CURRICULUM AND DETAILED SYLLABI

FOR

M.E. DEGREE (Power System Engineering) PROGRAM

FIRST SEMESTER SUBJECTS

&

LIST OF ELECTIVE SUBJECTS

FOR THE STUDENTS ADMITTED FROM THE ACADEMIC YEAR 2011-2012 ONWARDS

THIAGARAJAR COLLEGE OF ENGINEERING

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

MADURAI – 625 015, TAMILNADU

Phone: 0452 – 2482240, 41

Fax: 0452 2483427

Web: www.tce.edu

Passed in BOS meeting held on 30.4.2011 Approved in 43rd AC meeting held on 12.10.2011

Department of Electrical and Electronics Engineering

Graduating Students of M.E. program of Power System Engineering will be able to:

1. Specify, architect, design and analyze systems that efficiently and economically generate, transmit, distribute and utilize electrical power to meet the present power market strategy.
2. Specify, design, prototype and test modern Power Systems using various simulation packages and soft computing tools.
3. Work in a team using common tools and environments to achieve project objectives.

Thiagarajar College of Engineering: Madurai-625015

Department of Electrical and Electronics Engineering

Scheduling of Courses

Sem.	Theory Courses						Practical / Project
4th (12)							K41 Project Phase – II 0:12
3rd (16)	K31 Power System Planning and Reliability 3:1	KEX Elective -V 3:1	KEX Elective -VI 3:1				K34 Project Phase-I 0:4
2nd (24)	K21 Power System Optimization 3:1	K22 Power System Operation and Control 3:1	KEX Elective -I 3:1	KEX Elective -II 3:1	KEX Elective -III 3:1	KEX Elective -IV 3:0	K 27 Power System Laboratory - II 0:1
1st (24)	K11 Applied Mathematics for Electrical Engineers 3:1	K12 Systems Theory 3:1	K13 Power System Modelling and Analysis 3:1	K14 Digital Protection for Power System 3:1	K15 Power System Dynamics and Stability 3:1	K16 Power Converters for Distributed Generation Systems 3:0	K17 Power System Laboratory - I 0:1

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power System Engineering) PROGRAM

SUBJECTS OF STUDY

(For the candidates admitted from 2011-2012 onwards)

FIRST SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
K11	Applied Mathematics for Electrical Engineers	BS	3	1	-	4
K12	Systems Theory	DC	3	1	-	4
K13	Power System Modelling and Analysis	DC	3	1	-	4
K14	Digital Protection for Power System	DC	3	1	-	4
K15	Power System Dynamics and Stability	DC	3	1	-	4
K16	Power Converters for Distributed Generation Systems	DC	3	-	-	3
PRACTICAL						
K17	Power System Laboratory - I	DC	-	-	3	1
Total			**18**	**5**	**3**	**24**

BS : Basic Science
DC : Department Core
DE : Departmental Elective

L : Lecture
T : Tutorial
P : Practical

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2/3 Hours Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power Systems Engineering) PROGRAM
SCHEME OF EXAMINATIONS

(For the candidates admitted from 2011-2012 onwards)

FIRST SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	K11	Applied Mathematics for Electrical Engineers	3	50	50	100	25	50
2	K12	Systems Theory	3	50	50	100	25	50
3	K13	Power System Modelling and Analysis	3	50	50	100	25	50
4	K14	Digital Protection for Power System	3	50	50	100	25	50
5	K15	Power System Dynamics and Stability	3	50	50	100	25	50
6	K16	Power Converters for Distributed Generation Systems	3	50	50	100	25	50
PRACTICAL								
7	K17	Power System Laboratory - I	3	50	50	100	25	50

* CA evaluation pattern will differ from subject to subject 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.

** Terminal Examination will be conducted for maximum marks of 100 and subsequently be reduced to 50 marks for the award of terminal examination marks

List of Electives – M.E. Power System Engineering

Departmental Electives			
Sub. Code KEx	Subject Name	Pre/Co requisites	Credits
KEA	Power System Optimization	Power System Analysis	4
KEB / CNEH	Power Plant Instrumentation and Control	Measurement and Instrumentation	4
KEC	Flexible AC Transmission Systems	Power System Analysis Power Electronics	4
KED	Electrical Transients in Power system	Power System Analysis	4
KEE	Analysis of Electrical Machines	Electrical Machines	4
KEF	Renewable Energy Resources	Generation, Power Plant Engineering	4
KEG	Power Quality	Power System Analysis, Power Electronics	4
KEH	Soft Computing Techniques	Fuzzy Logic, Neural Networks	4
KEI / CN EA	Control of Electric Drives	Electrical machines, power Electronics	4
KEJ	Power System Reliability	Power System Analysis	4
KEK	Power System Voltage Stability	Power System Stability	4
KEL	Advanced Digital Signal Processing	Digital Signal Processing	4
KEM	Control of Electric Drives	Power Electronics	4
KEN	Control System Design	Control System, Systems Theory	4
KEO	Distributed Generation Systems	Generation, Transmission & Distribution	4
KEP	Energy Resource Management	Energy Conservation & Audit	4
KEQ	Power System Practices	Power system Analysis	4
KER	Custom Power Devices	Power System Analysis, Power Electronics	4
KES	Gas Insulated Substations	Power System Protection	4
KET / CN EI	Real Time Operating Systems	Micro Processors / Micro controllers	4
KEU / CN EO	SCADA	Micro Processors , Instrumentation, DSP	4

Sub Code	Lectures	Tutorial	Practical	Credit
K11	3	1	-	4

K11 Applied Mathematics for Electrical Engineers **3:1**

(Common to CN 11 in M.Tech. Control and Instrumentation)

Preamble

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

Prerequisite: Matrix, Probability and Statistics, Calculus.

Competencies

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

1. compute the pseudo- inverse of the rectangular matrix
2. decompose the non-square matrix by singular value decomposition.
3. derive the probability density function of a function of random variables.
4. determine the most reliable results of the population based on all the information available in a sample using non-parametric methods.
5. estimate the functions of time when the probability measure is associated through random process.
6. optimize the functional involving several variables and higher derivatives .

Assessment Pattern

S.No.	Bloom's category	Test 1	Test 2	Test 3 / End Semester Examination
1	Remember	10	10	10
2	Understand	10	10	20
3	Apply	80	80	70
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course level learning objectives

Remember

1. Define Generalized eigen vectors.
2. Write the Solution of the Eulers equation $v(y(x)) = \int F(y, y')dx$.
3. What is meant by independent random variable.
4. Mention the formula to test the hypothesis using Kolmogorov smirnov test.
5. What is wide sense stationary process.

Understand

1. Determine the singular value decomposition of $\begin{pmatrix} 1 & 2 \\ 1 & 1 \\ 1 & 3 \end{pmatrix}$

2. If the joint pdf of X and Y is f(x,y)= x+y,0<x<2,0<y<1

   = 0 else where

   Show that X and Y are statistically dependent.
3. The following arrangement indicates whether sixty consecutive care which went by the toll booth of a bridge had local plates,L,or out-of state plates O:

   L L O L L L L O O L L L L O L O O L L L L O L O O L L L L L O
   L L L O L O L L L L O O L O O O O L L L L O L O O L L L O.Illustrate whether this arrangement of L's and O's may be regarded as random by using the level of significance $\alpha = 0.05$.
4. Comparing two kinds of emergency flares, a consumer testing service obtained the following burning times(rounded to the nearest tenth of a minute)

   Brand C : 19.4, 21.5, 15.3, 17.4, 16.8, 16.6, 20.3, 22.5, 21.3, 23.4, 19.7, 21.0.
   Brand D : 16.5, 15.8, 24.7, 10.2, 13.5, 15.9, 15.7, 14.0, 12.1, 17.4, 15.6, 15.8 . Use the Mann-Whitney test and a level of significance of 0.01 to check whether it is reasonable to say that there is no difference between the true average burning times of the two kinds of flares.
5. Check whether the random process X(t) =A$e^{i\omega t}$ is a WSS if E[A]=0
6. Determine the extremals of $\int_0^{2}(y^{12} + z^{12} + 2y^{1})$dx satisfying the conditions y(0)=0,y($\frac{\pi}{2}$)= 1,z(0)=1 and z($\frac{\pi}{2}$) $= 0$.

Apply

1. construct QR decomposition of the matrix$\begin{pmatrix} -4 & 2 & 2 \\ 3 & -3 & 3 \\ 6 & 6 & 0 \end{pmatrix}$

2. 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.
3. The following are the number of minutes it took a sample of 15 men and 12 women to complete the application form for a position.

   Men: 16.5, 20.0, 17.0, 19.8, 18.5, 19.2, 19.0, 18.2, 20.8, 18.7, 16.7, 18.1, 17.9, 16.4, 18.9.
   Women: 18.6, 17.8, 18.3, 16.6, 20.5, 16.3, 19.3, 18.4, 19.7, 18.8, 19.9, 17.6. Apply the Mann-Whitney test at the level of significance $\alpha = 0.05$ to the null hypothesis that the two samples come from identical population.

4. The following are the number of misprints counted on pages selected at random from the Sunday editions of a newspaper:

April 11: 4, 10, 2, 6, 4, 12
April 18: 8, 5, 13, 8, 8, 10
April 25: 7, 9, 11, 2, 14, 7

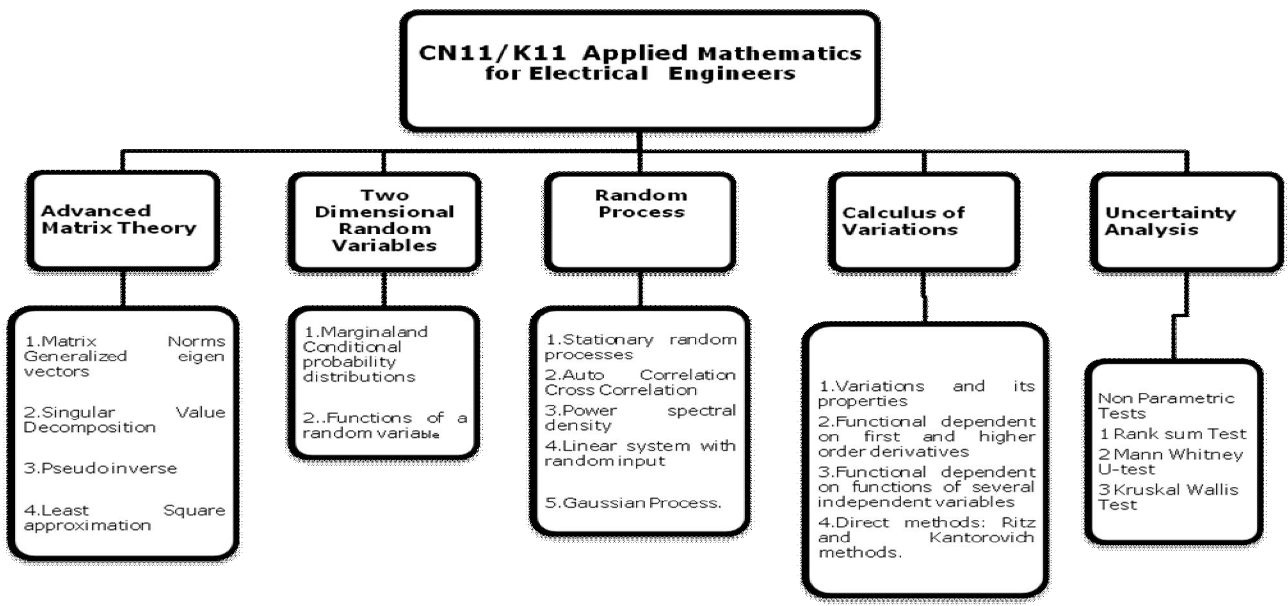
Apply Kruskal-Wallis test at the level of significance $\alpha = 0.05$ to test the null hypothesis that the three samples come from identical populations against the alternative that the compositors and/or proofreaders who worked on the three editions are not equally good.

4.Apply Ritz method to find approximate solution of the problem
y'' +y+x=0, 0≤x≤1,, y(0) =0= y(1).

