132/66 KV any utility Substation and IEC 61850 based SCADA Implementation issues in utility Substations.

Reference Books

1. Substation Automation Systems – Design & Implementation – By Evillo Padilla – Wiley & Sons - 2016
2. Stuart A. Boyer: SCADA-Supervisory Control and Data Acquisition, Instrument Society of America Publications,USA,2004
3. Gordon Clarke, Deon Reynders: Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems, Newnes Publications, Oxford, UK,2004
4. William T. Shaw, Cybersecurity for SCADA systems, PennWell Books, 2006
5. David Bailey, Edwin Wright, Practical SCADA for industry, Newnes, 2003
6. Michael Wiebe, A guide to utility automation: AMR, SCADA, and IT systems for electric Power, PennWell 1999
7. Dieter K. Hammer, Lonnie R. Welch, Dieter K. Hammer, "Engineering of Distributed Control Systems", Nova Science Publishers, USA, 1st Edition, 2001

Course contents and Lecture schedule

Sl.No.	Topic	No. of Lectures
1.0	**INTRODUCTION TO SCADA**	
1.1	Evolution of SCADA, SCADA definitions	2
1.2	SCADA Functional requirements and Components	1
1.3	SCADA Hierarchical concept	1
1.4	SCADA architecture, General features	2
1.5	SCADA Applications, Benefits	1
2.0	**SCADA SYSTEM COMPONENTS**	
2.1	Remote Terminal Unit (RTU)	1
2.2	Interface units, Human- Machine Interface Units (HMI)	2
2.3	Display Monitors/Data Logger Systems	1
2.4	Intelligent Electronic Devices (IED), Communication Network	1
2.5	SCADA Server, SCADA Control systems and Control panels	1
3.0	**INTRODUCTION TO SAS & COMMUNICATION PROTOCOLS**	
3.1	Evolution of SAS – Emerging Communication Technologies	1
3.2	IED's – Networking Mediums	1
3.3	Communication requirements – Standards	1
3.4	Structure of a SCADA Communications Protocol, Comparison of various communication protocols	1
3.4	IEC61850 based communication architecture	1
3.5	Communication media like Fiber optic & PLCC	1

3.6	Interface provision and communication extension, synchronization with NCC, DCC	1
4.0	**SWITCHYARD LEVEL EQUIPMENT LEVEL & SYSTEM FUNCTIONALITIES**	
4.1	Primary Equipments – Instrument Transformers – Power Transformers	1
4.2	Electrical Connections – Bay Concept	1
4.3	Substation Physical Layout	1
4.4	System Functionalities – Control Function – Monitoring Function	1
4.5	Measuring & Metering function – Protection Function	1
4.6	Event and Alarm-Event disturbance recording	1
4.7	Breaker Control- Report Generation & Device Parameterization Function	1
5.0	**SAS SYSTEM ENGINEERING, ATTRIBUTES & TESTING**	
5.1	System General Concept – System Topology	1
5.2	Signal Lists – Bay Level Engineering – Station Engineering	1
5.3	Functionalities Level Engineering – Network Topologies	1
5.4	Redundancy Options – Quality Attributes	1
5.5	Performance Requirements – Cyber security Considerations	1
5.6	Tests on SAS Components	1
5.7	Interoperability features-system installation- testing and commissioning	1
6.0	**CASE STUDIES**	2
	Total	**36**

Course Designers

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18PSPS0	ELECTRIC AND HYBRID VEHICLES	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

In future transportation sector of any country, electric vehicles and hybrid electric vehicles will play a major role as internal combustion engine (ICE) based vehicles creates many problems such as creation of more pollution, higher running cost and poor energy conversion efficiency. ICE based vehicles need petroleum products which are getting depleted day by day. Hybrid electric vehicles (HEV) and electric vehicles (EV) produce less pollution and have higher energy conversion efficiency. This course introduces the fundamental concepts, analysis and design of hybrid electric and electric vehicles. The students learn about the various aspects of hybrid and electric vehicles such as their configuration, powertrain sizing, types of electric machines and their control, and energy storage devices, etc.