7. Prove that the extremal of the isometric problem v(y(x))= $\int_1^4 y'^2$ dx, y(1)=3, y(4)=24 subject to $\int_1^4 y$ dx= 36 is a parabola

8. If the random process X(t)= $\sin(\omega t + y)$ where y is a random variable uniformly distributed in the interval $(0,2\pi)$,prove that for the process X(t),
$C(t_1,t_2) = R(t_1,t_2) = \frac{\cos\omega(t_1 - t_2)}{2}$

Concept map



Syllabus

Advanced Matrix Theory

Matrix Norms – Jordon canonical form – Generalized eigen vectors – Singular Value Decomposition – Pseudo inverse – Least Square approximation – QR algorithm.

(Treatment as per text book 1).

Two Dimensional Random Variables

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

Random Process

Classification – Stationary random processes – Auto Correlation – Cross Correlation – Power spectral density – Linear system with random input – Gaussian Process.

(Treatment as per text book 3).

Calculus of Variations

Variations and its properties –Euler's equation – Functional dependent on first and higher order derivatives – Functional dependent on functions of several independent variables – Some applications – Direct methods: Ritz and Kantorovich methods.

(Treatment as per text book 4).

Uncertainty Analysis

Sign test of paired data**,** Rank Sum test, Mann Whitney U-test, Kruskal Wallis test, One sample run test, Kolmogorov-Smirnov test.

(Treatment as per text book 5)

Reference Books

1. Bronson,R, " Matrix Operations, Schaums Outline Series", McGraw Hill, New York, 1989.
2. Paul L.Meyer, "Introductory Probability and statistical applications", Addison-Wesley,1981.
3. Peebles JR., P.Z., "Probability Random Variables and Random Signal Principles", McGraw Hill inc.,(1993)
4. Gupta .A.S. ,"Calculus of variations and applications", Prentice Hall of India, New Delhi, 1999.
5. Irwin Miller, John E.Freund "Probability and Statistics for Engineers" Prentice Hall of India Pvt. Ltd.; New Delhi, 1977.
6. T.Veerarajan "Probability, Statistics and Random Processes" Tata McGraw-Hill, New Delhi, 2003.
7. K.Murugesan, P.Gurusamy, "Probability Statistics & Random Processes" , Anuradha Agencies,2000.

Course contents and Lecture schedule

S.No	Topic	No. of Lectures
1.0	**Advanced Matrix Theory**	
1.1	Matrix Norms	1
1.2	Jordon canonical form – Generalized eigen vectors	1
1.3	Singular Value Decomposition	2
1.4	Pseudo inverse	1
1.5	Least Square approximation	1
1.6	QR algorithm	1
2.0	**Two Dimensional Random Variables**	
2.1	Marginal and Conditional probability distributions	1
2.2	Independent random Variables	1
2.3	Functions of a random variable	1
2.4	distribution of product and quotient of independent random variables	2

3.0	**Random Process**	
3.1	Classification	1
3.2	Stationary random processes	2
3.3	Auto Correlation, Cross Correlation	2
3.4	Power spectral density	2
3.5	Linear system with random input	2
3.6	Gaussian Process	1
4.0	**Calculus of Variations**	
4.1	Variations and its properties	2
4.2	Euler's equation	1
4.3	Functional dependent on first and higher order derivatives	2
4.4	Functional dependent on functions of several independent variables, Some applications	2
4.5	Direct methods: Ritz and Kantorovich methods	2
5.0	**Uncertainty Analysis: Non Parametric Tests**	
5.1	Sign test of paired data	1
5.2	Rank Sum test	2
5.3	Mann Whitney U-test	2
5.4	Kruskal Wallis test	2
5.5	One sample run test	1
5.6	Kolmogorov-Smirnov test	1
	Total No. of Lectures	40

Course Designers

V.Mohan vmohan@tce.edu
S.Jeyabharathi sjbmat@tce.edu
C.S. Senthil Kumar kumarstays@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K12	3	1	-	4

K12 Systems Theory 3:1

(Common to CN12 in M.Tech Control and Instrumentation)

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.

Competencies

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

1. Model linear time invariant dynamic system
2. Analyze SISO dynamic system for controllability , Observability, stabilizability, and Detectability using state models
3. Design state feedback controllers to get the desired performance for SISO systems
4. Design of estimators with and without noise for unmeasuarble SISO systems
5. Analyze MIMO dynamic system using frequency domain approach
6. Analyze nonlinear dynamic system behavior using phase –plane and describing function
7. Determine the stability of linear and nonlinear autonomous systems

Assessment Pattern

S.No.	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	20	20	20
2	Understand	20	20	20
3	Apply	60	60	60
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course level Learning Objectives

Remember

1. What are the advantages of state space of analysis?
2. What is state diagram?
3. Write the properties of state transition matrix.
4. What is free and forced response?
5. Define Stabilisability and detectability.
6. What are the properties of transfer function matrix?
7. Write the condition for asymptotically stable in large?
8. Mention the few applications of non linear problems.
9. Draw the input output characteristics of relay with dead zone and hysterisis.
10. What is meant by bandwidth and critical frequency?

Understand

1. Mention the types of non linearity and derive a describing function for a dead zone and saturation non linearity.
2. Explain the concept of Liapunov's stability criterion with basic theorems.
3. What is the need for different canonical models?
4. Why is state model not unique? Explain
5. What is the need for observer? Explain
6. Why are linear system analysis tools not useful for analyzing nonlinear systems?

Apply

1. Determine the transfer function and impulse response of the scalar system described by the state model of

$$\overset{0}{X} = \begin{bmatrix} 0 & 1 \\ 0 & -5 \end{bmatrix} X(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t); \quad y(t) = [1\ 0]X(t)$$

2. For the linear autonomous system given by determine the stability of the equilibrium using direct method of Lyapunov.

$$X(k+1) = \begin{bmatrix} 0.5 & 1 \\ -1 & -1 \end{bmatrix} X(t)$$

3. For a system represented by static equation $\dot{X}(t) = A\,X(t)$. The response is $X(t) = \begin{bmatrix} e^{-2t} \\ -2e^{-2t} \end{bmatrix}$ when $X(0) = \begin{bmatrix} 1 \\ -2 \end{bmatrix}$ and $X(t) = \begin{bmatrix} e^{-t} \\ -e^{-t} \end{bmatrix}$ when $X(0) = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$. Determine the system matrix A and the state transition matrix.

4. Determine the impulse response matrix for the following MIMO system.

$$G(s) = \begin{bmatrix} \dfrac{1}{s(s+2)} & \dfrac{1}{(s+1)} \\ \dfrac{1}{(s+1)} & \dfrac{1}{s(s+1)} \end{bmatrix}$$

5. Obtain the minimal realization of the given MIMO system

$$G(s) = \frac{1}{(s+1)(s+2)(s+3)} \begin{bmatrix} 6s^2 + 21s + 17 & 4s^2 + 14s + 10 \\ 14s^2 + 49s + 41 & 7s^2 + 23s + 16 \end{bmatrix}$$

6. 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.

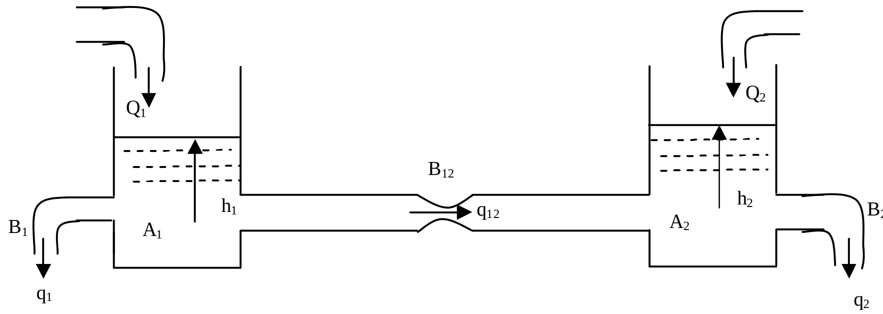


fig.1

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

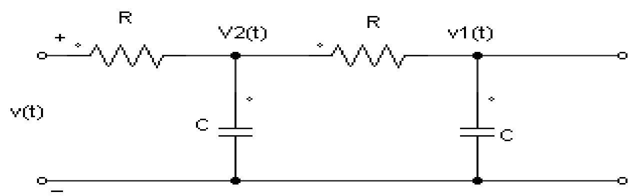


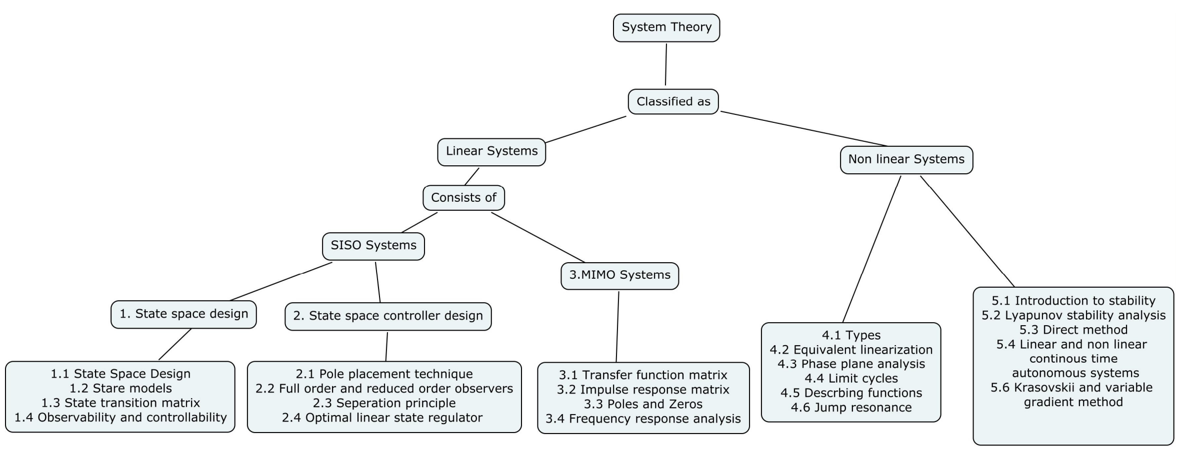
fig.2

8. Comment about the stability of given nonlinear system governed by the equations

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

$$\dot{x}_2 = -x_2$$

Concept Map



Syllabus

State Space Analysis

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

State Space Controller Design
Introduction – State Feedback control – Pole Placement by State Feedback – Full Order and Reduced Order Observers – Separation principle –Optimal linear state regulator – Stochastic optimal linear estimator.
MIMO Systems
Properties of transfer functions Matrix – Impulse response matrices – Poles and zeros of transfer function matrices – Critical frequencies – Resonance – Steady state and dynamic response – Bandwidth- Nyquist plots – Singular value analysis.
Non-Linear Systems
Types of non-linearity – Typical examples – Equivalent linearization – Phase plane analysis – Limit cycles – Describing functions- Analysis using Describing functions – Jump resonance.
Stability
Introduction – Equilibrium Points – Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems – The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems – Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems – Krasovskii and Variable-Gradient Method.

Reference Books

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

Course contents and Lecture schedule

Sl.No.	Topic	No. of Lectures
1.0	**State Space Analysis**	**09**
1.1	Introduction - Concept of state space model for dynamic systems	1
1.2	Time invariance and Linearity, Non-uniqueness, Minimal realization, Canonical state models	2
1.3	Solution of state equations – State transition matrix	2
1.4	Free and forced responses	1
1.5	Controllability and Observability	2
1.6	Stabilisability and Detectability	1
2.0	**State Space Controller Design**	**10**
2.1	Introduction – State Feedback control	1
2.2	Pole Placement by State Feedback	2
2.3	Full Order and Reduced Order Observers	2
2.4	Separation principle	2
2.5	Optimal linear state regulator	2
2.6	Stochastic optimal linear estimator	1

3.0	**MIMO Systems**	**08**
3.1	Properties of transfer functions Matrix	1
3.2	Impulse response matrices	2
3.3	Poles and zeros of transfer function matrices	1
3.4	Critical frequencies, Resonance, Steady state and dynamic response, Bandwidth	1
3.5	Nyquist plots	2
3.6	Singular value analysis	1
4.0	**Non-Linear Systems**	**09**
4.1	Types of non-linearity – Typical examples	2
4.2	Equivalent linearization	1
4.3	Phase plane analysis	2
4.4	Limit cycles	1
4.5	Describing functions- Analysis using Describing functions	2
4.6	Jump resonance	1
5.0	**Stability**	**09**
5.1	Introduction – Equilibrium Points	1
5.2	Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems	2
5.3	Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems	2
5.4	The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems	1
5.5	Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems	1
5.6	Krasovskii and Variable-Gradient Method	2
	Total	**45**

Course Designers

S.Baskar sbeee@tce.edu
S.Charles Raja charlesrajas@tce.edu
V.Mahesh maheshv@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K13	3	1	-	4

K13 Power System Modelling and Analysis **3:1**

Preamble

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

Competencies

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

1. Represent various power system components that are adequate for the basic System studies of load flow and short-circuit.
2. Develop nodal representation of the power transmission network.
3. Facilitate the modification of Y_{bus} to reflect the network changes.
4. Frame Z_{bus} by building algorithm.
5. Calculate the voltage magnitude and angle at each bus of the power network under specified operating condition by different methods.
6. Carry out short circuit studies for both symmetrical and unsymmetrical faults both in terms of phase quantities and symmetrical components.

Assessment Pattern

S.No.	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	10	10	10
2	Understand	30	30	30
3	Apply	30	30	30
4	Analyze	30	30	30
5	Evaluate	0	0	0
6	Create	0	0	0

Course level Learning Objectives

Remember

1. Define primitive network.
2. Define incidence matrix.
3. What is slack bus? Why it is required?
4. Write the general power flow equations of a power system.
5. What are all the assumptions made in the short circuit studies?
6. Draw the primitive model representation of network components in impedance form.
7. Define basic cut-set incidence matrix.
8. Mention the assumptions made in the FDLF method.

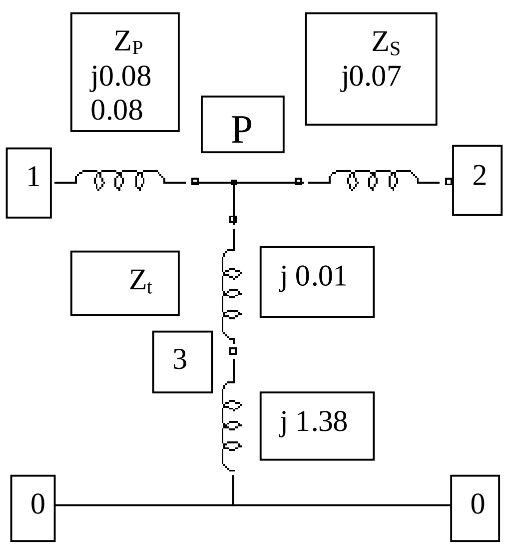
9. Define symmetrical fault on a power system.
10. What is the significance of symmetrical component?

Understand

1. Why addition of a link to an existing network does not change the size of the old Z_{bus}?
2. How modification of the bus impedance matrix is performed for changes in the network?
3. Signify accelerating factor in load flow studies.
4. How a change in primitive value is incorporated in the Z_{bus}?
5. How do you determine short circuit KVA in three phase circuits?
6. Formulate the cutset and tieset matrices for a simple network.
7. Which type of fault is severe whether symmetrical or unsymmetrical?
8. How approximations are done in NR methods?

Apply

1. A three-winding 132/6.6/33 kV , 3-phase,50Hz transformer has the following measured impedances between the windings referred to the 132kV winding.



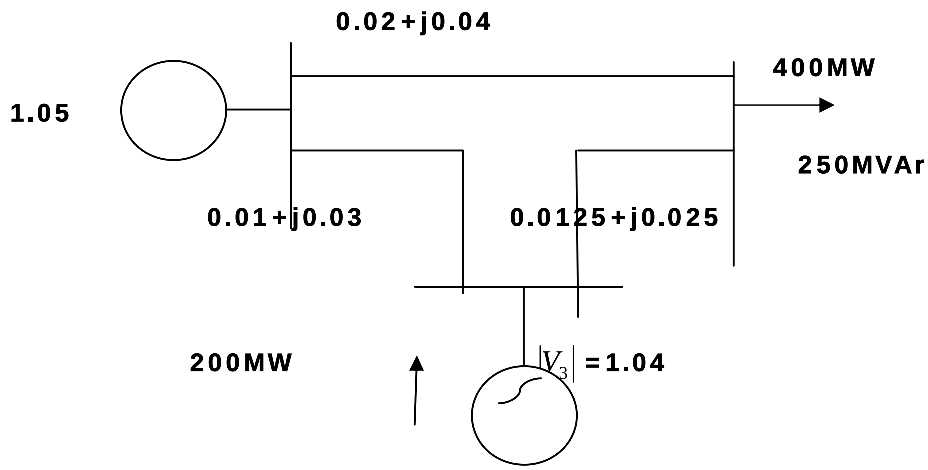
$$Z_{PS} = 0 + j\,0.15\,p.u$$
$$Z_{PT} = 0 + j\,0.09\ \ p.u$$
$$Z_{ST} = 0 + j\,0.08\ \ p.u$$

The 6.6kV secondary winding supplies a balanced load, taking a current of 200 A at 0.8 lagging power factor (p.f) and the 33KV tertiary supplies a star connected inductive reactor of (0+j50)ohm per phase. Determine the voltage required at the 132KV primary terminals to maintain 6.6KV at the secondary terminals. The base MVA is 30.

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

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

3. Consider the three bus system shown in figure below. Find the state variables for the system for the two iterations using Guass-Seidel method.



4. (a) For the network shown in figure below, form the incidence matrices K,A and C. The graph of the network is given figure below.

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

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

The schedule of generator and load

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

The line admittance

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

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

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

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

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

Compute the new bus admittance matrix.

8. For the sample system shown in figure below, the following data is given (Tables 1 and 2)

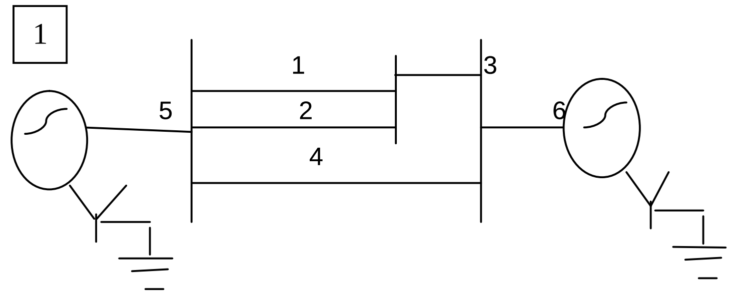


Table.1 Line Reactances

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

Table.2 Generator Reactances

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

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

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

(1) Fault currents

(2) Line currents

(3) Bus voltages during fault.

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

(1) Fault currents

(2) Line currents

(3) Bus voltage during fault.

Analyze

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

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

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

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

2. The Y_{BUS} matrix of a 4 bus system with bus 1 as reference is

Y_{BUS} =

	2	3	4
2	15.5	8	5.4
3	8.2	10.2	3.6
4	5.4	3.6	8.9

Find a) the Y_{BUS} of the system with the bus 2 as reference .b) the reference is once again changed to bus 1. Find the Y_{BUS} for bus 1 as reference and cross check your result.

3. Consider the power system with the following data:

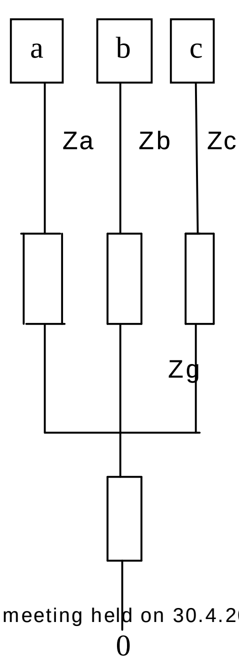
$$Y_{BUS} = \begin{bmatrix} -j12 & j8 & j4 \\ j8 & -j12 & j4 \\ j4 & j4 & -j8 \end{bmatrix}$$

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

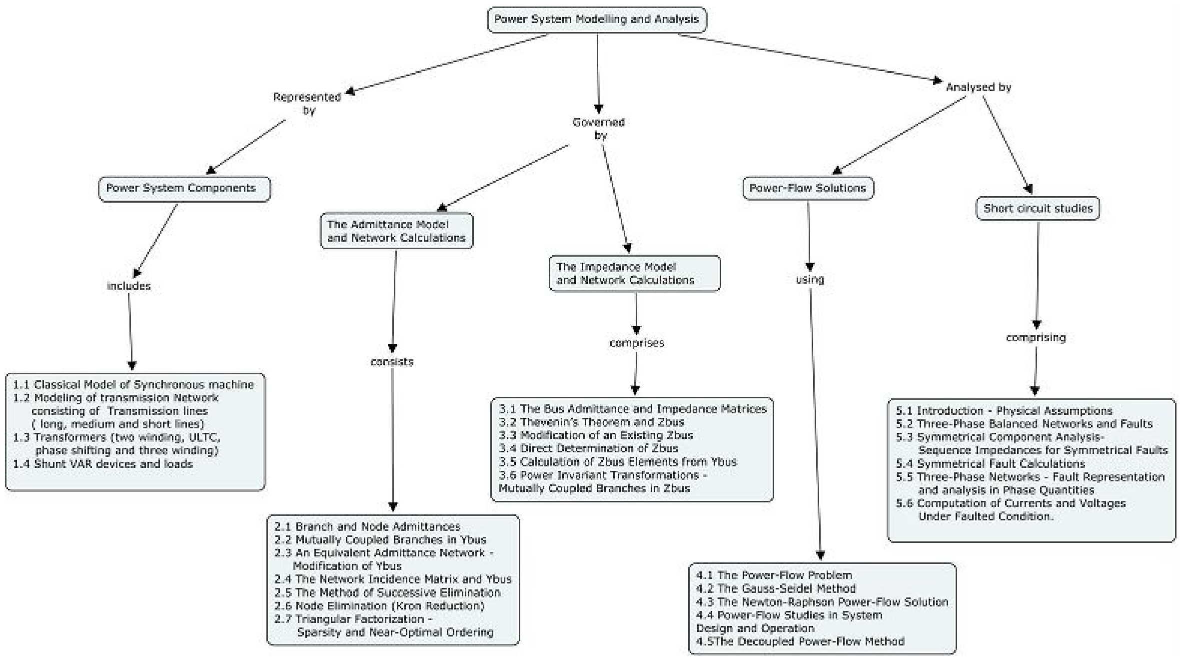
Assume that the bus 2 can supply any amount of reactive power. Assuming flat voltage profile perform the first iteration of power flow analysis using Newton Raphson method.

4. One conductor of a three phase line is open. The current flowing to the delta connected load through line A is 10A and line B is $10\angle 180$ A. Assuming that line C is opened, examine the change in symmetrical components' of currents?

5. For the figure shown in below, write the node equations taking node 0 as reference and then eliminate the node connecting y_a, y_b, y_c , to obtain $Y_F^{a,b,c}$.



Concept Map



Syllabus

Power System Components

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

The Admittance Model and Network Calculations

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

The Impedance Model and Network Calculations

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

Power-Flow Solutions

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

Short-Circuit Studies

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

Reference Books

1. John J. Grainger and Stevenson Jr. W.D., "Power System Analysis", McGraw Hill International Fourth Edition, in,1994
2. M.A.Pai,"Computer techniques in power system analysis", Second edition TATA McGraw Hill, 2006.
3. G.W.Stagg & A.H.EL-Abaid "Computer methods in power system analysis", McGraw Hill International student Edition,1968 .
4. L.P.Singh, "Advaced power system analysis and dynamics", Wiley Eastern Ltd.,Third edition 1992.
5. George L.Kusic,"Computer Aided Power system Analysis", Prentice Hall of india Ltd., 1986.
6. Nagrath.I.J,Kothari.D.P, "Modern power system analysi", TATA McGraw Hill Pub.Co.Ltd., Third edition ,2004.