Prerequisite

-NIL

Course outcomes

CO1	Explain the basics of concepts of Electric vehicle (EV) and hybrid electric vehicles(HEV)	Understand
CO2	Calculate the tractive force, tractive power and energy required for the given road, acceleration and velocity profile condition in a vehicle	Apply
CO3	Calculate the power rating of motor and ICE and battery energy requirements for the given EV and HEV specifications	Apply
CO4	Analyze the performance of EV / HEV using simulation software	Analyze
CO5	Explain the different energy storage systems used in EV and HEV and their characteristics and charging methods	Understand
CO6	Explain the DC drives and AC drives used for motor control in EV and HEV	Understand
CO7	Explain the different control strategies used in HEV and in-vehicle communication	Understand

Mapping with Programme Outcomes

COs	PO 1	PO2	PO 3	PO 4	PO 5	PO 6	PO7	PO8	PO 9	PO10	PO11	PO12
CO1	M	L						M		M		
CO2	S	M	L	L				M		M		
CO3	S	M	L	L				M		M		
CO4	S	S	M	M				M		M		
CO5	M	L						M		M		
CO6	M	L						M		M		
CO7	M	L						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	30	30	30	30
Apply	50	50	50	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

CO4 will be assessed using an assignment on simulation of some part of EV/HEV.

Course Level Assessment Questions

Course Outcome 1 (CO1):
1.Draw the block diagram of electric vehicle and explain its operation.
2.How the electric motor and engine ratings are selected in a HEV

Course Outcome 2 (CO2):
1.Explain laws of motion with respect to vehicle.
2.Define tractive force and tractive power.

3. A straight roadway has a profile in the $x_f y_f$ plane given by
$f(x_f) = 3.9\sqrt{x_f}$ for $0 \leq x_f \leq 2$mi. x_f and y_f arre given in feet.
   a) Plot the roadway,
   b) Find $\beta(x_f)$
   c) Find the percent grade at x_f = 1mi.,
   d) Find the tangential road length between 0 and 2mi.

4. An electric vehicle has the following parameter values:
m=800kg, C_D= 0.2, A_f=2.2m^2, C_0=0.008, C_1=1.6 × 10^{-6} s^2/m^2,
Also, take density of air ρ=1.18kg/m^3, and acceleration due to gravity g=9.81 m/s^2,
the vehicle profile is given by $v(t) = 0.29055t^2$ for $0 \leq t \leq 10$s.
   a) Calculate $F_{TR}(t)$ for $0 \leq t \leq 10$s.
   b) Calculate $P_{TR}(t)$ for $0 \leq t \leq 10$s.

5. An electric vehicle has the following parameter values ρ=1.16Kg/m^3, m=692Kg, C_D=0.2, A_F =2m^2, g=9.81m/s^2, C_o=0.009, and C_1=1.75 x 10^{-6} s^2 /m^2. The electric vehicle undergoes constant F_{TR} acceleration on a level road starting from rest at t=0. The maximum continuous F_{TR} that the electric motor is capable of delivering to the wheels is 1548N.
   a) Find V_T (F_{TR}) and plot it.
   b) If F_{TR} =350N, (i) find V_T , (ii) plot v(t) for t≥0, (iii) find t_{VT} , (iv) calculate the time required to accelerate from 0 to 60 mi/h. (v calculate P_{TRpk}, $\bar{P}_{TR}$, $\Delta\ell_{TR}$ corresponding to acceleration to 0.98V_T.

Course Outcome 3 (CO3):

1.Explain the procedure to find the rating of motor and battery in a EV.

2. Explain the procedure to find the rating of motor, ICE and battery in a HEV.

3. The parameters of a parallel HEV are as follows:

Description	**Parameters**
Vehicle mass	1800Kg
Driver/one passenger	80Kg
Rolling resistance coefficient, c_o	0.01
Aerodynamic drag coefficient, C_{AD}	0.4
Frontal area, A_f	2.6m^2

The vehicle is to accelerate uniformly (i.e., constant acceleration) from 0 to 60mi/h in 10s.

a) Find an expression for traction force as a function of time F_{TR} (t) for this initial acceleration period.

b) Find an expression for traction power as a function of time P_{TR}(t) for the initial acceleration period.

c) Find the energy $\Delta\ell_{TR}$ require for initial acceleration between 0 and 10s.