Course contents and Lecture schedule

Sl.No.	Topic	No. of Lectures
1.0	**Power System Components**	**06**
1.1	Classical Model of Synchronous machine	1
1.2	Modeling of transmission Network consisting of Transmission lines (long, medium and short lines)	2
1.3	Transformers (two winding, ULTC, phase shifting and three winding)	2
1.4	Shunt VAR devices and loads.	1
2.0	**The Admittance Model and Network Calculations**	**10**
2.1	Branch and Node Admittances	1
2.2	Mutually Coupled Branches in Y_{bus}	1
2.3	An Equivalent Admittance Network - Modification of Y_{bus}	3
2.4	The Network Incidence Matrix and Y_{bus}	2
2.5	The Method of Successive Elimination	1
2.6	Node Elimination (Kron Reduction)	1
2.7	Triangular Factorization - Sparsity and Near-Optimal Ordering	1
3.0	**The Impedance Model and Network Calculations**	**10**
3.1	The Bus Admittance and Impedance Matrices	2

3.2	Thevenin's Theorem and Z_{bus}	2
3.3	Modification of an Existing Z_{bus}	2
3.4	Direct Determination of Z_{bus}	1
3.5	Calculation of Z_{bus} Elements from Y_{bus}	1
3.6	Power Invariant Transformations - Mutually Coupled Branches in Z_{bus}.	2
4.0	**Power-Flow Solutions**	**08**
4.1	The Power-Flow Problem - The Gauss-Seidel Method	2
4.2	The Newton-Raphson Power-Flow Solution	3
4.3	Power-Flow Studies in System Design and Operation	2
4.4	The Decoupled Power-Flow Method	1
5.0	**Short-Circuit Studies**	**11**
5.1	Introduction - Physical Assumptions	1
5.2	Three-Phase Balanced Networks and Faults	1
5.3	Symmetrical Component Analysis- Sequence Impedances for Symmetrical Faults	2
5.4	Symmetrical Fault Calculations	3
5.5	Three-Phase Networks - Fault Representation and analysis in Phase Quantities	2
5.6	Computation of Currents and Voltages Under Fault Condition.	2
	Total	**45**

Course designers

P.Venkatesh pveee@tce.edu

K.Selvi kseee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K14	3	1	-	4

K14 Digital Protection for Power System 3:1

Preamble

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

Competencies

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

1. Explain the basic principles of different types of Power system protective schemes.
2. Explain and determine the different relaying characteristics under different operating and load conditions.
3. Determine the performance of various protective schemes.
4. Choose from currently commercially available power system protective schemes for a given application.
5. Analyze the given fault and select suitable protective systems.
6. Diagnose the faults in a system.

Assessment Pattern

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

Course Level learning objectives

Remember

1. What is known as relay coordination?
2. Mention any two applications of Buchholz relay.
3. What is meant by interfacing?
4. What are the drawbacks of a very high sampling frequency in a digital filter?
5. What is the basic operating principle of a vector-product device?
6. What is a quadrilateral relay?

Understand

1. Explain the duality between phase and amplitude comparators.

2. Explain why the first ground fault on the rotor does not cause any damage while a second part can be catastrophic.
3. State and explain Shannon's sampling theorem.
4. What is a static relay? Explain the construction and operation of a static protective relay with a neat block diagram.
5. What are the effects of single phasing in induction motor?
6. Describe the theory and operating principle of a microprocessor based quadrilateral distance relay for 3-zone protection.
7. Enumerate different types of carrier-aided distance protection schemes. Briefly explain any of these schemes.

Apply

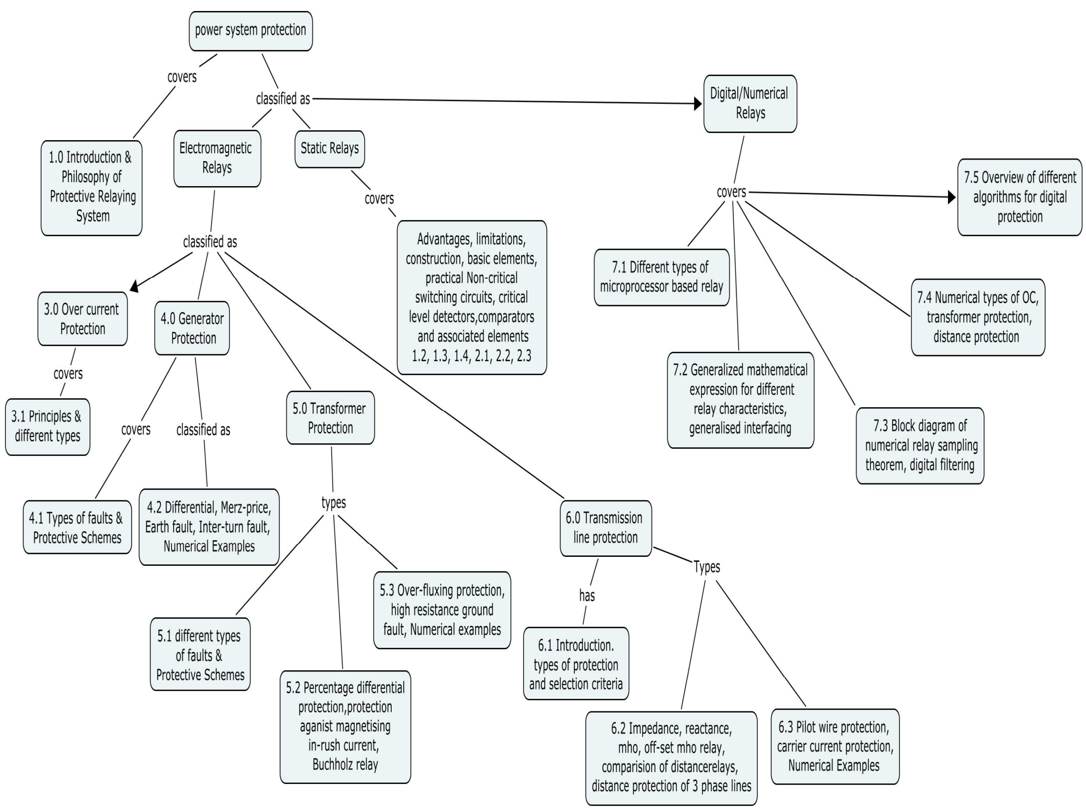
1. A three phase power transformer having a line voltage ratio of 400V to 33kV is connected in star-delta. The CT.s on 400V side has current ratios 1000/5. What must be the CT ratio on 33kV side?
2. List the various types of faults which can occur in synchronous generators. Why unit protection scheme fails during interterm fault in a synchronous machine? Also, discuss how this difficulty is overcome in digital protection schemes.
3. Describe the function of practical non-critical switching circuits and critical level detectors used in power system protection.
4. Describe the operating principle and characteristics of various types of over current relays. Also, mention their applications.
5. Describe the applications of
6. (a) Direct trip devices
   (b) Vector product devices.

Analyze

1. Explain why conventional differential protection cannot detect interturn faults on the same phase.
2. Explain why distance protection schemes are preferred than over current protection for the transmission lines.
3. Compare the characteristics of various types of over current relays.
4. How is loss of prime mover detected and how protection for this problem is implemented?
5. Why a three stepped distance protection of a transmission line is required?
6. Why over current relays are not used for primary protection of EHV lines?
7. Compare the FIR and IIR filters.
8. Develop the differential equation algorithm for distance protection of a transmission line.

9. Suggest some suitable areas in the field of power system protection where thermal relays can be used.

Concept Map



Syllabus

Introduction and Philosophy of a Protective Relaying System

Characteristic functions of protective relays- basic relay terminology

Introduction to Static Relays

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

Comparators and Associated elements

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

Over current Protection

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

Generator Protection

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

Transformer Protection

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

Transmission Line Protection

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

Digital / Numerical Protection

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

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

Reference Books

1. Y.G. Paithankar and S.R Bhide, “Fundamentals of Power System Protection”, Prentice-Hall of India, 2003.
2. T.S. Madhava Rao, “Power System Protection- static relays with Microprocessor applications”, II Edition, TMH, 1989.
3. Sunil S.Rao, “Protection and switchgear”, Khanna Publishers-IV th Edition.

4. T.S. Madhava Rao, "Digital/Numerical Relays", Tata McGraw- Hill Publishing Company, 2005.
5. Badri Ram and D.N. Vishwakarma, "Power System Protection and Switchgear", Tata McGraw- Hill Publishing Company, 2002.
6. P.Kundur, "Power System Stability and Control", McGraw-Hill, 1993.
7. L.P.Singh, "Digital Protection –Protective Relaying from Electromechanical to microprocessor", New Age International (P) Limited Publishers – 2nd Edition, 1997.
8. A.T.Johns & S.K.Salman "Digital Protection for power systems", IEE Power Engg. Series 15, 1995.
9. Batra, Basu and Chowdry, "Power System Protection", Oxford and IPH Publishing Company.
10. Oza, Nair, Mehta and Makwana, "Power System Protection and Switchgear", Tata McGraw- Hill.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.0	Introduction and Philosophy of Protective Relaying System	
1.1	Characteristic functions of protective relays- basic relay terminology	2
1.2	Introduction to Static Relays**,** Advantages of static relays over Electromagnetic Relays, Limitations of static relays	1
1.3	Basic construction and Basic elements of static relays	1
1.4	Practical non-critical switching circuits, critical level detectors, Influence of static protective relays on associated equipment	2
2.0	**Comparators and Associated elements**	
2.1	Mixing transformers/circuits, Phase & amplitude comparators, Duality	2
2.2	Different types of comparators-Amplitude, Phase comparators, Vector product devices	2
2.3	Dynamic design of static Comparators	1
3.0	**Over current Protection**	
3.1	Introduction to over current relays – Basic principles and different types of time-over current relays	2
3.2	Practical circuits for time-over current relays, Direct trip devices	2
3.3	Introduction to Relay Co-ordination, Co-ordination of over current relays in an Interconnected power system.	2
4.0	**Generator Protection**	
4.1	Different types of faults and different types of Protective schemes used for Synchronous generators	2
4.2	Generator differential protection, Merz-Price protection, Stator earth fault protection, Stator inter-turn fault protection, Rotor earth fault protection. Numerical examples for typical generator protection schemes.	3
5.0	**Transformer Protection**	
5.1	Different types of faults and different types of Protective schemes in transformers	2

5.2	Percentage differential protection, Protection against magnetizing in-rush current, incipient fault protection (Buchholz relay)	2
5.3	Over-fluxing protection, High resistance ground fault in transformers. Numerical examples for typical transformers protection schemes.	2
6.0	**Transmission Line Protection**	
6.1	Types of line protection and selection criteria, Introduction to distance protection	1
6.2	Impedance, reactance, mho(admittance), off-set mho relay, comparison of distance relays, Distance protection of three phase lines	2
6.3	Reasons for inaccuracy of distance relay reach – Three stepped distance protection –Pilot wire and carrier current protection, numerical example for a typical distance protection scheme for a transmission line.	3
7.0	**Digital / Numerical Protection**	
7.1	Introduction to Digital protective relays - over current relay, impedance relay	2
7.2	Generalized mathematical expression for distance relays - mho relay, off-set mho, Quadrilateral relay characteristics realization, generalized interfacing for distance relays.	3
7.3	Block diagram of numerical relay, Sampling theorem, correlation with a reference wave, digital filtering	2
7.4	Numerical over current protection, numerical transformer differential protection, numerical distance protection of transmission lines, Introduction to Fast Fourier Transform(FFT) and Discrete Wavelet Transform(DWT) to digital protection	3
7.5	Overview of different algorithms for digital protection	1
	Total No. of Lectures	**45**

Course Designers

M.Geethanjali mgeee@tce.edu

N.Shanmuga Vadivoo nsveee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K15	3	1	0	4

K15 Power System Dynamics and Stability **3:1**

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

Competencies

After completion of the course the students able to:

1. Demonstrate the modelling of power system components.
2. Understand the dynamic principle of power system and synchronous machine.
3. Understand the concept of transient, steady state and dynamic stability.
4. Analyze the stability for power system by point-by point method, Modified Euler's and Runke – Kutta method.
5. Determine the critical clearing angle and clearing time for power system using equal area criterion.