4. The vehicle parameters and performance requirements of the vehicle are used for sizing calculations:

Description	Requirements
Vehicle mass	1800 kg
Driver / one passenger	176 lb/80 kg
Trailering capacity	1000 kg
Rolling resistance coefficient, C_0	0.01
Wheel radius, r_{wh}	0.3305m
Aerodynamic drag coefficient, C_{AD}	0.45
Frontal area, A_f	2.5 m^2
0-60 mi/h	8.0 s
50-70 mi/h	6.3 s
Sustained cruising speed (with trailer)	55 mi/h at 7% grade
Sustained cruising speed (without trailer)	70 mi/h at 0.5% grade
Zero emission range speed (without trailer)	5 mi at 40 mi/h

The initial acceleration requirement is without the trailer, but the total mass must account for the driver and one passenger:

a) Calculate the velocity and power at the end of 5s for a constant force initial acceleration. The constant force is 7600N.

b) The vehicle accelerates in the constant power mode after the initial constant force acceleration period of part (a) with a constant power of 140 kW. Write the dv/dt equation for constant power acceleration for the given conditions. What is the velocity after a total time of 8s?. (you can solve the equation numerically).

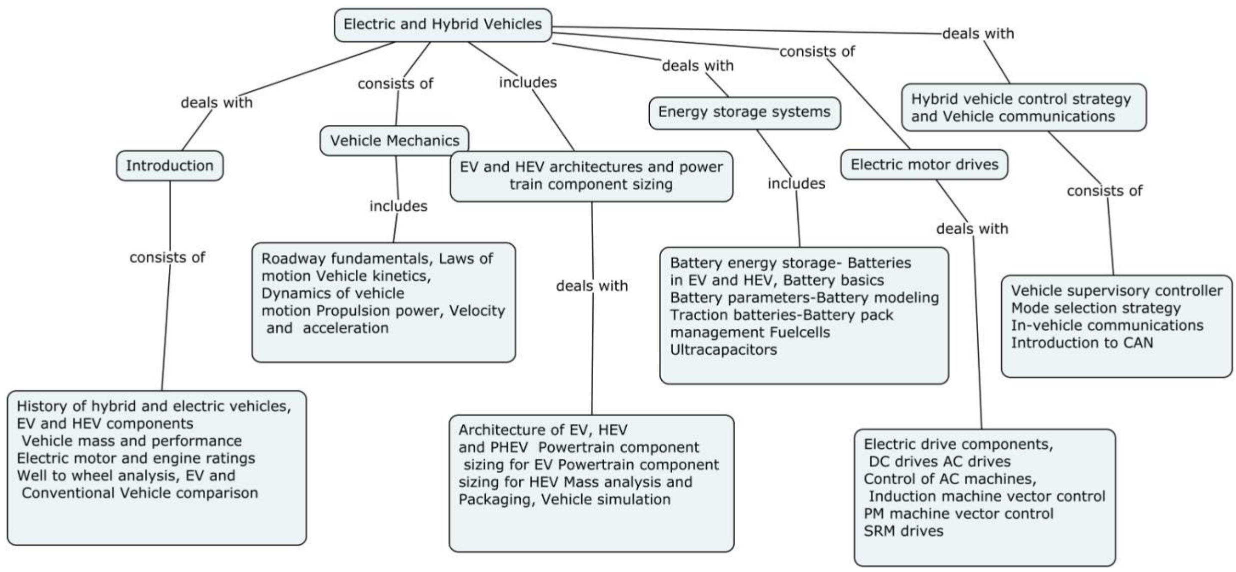
c) Calculate the power required for a steady state velocity of 55mi/h at 7% with trailer.

Course Outcome 4 (CO4):
1. Develop the model of EV for simulation.
2. Develop the model of HEV for simulation.