Assessment Pattern

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

Course Level Learning Objectives

Remember

1. Give the circuit diagram of the classical model of synchronous machine for stability studies and explain.
2. What are the requirements of excitation systems?
3. Write the factors affecting transient stability.
4. What is the physical interpretation of dq0 transformation? stabilizers?
5. Define direct and quadrature axes of a synchronous machine.
6. What is the need for reduced order model?
7. Write any two bad effects of instability
8. Define inertia constant H.
9. Write the swing equation taking the effect of damping with account.
10. Define critical clearing angle.

Understand

1. Determine the flux linkage state space model of a single machine connected to infinite bus system using flux linkage equations.
2. Explain the operation of Power System Stabilizer with necessary block diagram.
3. Explain the Runge-Kutta method for solving the swing equation.
4. Develop and explain the Phasor diagram for transient conditions of a synchronous machine.
5. Discuss in detail about the effect of field flux variations on system stability.
6. State and derive the swing equation.
7. Discuss the effect of synchronous machine field circuit dynamics.
8. With neat sketch, explain the block diagram of PSS.
9. Briefly discuss about the methods of improving transient stability.
10. What are the bad effects of instability?

Apply

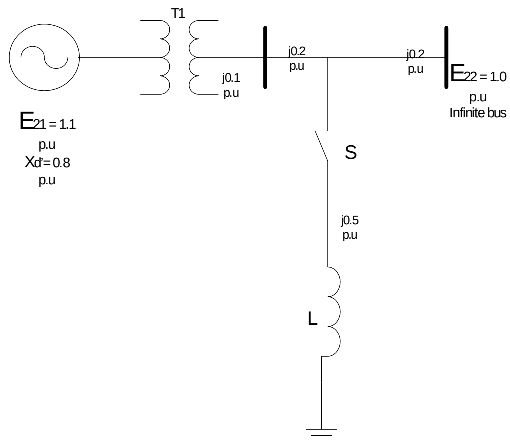
1. A 55MVA, 24KV, 3 phase synchronous generator has the following inductances associated with the stator and rotor field winding;

l_{aa} = 3.2758+0.0458cos(2θ) mH
l_{ab} = -1.6379+0.0458cos(2θ + π/3) mH
l_{afd} = 40 cosθ mH
l_{ffd} = 576.92mH and
leakage inductance l_l = 0.4129 mH

Determine l_d, l_q, l_{ad} and l_{aq} in henrys.

2. A 1500 MVA, 1800 rpm synchronous generator has $WR^2 = 6x10^6$ l b.ft^2. Find the inertia constant H of the machine relative to the 100 MVA base.
3. A 2 pole, 50 Hz, 11.5KV turbo generator has a rating of 60MW, 0.85 P.F lagging. Its rotor has moment of inertia of 8800kg-m^2 . Calculate its inertia constant in MJ/MVA and its momentum in MJ-sec/ elec.deg.
4. A cylindrical rotor generator is delivering 1.0.p.u power to an infinity bus through a loss less transmission network. The Maximum power which can be transferred for Pre fault, during fault and post fault condition 1.8, 0.4 and 1.3 p.u. respectively. Find the critical clearing angle
5. A 3- ph 50hz, 50MVA synchronous generator has H=4.5MJ/MVA in steady state with input and output=0.7 p. u. and displacement angle of 30 deg(elec) w.r.t infinity bus. Consequent upon the occurrence of fault. The output power angle relation is given by P_u=1.0sinδ. Assume that its input power remains constant determine and draw the swing curve by step- step method II taking the time interval **Δt** = 0.05sec.

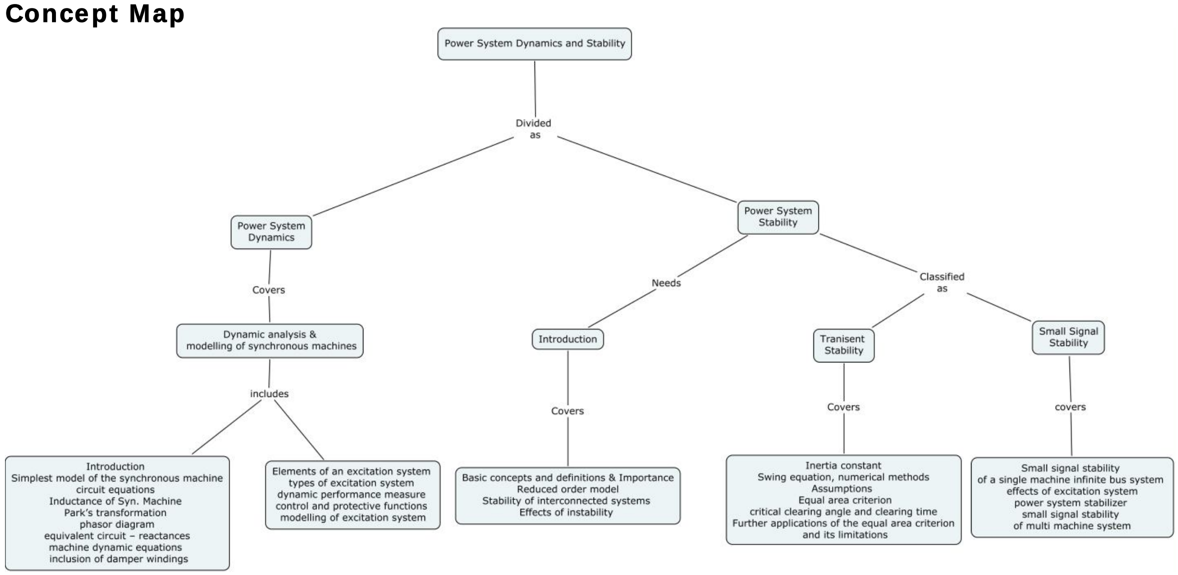
6. For the system shown below find the steady state stability limit for the following conditions



   a. when switch 'S' is open
   b. when switch 'S' is closed
   c. Inductor is replaced by a capacitor of same p.u. reactance.

7. An industrial area receives 60MW over a transmission line from another area. The transmission system has a steady state stability limit of 120MW. What is the permissible maximum sudden load that can be switched ON Without loss of stability?

Concept Map



Syllabus

Dynamic analysis and modelling of synchronous machines

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

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

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

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

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

Reference Books

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

Course contents and Lecture Schedule

Sl. No.	Topic	No. of lectures
1.0 Dynamic analysis and Modelling of synchronous machines		
1.1	Introduction - Dynamic analysis and Modelling of synchronous machines - Simplest model of the synchronous machine	2
1.2	Circuit equations – Equation in physical quantities - Inductance of Synchronous Machine	2
1.3	Park's transformation to dq0 components – Assumptions of balanced currents and voltages in the armature – Phasor diagram	2
1.4	Equivalent circuit – Reactances – Final machine dynamic equations – Inclusion of damper windings	2
2.0 Excitation systems		
2.1	Elements of an excitation system – types of excitation system	2
2.2	Dynamic performance measure – control and protective functions	2
2.3	Modelling of excitation system	3
3.0 Introduction to power system stability		
3.1	Basic concepts and definitions – classification of stability – Blackouts causes - events	2
3.2	Need for reduced order model - Stability of interconnected systems	3
3.3	Bad effects of instability – Importance of stability to system operation and design	3
3.4	Method of improving stability limits	2

4.0 Transient stability		
4.1	Inertia constant and equivalent inertia constant –Power angle curve	2
4.2	Swing equation – Point by point solution, numerical methods (Modified Euler's method and Runke Kutta IV order method	3
4.3	– Assumptions made in stability studies- Equal area criterion to test the transient stability of simple power systems	3
4.4	Calculation of critical clearing angle and clearing time – Further applications of the equal area criterion and its limitations	2
5.0 Small signal stability		
5.1	Small signal stability of a single machine infinite bus system	3
5.2	Effects of excitation system	2
5.3	Power System Stabilizer	3
5.4	Small Signal Stability of Multi Machine System	2
	Total No. of lectures	**45**

Course designers

V. Ramanathan vreee@tce.edu

C. K. Babulal ckbeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K16	3	-	-	3

K16 Power Converters for Distributed Generation Systems 3:0

Preamble

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

Competencies

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

1. Understand the concept of power converters in power system applications.
2. To classify the choice of power converters.
3. Analyze and characterize various control strategies of power converters.
4. Analyze and characterize the power quality issues of power electronic converters.
5. Select a suitable converters for the given type of generation systems
6. Design a converter for a given applications.

Assessment pattern

S. No.	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	20	15	10
2	Understand	20	15	10
3	Apply	30	35	40
4	Analyze	30	35	40
5	Evaluate	0	0	0
6	Create	0	0	0

Course level Learning Objectives

Remember

1. State the advantages of DC transmission system.
2. What is dc link control?
3. What is meant by firing angle?
4. Draw the block diagram of solar energy conversion system.
5. List the different schemes for PV energy conversion.
6. Draw the block diagram of wind energy conversion system.
7. Define - harmonics.

Understand

1. Discuss the characteristics of twelve pulse converter.
2. Explain the principle of operation of boost converters.
3. Describe the parameters to be considered for the selection of inverters.
4. Write Short notes on multilevel inverters.

5. Discuss the Power converter topologies for smart grid Distributed Generation systems.
6. Elaborate the working principle pf UPQC.

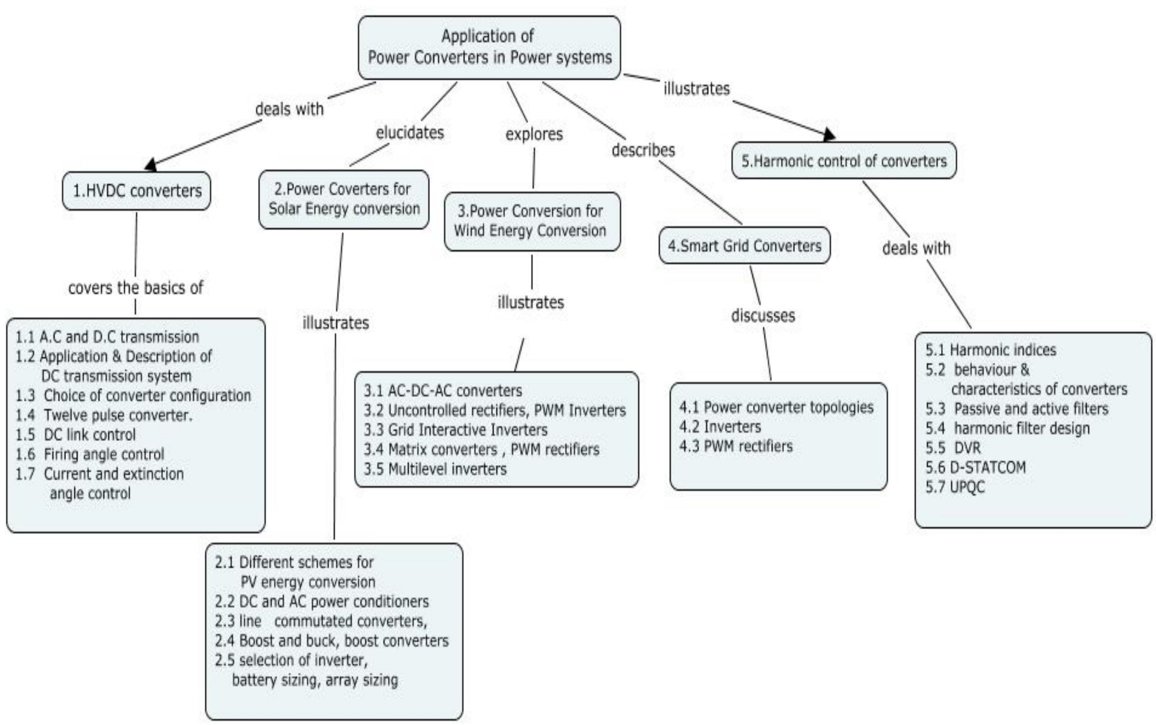
Apply

1. In a three phase inverter, V_{LL}=460 V at 50 Hz, E=550 V, and L_s=0.5mH. Assume L_d is very large, to yield $i_d(t)=i_d$. Calculate firing angle and extinction angle.
2. In a buck boost converter operating at 20KHz, L=0.05 mH. The output capacitor C is sufficiently large and V_d=158V.The output is to be regulated at 10V and the converter is supplying a load of 10W.Calculate the duty ratio D.
3. In a full bridge dc-dc converter, the input V_d is constant and the output voltage is controlled by varying the duty ratio. Calculate the rms value of the ripple V_r in the output voltage as a function of the average Vo for
    a) PWM with bipolar voltage switching and
    b) PWM with unipolar voltage switching.
4. In a single phase full bridge PWM inverter, V_d varies in the range of 295-325 V. The output voltage is required to be constant at 200V, and the maximum load current is 10A. Calculate the combined switch utilization ratio.
5. In a step down converter, consider all components to be ideal. Let Vo be held constant at 5V by controlling duty ratio D. Calculate the minimum inductance L required to keep the converter operation in continuous conduction mode under all conditions if V_d is 10-40 V, P_o>5W , and f_s=50kHz.
6. In a buck boost converter, V_d=12V,V_0=15V,I0=250mA ,L=0.15mH, c=0.47mF and fs=20kHz.Calculate ΔV_0(peak to peak)

Analyze

1. Compare AC and DC transmission.
2. Analyze the characteristics of Converter Bridge.
3. Differentiate the DC and AC power conditioners.
4. Categorize the power converters for solar energy conversion.
5. Analyze the effect of harmonics of converters on wind energy systems.
6. Discuss the working of D-STATCOM.

Concept Map



Syllabus

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

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

POWER CONVERTERS FOR WIND ENERGY CONVERSION
Basic components - AC-DC-AC converters - Uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters - Matrix converters – PWM rectifiers – Multilevel inverters.

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

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

Reference Books

1. K.R.Padiyar, HVDC Power Transmission Systems, New Age International (P) Ltd., New Delhi, 2002.
2. Ned Mohan, Tore Undeland & William Robbins, Power Electronics: Converters Applications and Design-John Willey and sons 2003.
3. D.Grahame Holmes & Thomas Lipo, Pulse width modulation for power converters, Wiley-Interscience, 2003.
4. Ali Keyhani, M.N.Marwali & Min Dai, Integration of green and renewable energy in electrical power systems, Wiley and sons, 2010.
5. Felix A.Farret & M.G.Simoes, Integration of alternative sources of energy, Wiley-IEEE press, 2007.
6. S.Choudhury, SP.Choudhury & P.Crossley, Micro grids and active distribution networks, IET publications, 2009.
7. Arindam Ghosh & Gerald Ledwich, Power quality enhancement using custom power devices, Kluwer Academic Publishers, 2002.
8. G.T.Heydt, Electric Power Quality, Stars in Circle Publications, 1994.

Course Contents and lecture Schedule

S.No.	Topic	No. of Lectures
1.	**HVDC Converters**	
1.1	AC and DC transmission	1
1.2	Application & Description of DC transmission system	1
1.3	Choice of converter configuration	1
1.4	Converter bridge characteristics – Characteristics of a twelve pulse converter	1

1.5	General principles of DC link control – Converter control characteristics	2
1.6	Firing angle control & Power control	1
1.7	Current and extinction angle control	1
2.	**Power converters for solar energy conversion**	
2.1	Basic components – Different schemes for PV energy conversion	2
2.2	DC and AC power conditioners	2
2.3	Line commutated converters	1
2.4	Boost and buck-boost converters	2
2.5	Selection of inverter, battery sizing, array sizing	1
3.	**Power converters for wind energy conversion**	
3.1	AC-DC-AC converters	2
3.2	Uncontrolled rectifiers, PWM Inverters	2
3.3	Grid Interactive Inverters	3
3.4	Matrix converters – PWM rectifiers	3
3.5	Multilevel inverters	2
4.	**Smart grid converters**	
4.1	Power converter topologies for smart grid Distributed Generation systems	3
4.2	Inverters	2
4.3	PWM rectifiers	2
5.	**Harmonic control of converters**	
5.1	Harmonic indices	1
5.2	Harmonic behaviour & characteristics of HVDC converters, Solar and Wind converters	3
5.3	Passive and active filters	2
5.4	Harmonic filter design	2
5.5	D-STATCOM	1
5.6	UPQC	1
	Total	**45**

Course designers

V. Suresh Kumar vskeee@tce.edu

S. Latha sleee@tce.edu

R. Medeswaran medes@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K17	0	0	3	1

K17 Power System Laboratory - I 0:1

Preamble

The aim of this lab course is to train the Post graduate students in solving the power system problems using Matlab and other Simulation software package.

Matlab Program

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

Matlab Simulink

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

Study / Demo

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

Course designers

R. Medeswaran medes@tce.edu

P.S. Manoharan psmeee@tce.edu

CURRICULUM AND DETAILED SYLLABI

FOR

M.E. DEGREE (Power System Engineering) PROGRAM

SECOND SEMESTER SUBJECTS

&

ELECTIVE SUBJECTS

FOR THE STUDENTS ADMITTED FROM THE ACADEMIC YEAR 2011-2012

THIAGARAJAR COLLEGE OF ENGINEERING

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

MADURAI – 625 015, TAMILNADU

Phone: 0452 – 2482240, 41

Fax: 0452 2483427

Web: www.tce.edu

Email:hodeee@tce.edu

Department of Electrical and Electronics Engineering

Graduating Students of M.E. program of Power System Engineering will be able to:

1. Specify, architect, design and analyze systems that efficiently and economically generate, transmit, distribute and utilize electrical power to meet the present power market strategy.
2. Specify, design, prototype and test modern Power Systems using various simulation packages and soft computing tools.
3. Work in a team using common tools and environments to achieve project objectives.

Thiagarajar College of Engineering: Madurai-625015

Department of Electrical and Electronics Engineering

Scheduling of Courses

Sem.	Theory Courses						Practical / Project
4th (12)							K41 Project 0:12
3rd (16)	K31 Power System Deregulation 3:1	KEX Elective -V 3:1	KEX Elective -VI 3:1				K34 Project 0:4
2nd (24)	K21 Power System Security 3:0	K22 Power System Operation and Control 3:1	KEX Elective -I 3:1	KEX Elective -II 3:1	KEX Elective -III 3:1	KEX Elective -IV 3:1	K 27 Power System Laboratory - II 0:1
1st (24)	K11 Applied Mathematics for Electrical Engineers 3:1	K12 Systems Theory 3:1	K13 Power System Modelling and Analysis 3:1	K14 Digital Protection for Power System 3:1	K15 Power System Dynamics and Stability 3:1	K16 Power Converters for Distributed Generation Systems 3:0	K17 Power System Laboratory - I 0:1

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power System Engineering) PROGRAM

SUBJECTS OF STUDY

(For the candidates admitted from 2011-2012)

FIRST SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
K11	Applied Mathematics for Electrical Engineers	BS	3	1	-	4
K12	Systems Theory	DC	3	1	-	4
K13	Power System Modelling and Analysis	DC	3	1	-	4
K14	Digital Protection for Power System	DC	3	1	-	4
K15	Power System Dynamics and Stability	DC	3	1	-	4
K16	Power Converters for Distributed Generation Systems	DC	3	-	-	3
PRACTICAL						
K17	Power System Laboratory - I	DC	-	-	3	1
	Total		**18**	**5**	**3**	**24**

Subject code	Name of the subject	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
K21	Power System Security	DC	3	0	-	3
K22	Power System Operation and Control	DC	3	1	-	4
KEx	Elective-I	DE	3	1	-	4
KEx	Elective-II	DE	3	1	-	4
KEx	Elective-III	DE	3	1	-	4
KEx	Elective-IV	DE	3	1	-	4
PRACTICAL						
K27	Power System Laboratory - II	DC	-	-	3	1
	Total		**18**	**5**	**3**	**24**

BS : Basic Science

DC : Department Core

DE : Departmental Elective

L : Lecture

T : Tutorial

P : Practical

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2/3 Hours Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power Systems Engineering) PROGRAM

SCHEME OF EXAMINATIONS

(For the candidates admitted from 2011-2012)

FIRST SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	K11	Applied Mathematics for Electrical Engineers	3	50	50	100	25	50
2	K12	Systems Theory	3	50	50	100	25	50
3	K13	Power System Modelling and Analysis	3	50	50	100	25	50
4	K14	Digital Protection for Power System	3	50	50	100	25	50
5	K15	Power System Dynamics and Stability	3	50	50	100	25	50
6	K16	Power Converters for Distributed Generation Systems	3	50	50	100	25	50
PRACTICAL								
7	K17	Power System Laboratory - I	3	50	50	100	25	50

SECOND SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	K21	Power System Security	3	50	50	100	25	50
2	K22	Power system Operation and Control	3	50	50	100	25	50
3	KEx	Elective-I	3	50	50	100	25	50
4	KEx	Elective-II	3	50	50	100	25	50
5	KEx	Elective-III	3	50	50	100	25	50
6	KEx	Elective-IV	3	50	50	100	25	50
PRACTICAL								
7	K27	Power System Laboratory - II	3	50	50	100	25	50

* CA evaluation pattern will differ from subject to subject 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.

** Terminal Examination will be conducted for maximum marks of 100 and subsequently be reduced to 50 marks for the award of terminal examination marks

List of Electives – M.E. Power System Engineering

Departmental Electives			
Sub. Code KEx	Subject Name	Pre/Co requisites	Credits
KEA	Power System Optimization	Power System Analysis	4
KEB / CNEH	Power Plant Instrumentation and Control	Measurement and Instrumentation	4
KEC	Flexible AC Transmission Systems	Power System Analysis Power Electronics	4
KED	Electrical Transients in Power system	Power System Analysis	4
KEE	Analysis of Electrical Machines	Electrical Machines	4
KEF	Renewable Energy Sources	Generation, Power Plant Engineering	4
KEG	Power Quality	Power System Analysis, Power Electronics	4
KEH	Soft Computing Techniques	Fuzzy Logic, Neural Networks	4
KEI / CN EA	Control of Electric Drives	Electrical machines, power Electronics	4
KEJ	Power System Reliability	Power System Analysis	4
KEK	Power System Voltage Stability	Power System Stability	4
KEL	Advanced Digital Signal Processing	Digital Signal Processing	4
KEM	Control of Electric Drives	Power Electronics	4
KEN	Control System Design	Control System, Systems Theory	4
KEO	Distributed Generation Systems	Generation, Transmission & Distribution	4
KEP	Energy Resource Management	Energy Conservation & Audit	4
KEQ	Power System Practices	Power system Analysis	4
KER	Custom Power Devices	Power System Analysis, Power Electronics	4
KES	Gas Insulated Substations	Power System Protection	4
KET / CN EI	Real Time Operating Systems	Micro Processors / Micro controllers	4
KEU / CN EO	SCADA	Micro Processors , Instrumentation, DSP	4

Sub Code	Lectures	Tutorial	Practical	Credit
K21	3	-	-	3

K21 Power Systems Security 3:0

Preamble

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

Programme Outcomes addressed

a. Ability to perform contingency analysis of power system and find out the security level status of the power system
b. Ability to get the knowledge of state estimation procedure carried out in the energy management/ operations control centre
c. Ability to formulate optimisation problem by knowing the various objective functions and constraints involved in the power system
d. Ability to find out the solution methodology for optimizing real and reactive power flow in the power system

Competencies

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

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

Assessment Pattern

S.No.	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	20	20	20
2	Understand	20	20	20
3	Apply	60	60	60
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course level Learning Objectives

Remember

1. What is meant by cascading outage?
2. What is SCADA?
3. What is the estimation formula used in state estimation?
4. What is meant by number of degrees of freedom?
5. What are the assumptions made in DC power flow analysis?
6. What is meant by Performance Index?
7. What are the different methods to solve OPF problems?
8. What is the significance of security constrained economic dispatch problems?