Course Outcome 5(CO5):
1. Explain the different types of batteries along with their characteristics that can be used in EV/HEV.
2. Explain the different types of fuel cells along with their characteristics that can be used in EV/HEV.
3. Explain the different types of ultra capacitors along with their characteristics that can be used in EV/HEV.

Course Outcome 6 (CO6):
1. Explain the different control strategies used in HEV in detail.
2. Explain the in-vehicle communication used in EV/HEV.
3. Explain the working principle of CAN protocol.

Concept Map:



Syllabus

Introduction

History of Electric vehicles (EV) and Hybrid electric vehicles (HEV)-EV and HEV components-Vehicle mass and performance-Electric motor and engine ratings- Well to wheel analysis- EV and Conventional Vehicle comparison

Vehicle Mechanics
Roadway fundamentals-Laws of motion-Vehicle kinetics-Dynamics of vehicle motion-Propulsion power-Velocity and acceleration

EV and HEV architectures and powe train component sizing
Architecture of EV, HEV and PHEV- Powertrain component sizing for EV,HEV- Mass analysis and Packaging – Vehicle simulation-PHEV-V2G and G2V - Fuel cell vehicles

Energy storage systems
Battery energy storage- Batteries in EV and HEV-Battery basics-Battery parameters-Battery modeling- Traction batteries-Battery pack management-SOC and Fast charging-Ultra capacitors

Electric motor drives
Electric drive components- DC drives- AC drives-Control of AC machines-Induction machine vector control- PM machine vector control – SRM drives

Hybrid vehicle control strategy and Vehicle communications
Vehicle supervisory controller-Mode selection strategy- In-vehicle communications- Introduction to CAN

References Books:

1. Iqbal Husain, Electric and hybrid vehicles-Design fundamentals, Second edition, CRC Press,2011
2. Chris Mi, M. Abul Masrur, David Wenzhong Gao, 'Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives', Wiley, 2011.
3. Mehr Ehsani, Yimin Gao, Sebestien E. Gay and Ali Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design", CRC Press, 2004.
4. S. Onori, L. Serrao and G. Rizzoni, "Hybrid Electric Vehicles: Energy Management Strategies", Springer, 2015.
5..T. Denton, "Electric and Hybrid Vehicles", Routledge Pub., 2016.
6. Ion Boldea and S.A Nasar, 'Electric drives', CRC Press, 2005.
7. James Larminie & John Lowry "Electric Vehicle Technology Explained " ,John Wiley & sons, 2012

Course Contents and Lecture Schedule

S.No.	Topics	No. of Lectures
1.	**Introduction**	
1.1	History of hybrid and electric vehicles, EV and HEV components	2
1.2	Vehicle mass and performance	1
1.3	Electric motor and engine ratings	2
1.4	Well to wheel analysis, EV and Conventional Vehicle comparison	1
2	**Vehicle Mechanics**	
2.1	Roadway fundamentals, Laws of motion	2
2.2	Vehicle kinetics, Dynamics of vehicle motion	2
2.3	Propulsion power, Velocity and acceleration	2

3.	**EV and HEV architectures and powertrain component sizing**	
3.1	Architecture of EV, HEV and PHEV	1
3.2	Powertrain component sizing for EV	1
3.3	Powertrain component sizing for HEV	1
3.4	Mass analysis and Packaging, Vehicle simulation- PHEV-V2G and G2V - Fuel cell vehicles	2
4.	**Energy storage systems**	
4.1	Battery energy storage- Batteries in EV and HEV, Battery basics	2
4.2	Battery parameters-Battery modeling	2
4.3	Traction batteries-Battery pack management	2
4.4	SOC and Fast charging	1
4.5	Ultra capacitors	1
5	**Electric motor drives**	
5.1	Electric drive components, DC drives	2
5.2	AC drives	1
5.3	Control of AC machines, Induction machine vector control	2
5.4	PM machine vector control	1
5.5	SRM drives	1
6.	**Hybrid vehicle control strategy and Vehicle communications**	
6.1	Vehicle supervisory controller	1
6.2	Mode selection strategy	1
6.3	In-vehicle communications	1
6.4	Introduction to CAN	1
	Total	**36**

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18PG250	RESEARCH METHODOLOGY AND IPR	Category	L	T	P	Credit
		CC	2	0	0	2

Preamble

The course on the Research Methodology and IPR is offered as common Core course. The objective of this course is to understand and analyze Research Methodology and IPR protection.