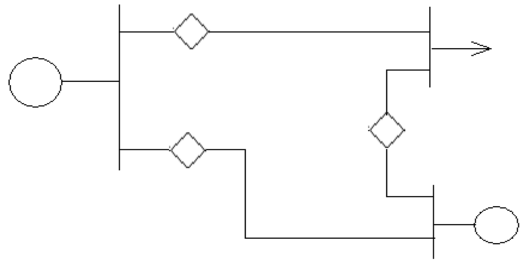
Understand

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. Formulate the given problem using Lagrange multiplier method assuming all the starting point variables are assumed to be one.
   Minimize $f = 0.25\ x_1^2 + x_2^2$
   Subject to $5- x_1 - x_2 = 0$; $x_1 + 0.2\ x_2 - 3 \leq 0$

Apply

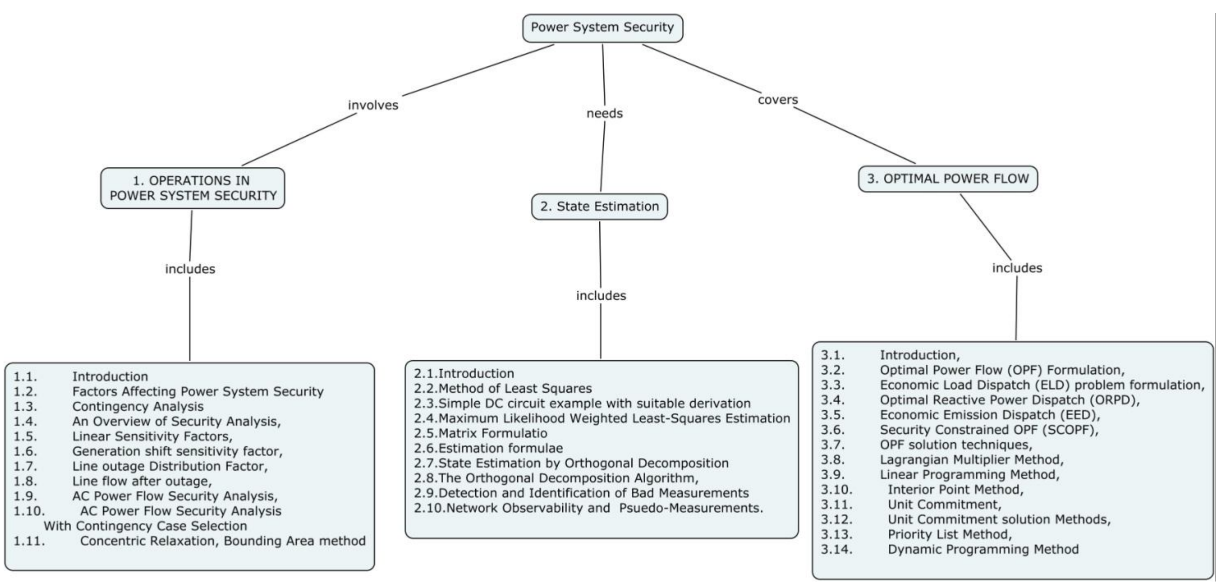
1. The line reactance of the test system is X_{12}=0.2.p.u,X_{13}=0.4.p.u, X_{23}=0.25.p.u.Calculate the sensitivity matrix and obtain the base case DC power flow of the test system shown below. Suppose the outage of the generator at bus 3 takes place then obtain the post outage flow of the line 1-2 using generation shift sensitivity factor.
2. Three meters are installed on the three bus system of figure 1 to measure line real power flows are X_{12}=0.2.p.u,M_{12}=0.6.p.u, X_{13}=0.4.p.u,

M_{13}=0.04p.u, X_{23}=0.25.p.u,M_{32}=0.405p.uand the variances are same σ^2= $(0.01)^2$ .Compute the weighted least square estimates of the phase angles with bus3 as the reference.



3. Formulate the LPOPF problem for the data given below:
   Unit 1:F(P)=600+6P+0.002P^2 ; 70<=P_1<=250MW
   Unit 2: F(P)=220+7.3P+0.003P^2 ;70<=P_2<=135MW
   Unit 3: F(P)=100+8P+0.004P^2 ; 60<=P_3<=160MW
   Three straight line segments with break points as below:
   Unit 1: Break points at 70,130,180,250MW;
   Unit 2: Break points at 55,76,95,135MW;
   Unit 3: Break points at 70,80,120,160MW

Concept Map



Syllabus

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

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

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

Reference books

1. A.J.Wood and B.F. Wollenberg., Power generation, operation and control, John Wiley and sons, 1996.
2. John J. Graignaer and William D. Stevenson, Power system analysis, Tata Mc Graw Hill, 2003.

Course contents and Lecture schedule

S.No.	Topics	No. of Periods
	OPERATIONS IN POWER SYSTEM SECURITY	
1.1.	Introduction	1
1.2.	Factors Affecting Power System Security	1
1.3.	Contingency Analysis	2
1.4.	An Overview of Security Analysis	1
1.5.	Linear Sensitivity Factors	1
1.6.	Generation shift sensitivity factor	1
1.7.	Line outage Distribution Factor	1
1.8.	Line flow after outage,	1
1.9.	AC Power Flow Security Analysis	2

1.10.	AC Power Flow Security Analysis With Contingency Case Selection	2
1.11.	Concentric Relaxation, Bounding Area method	2
STATE ESTIMATION		
2.1.	Introduction	1
2.2.	Method of Least Squares	1
2.3.	Simple DC circuit example with suitable derivation	2
2.4.	Maximum Likelihood Weighted Least-Squares Estimation	2
2.5.	Matrix Formulation	1
2.6.	Estimation formulae	1
2.7.	State Estimation by Orthogonal Decomposition	1
2.8.	The Orthogonal Decomposition Algorithm,	1
2.9.	Detection and Identification of Bad Measurements	2
2.10.	Network Observability and Psuedo-Measurements.	2
OPTIMAL POWER FLOW		
3.1.	Introduction,	1
3.2.	Optimal Power Flow (OPF) Formulation,	2
3.3.	Economic Load Dispatch (ELD) problem formulation,	1
3.4.	Optimal Reactive Power Dispatch (ORPD),	1
3.5.	Economic Emission Dispatch (EED),	1
3.6.	Security Constrained OPF (SCOPF),	1
3.7.	OPF solution techniques,	1
3.8.	Lagrangian Multiplier Method,	1
3.9.	Linear Programming Method,	1
3.10.	Interior Point Method,	1
Total		40

Course Designer

P. Venkatesh pveee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K22	3	1	0	4

K22 Power System operation and Control 3:1

Preamble

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

Program Outcomes addressed

a. An ability to apply knowledge of engineering, information technology, mathematics, and science

b. An ability to design and conduct experiments, as well as to analyze and interpret data

c. An ability to design a system or component, or process to meet stated specifications

d. An ability to identify, formulate and solve engineering problems

e. An ability to use techniques, skills, and modern engineering tools to implement and organize engineering works under given constraints

Competencies

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

1. Solve economic load dispatch and unit commitment problems.
2. Understand the relation between real power and frequency control.
3. Understand various operating states of power system and control actions required secure operation.
4. Know various energy management system and control strategies used around the world.

Assessment Pattern

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

Course Level Learning Objectives

Remember

1. What is meant by economic dispatch?
2. Define AGC.
3. State the advantages of state variable model.
4. Name the methods of providing automatic voltage regulation in distribution system.
5. Name the three modes of EDC.
6. List the sources and sinks of reactive power.
7. Compare shunt and series capacitor.
8. List the constraints in Unit Commitment.
9. What is meant by penalty factor?
10. Draw state transition diagram.

Understand

1. Derive the coordination equation taking losses into account.
2. With the help of a flow chart explain the solution of UC problem by Lagrangian relaxation method.
3. Discuss in detail the modeling of reactive compensating devices in power flow analysis and in stability studies.
4. Draw the block diagram representation of two area system and develop the state variable model for the same.
5. Draw the block diagram of two-area system and discuss the salient features under static and dynamic conditions.
6. What are the different modes of operation of power system? Explain them in detail.
7. Describe the various methods of voltage control analytically.
8. Illustrate SCADA with the typical schematic diagram.
9. Briefly discuss the various functions of energy control center.

Apply

1. Two identical 60MW synchronous generators operate in parallel. The governor setting on the machines are such that they have 4% and 3% droops from no load to full load. Determine (i) The load taken by each m/c for a total load of 100MW. The % adjustments with no load speed to be made by the speeder motor if the machines are to share the load equally.
2. For the two interconnected areas of capacity respectively 1500 MW and 500MW, if the incremental regulation and damping torque coefficient for each

area on its own base are equal to 0.1 p.u and 1.0p.u. respectively, following a 50 MW change in load of area 1, find the steady state change in system frequency from a nominal frequency of 50 Hz and the change in steady state tie-line power flow.

3. Consider the data for two-area system.

   Pr1 = 2100 MW, Pr2 = 700 MW, R = 0.2 pu, D = 1 pu

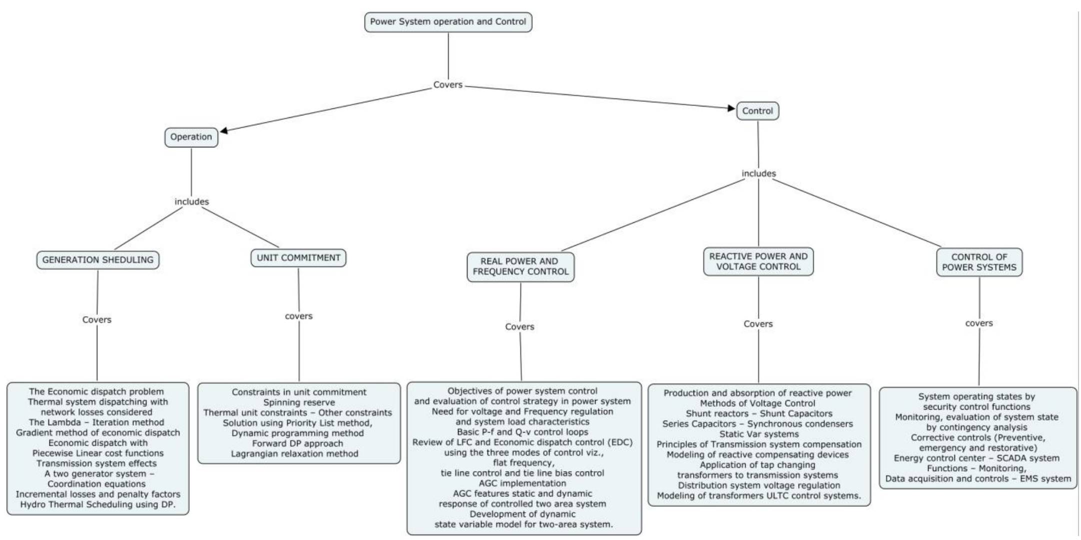
   F0 = 50 Hz, ∆PD1 = 50 MW. Find the steady state changing frequency and tie-line power.

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

   dC1/dPG1 = 0.10 PG1 + 20.0

   dC2/dPG2 = 0.12 PG2 + 15.0 with powers PG in MW and costs C in Rs/hr. Determine (a) the most economical division of load between the generators, and (b) the saving in Rs/day thereby obtained compared to equal load sharing between machines.