Prerequisite

NIL

Course Outcomes

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

1. Understand research problem formulation.
2. Analyze research related information
3. Follow research ethics
4. Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
5. Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.
6. Understand that IPR protection provides an incentive to inventors for further research work and investment in R&D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester 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

Syllabus

Module 1: Meaning of research problem, Sources of research problem, Criteria, Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem, Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Module 2: Effective literature studies approaches, analysis Plagiarism, Research ethics

Module 3: Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Module 4: Nature of Intellectual Property: Patents, Designs, Trade and Copyright, Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Module 5: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Module 6: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs

Reference Books

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'" 2nd Edition,
2. "Research Methodology: A Step by Step Guide for beginners"
3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
4. Mayall, "Industrial Design", McGraw Hill, 1992.
5. Niebel, "Product Design", McGraw Hill, 1974.
6. Asimov, "Introduction to Design", Prentice Hall, 1962.
7. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
8. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Designers:

1. Adapted from AICTE Model Curriculum for Postgraduate Degree Courses in Engineering & Technology, Volume-I, January 2018.

18PGAA0	PROFESSIONAL AUTHORING	Category	L	T	P	Credit
		AC	2	0	0	2

Preamble

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

1. Explain how to improve your writing skills and level of readability
2. Write each section of research paper
3. Write good quality technical paper

Syllabus

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction

Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.

Key skills for writing a Title, writing an Abstract, writing an Introduction, writing a Review of the Literature,

Skills for Writing the Methods, Results, Discussion and Conclusions

Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission

Assessment Pattern

Abstract	:	10
Introduction	:	10
Literature Review	:	10
Research Question	:	10
Methods	:	10
Results and Discussion	:	10
Conclusions	:	10
Appropriateness of Title	:	05
Quality of the Paper and Plagiarism	:	25

References

1. Goldbort R, ‘Writing for Science’, Yale University Press, 2006
2. Day R, ‘How to Write and Publish a Scientific Paper’, Cambridge University Press, 2006
3. Highman N, ‘Handbook of Writing for the Mathematical Sciences, SIAM Highman’s book, 1998
4. Adrian Wallwork, ‘English for Writing Research Papers’, Springer New York Dordrecht Heidelberg London, 2011

18PGAB0	VALUE EDUCATION	Category	L	T	P	Credit
		AC	2	0	0	2

Preamble

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

1. Experience self-development
2. Explain the importance of Human values
3. Develop the overall personality

Syllabus

Values and self-development –Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non- moral valuation. Standards and principles, Value judgements

Importance of cultivation of values, Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness, Honesty, Humanity, Power of faith, National Unity, Patriotism, Love for nature, Discipline

Personality and Behavior Development, Soul and Scientific attitude, Positive Thinking. Integrity and discipline, Punctuality, Love and Kindness, Avoid fault Thinking, Free from anger, Dignity of labour, Universal brotherhood and religious tolerance, True friendship, Happiness Vs suffering, love for truth.

Aware of self-destructive habits, Association and Cooperation, Doing best for saving nature

Character and Competence –Holy books vs Blind faith, Self-management and Good health, Science of reincarnation, Equality, Nonviolence , Humility, Role of Women, All religions and same message, Mind your Mind, Self-control, Honesty, Studying effectively

Assessment Pattern

Bloom's Category	Continuous Assessment Test	Terminal Examination
Remember	20	20
Understand	40	40
Apply	40	40
Analyse	0	0
Evaluate	0	0
Create	0	0

References

1. Chakroborty, S.K. "Values and Ethics for organizations Theory and practice", OxforUniversity Press, New Delhi