Concept Map



Syllabus

GENERATION SHEDULING

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

UNIT COMMITMENT

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

REAL POWER AND FREQUENCY CONTROL

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

REACTIVE POWER AND VOLTAGE CONTROL

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

CONTROL OF POWER SYSTEMS

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

Reference Books

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

Course content and Lecture Schedule

No.	Topic	No. of Lectures
1.0	**GENERATION SHEDULING**	
1.1	Introduction – Power system operation control - Economic dispatch problem	2
1.2	The Lambda – Iteration method	1
1.3	Gradient method of economic dispatch – Economic dispatch with Piecewise Linear cost functions	2
1.4	Thermal system dispatching with network losses considered	2
1.5	A two generator system – Coordination equations	1
1.6	Incremental losses and penalty factors	1
1.7	Hydro Thermal Scheduling using DP	1
2.0	**UNIT COMMITMENT**	
2.1	Unit commitment problem- Spinning reserve – Thermal unit constraints	2
2.2	Bank & Other constraints	1
2.3	Solution using Priority List method	1
2.4	Dynamic programming method	1
2.5	Forward DP approach	1
2.6	Lagrangian relaxation method- Adjusting λ.	2
3.0	**REAL POWER AND FREQUENCY CONTROL**	
3.1	Objectives of power system control and evaluation of control strategy in power system	1
3.2	Need for voltage and Frequency regulation and system load	1

	characteristics	
3.3	Basic P-f and Q-v control loops	1
3.4	Review of LFC and Economic dispatch control (EDC) using the three modes of control viz., flat frequency, tie line control and tie line bias control	2
3.5	AGC implementation – AGC features static and dynamic response of controlled two-area system	2
3.6	Development of dynamic state variable model for two-area system	1
4.0	**REACTIVE POWER AND VOLTAGE CONTROL**	
4.1	Production and absorption of reactive power – Methods of Voltage Control	1
4.2	Shunt reactors – Shunt Capacitors – Series Capacitors	2
4.3	Synchronous condensers – Static VAR systems	1
4.4	Principles of Transmission system compensation -Modeling of reactive compensating devices	1
4.5	Application of tap changing transformers to transmission systems	1
4.6	Distribution system voltage regulation	1
4.7	Modeling of transformers ULTC control systems	1
5.0	**CONTROL OF POWER SYSTEMS**	
5.1	System operating states by security control functions – Monitoring, evaluation of system state by contingency analysis	1
5.2	Corrective controls (Preventive, emergency and restorative)	1
5.3	Energy control center – SCADA system	2
5.4	Functions – Monitoring, Data acquisition and controls – EMS	2

	system	
	Total	40

Course designers

V. Ramanathan vreee@tce.edu
C. K. Babulal ckbeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
K27	0	0	3	1

K27 Power System Laboratory II 0:1

List of Experiments:

1. Realization of overcurrent relay characteristics / distance relay characteristics using DSP.
   Incharge : Dr.N.Geethanjali

2. Reactive Power compensation using Voltage Source Converter based STATCOM hardware module.
   Incharge : Dr.P.Venkatesh

3. Power flow solution using Power world Simulator.
   Incharge : Dr.P.Venkatesh

4. Contingency analysis using Matlab coding.
   Incharge : Dr.N.Kamaraj

5. Security assessment of grid connected DGS using Matlab simulink.
   Incharge : Dr.N.Kamaraj

6. DC motor control using PLC drive.
   Incharge : Dr.M.Saravanan

7. Performance analysis of TCSC controller
   Incharge : Dr.S.Latha

8. Modelling of Synchronous generator using Simulink
   Incharge : Dr K.Selvi

9. Multi parameter measurement & monitoring in Electrical networks using Power quality analyzer
   Incharge: Dr V.Saravanan

Sub code	Lectures	Tutorial	Practical	Credit
KEA	**3**	**1**	**-**	**4**

KEA Power System Optimization 3:1

Preamble

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

Program Outcomes addressed

a. Ability to apply knowledge of engineering, information technology, mathematics, and science
b. Ability to design and conduct experiments, as well as to analyze and interpret data
c. Ability to design a system or component, or process to meet stated specifications
d. Ability to identify, formulate and solve engineering problems
e. Ability to use techniques, skills, and modern engineering tools to implement and organize engineering works under given constraints
i. Ability to consider social, environmental, economic and ethical impact of engineering activities in a given context.
j. Ability to consider issues from global and multilateral views.

Competencies

At the end of the course the students will be able to:

1. Understand the various optimization techniques applied to power systems problems.
2. Solve optimization problems in various power plants .

Assessment Pattern

S.No.	Bloom's Category	Test 1	Test 2	Test3 / End-semester examination
1	Remember	30	30	30
2	Understand	40	40	40
3	Apply	30	30	30
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course Level Learning Objectives

Remember

1. State the economic dispatch problem.
2. Define – short range hydro thermal scheduling.
3. What are loss coefficients?
4. What is emission dispatch?
5. State Kuhn Tucker conditions.

Understand

1. Explain the model for Short range hydrothermal scheduling.
2. Discuss in detail the concept of pumped storage plant.
3. Explain ε Constraint method to solve the Multiobjective thermal dispatch problem.
4. Explain the method of solving economic dispatch problem by penalty factor.
5. Illustrate the Base point and participation factor method for economic dispatch problem.

Apply

1.The fuel cost equations of three plants are given.

$F1= 500+7P_1+0.009p_1^2$ R/hr

$F2=300+6P_2+0.002P_2^2$ R/hr

$F3=56+6P_3+0.004P_3^2$ P32 R/hr

Solve the economic load Dispatch for a total load demand of 800MW.

2. Illustarate the application of exact loss formula.

3. A load is to be supplied from hydro plant and a steam plant whose characteristics are given here.

Steam system : $H= 500+8\ Ps+0.006Ps^2$

Fuel cost = 1.10R/Mbtu

Hydro plant: $q=330+4P_H$

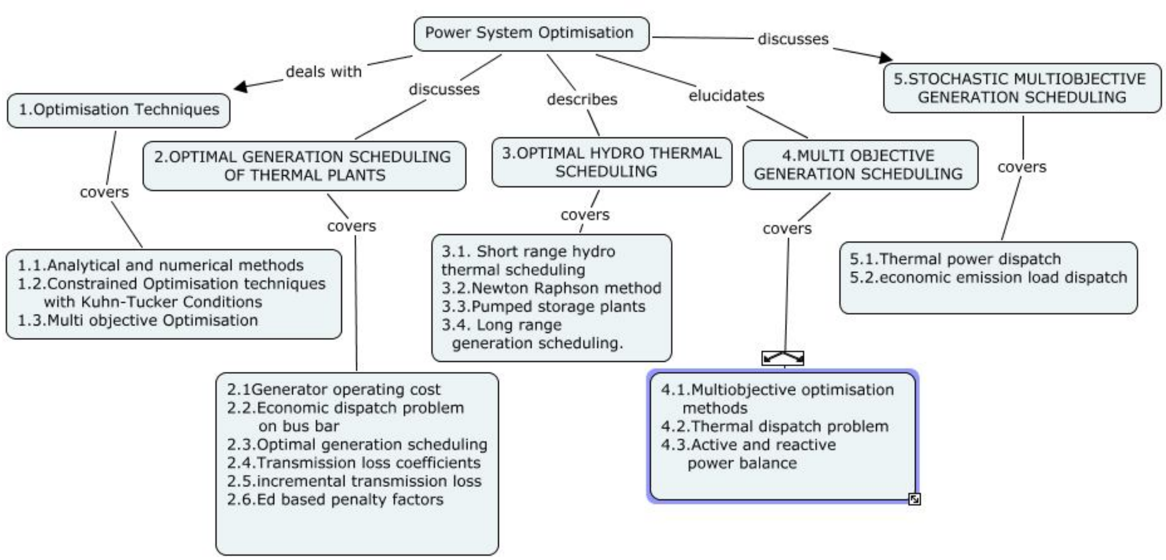
PLoss=0.00009Ph2 MW

The load to be supplied is for the first 12 hours 1200 MW and for the next 12 hours 2400 MW.

The hydro unit reservoir is limited to a drawdown of 1,00,000 acre-ft over 24 hr period. Solve for optimal hydro thermal scheduling.

4. Apply a suitable method to solve stochastic economic emission load dispatch problem.

Concept Map



Syllabus

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

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

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

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

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

Reference Books

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

Course content and Lecture schedule

S.No.	Topic	No. of Lectures
1.0	**OPTIMISATION TECHNIQUES**	
1.1	Statement of an optimization problem – One dimensional minimization- Analytical methods and numerical methods	2
1.2	Constrained optimization - Kuhn Tucker conditions , Lagrangian method , penalty function method	2

1.3	dynamic programming – Multi objective optimization	2
2.0	**OPTIMAL GENERATION SCHEDULING OF THERMAL PLANTS**	
2.1	Introduction-Generator operating cost	2
2.2	Economic dispatch problem -constraints	2
2.3	Optimal generation scheduling-Newton Raphson method	3
2.4	Transmission loss coefficients-exact loss formula	2
2.5	Incremental transmission loss	2
2.6	ED based on penalty factors	2
3.0	**OPTIMAL HYDROTHERMAL SCHEDULING**	
3.1	Introduction – Short range hydrothermal scheduling-Model	2
3.2	Transmission losses- Solution using Newton Raphson method	3
3.3	Hydro plant modelling for long term operation -Pumped storage plants	2
3.4	Long range generation scheduling	3
4.0	**MULTI OBJECTIVE GENERATION SCHEDULING**	
4.1	Multiobjective optimisation methods	3
4.2	Multiobjective thermal dispatch problem- ε Constraint method	2
4.3	Multiobjective dispatch for active and reactive power balance	2
5.0	**STOCHASTIC MULTIOBJECTIVE GENERATION SCHEDULING**	
5.1	Multiobjective stochastic optimal thermal power dispatch	2
5.2	Stochastic economic emission load dispatch-Problem formulation-Solution approach	2
	Total	40

Course Designer

K.Selvi kseee@tce.edu
R.Medeswaran rmedes@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEB / CN EH	**4**	**-**	**-**	**4**

KEB / CNEH Power Plant Instrumentation and Control 4:0

(Common to M.Tech. C & I)

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.

Programme Outcomes addressed

a. Graduates will demonstrate knowledge of power plant instrumentation and control engineering.
b. Graduates will have an ability to identify, formulate and solve power plant instrumentation and control engineering problems.
c. Graduates will have an ability to use the techniques, skills and modern instrumentation and control for power plants.
d. Graduates can participate and succeed in competitive examinations.

Competencies

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

1. Explain the basic principles of power system instrumentation and control.
2. Explain and determine the different types of instrumentation and control systems used for power plants.
3. Determine the performance of various power plant instrumentation and control systems.
4. Choose from currently commercially available power plant instrumentation and control systems for a given application.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	20	20	20
2	Understand	40	40	20
3	Apply	20	20	40
4	Analyze	20	20	20
5	Evaluate	0	0	0
6	Create	0	0	0

Course Level Learning Objectives

Remember

1. Name the different methods of conventional power generation.
2. State the importance of instrumentation.
3. Define the term thermal efficiency.
4. Name the different types of feed water control.
5. What is meant by dearreator?
6. What is meant by combined heatened power plant?
7. List any two types of attemperator.
8. List the different modules of boiler control mechanism.
9. What is meant by DCS?
10. State any two advantages of electrical actuators.

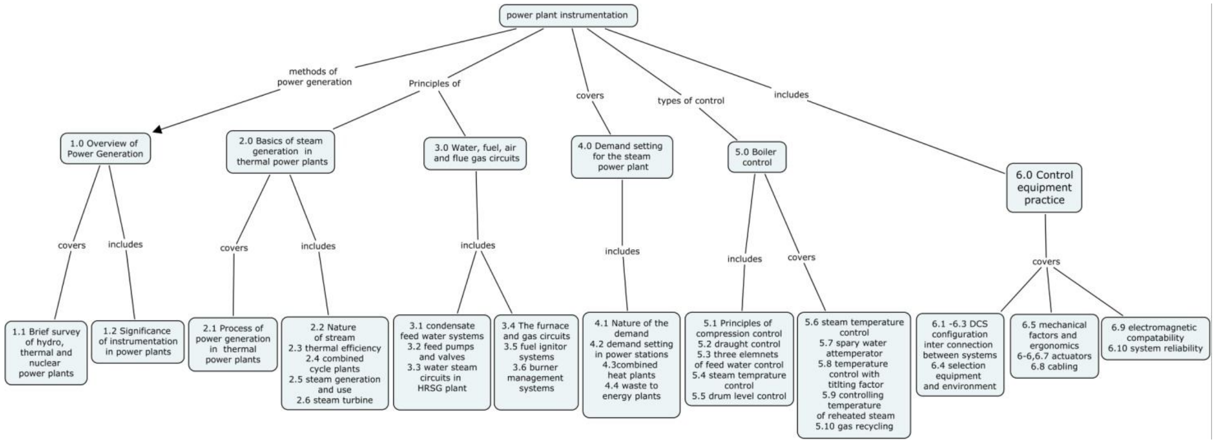
Understand

1. Explain the nature of steam and the uses of steam.
2. Describe how the demand setting in power station is done.
3. Discuss briefly about waste to energy plants.
4. Explain how temperature is controlled with tilting burners.

Analyse

1. Compare the operation of two element and three element control used for feed water pumping.
2. Differentiate the operation of different methods of draught control in a power plant.
3. Organise the steps involved in compression control.
4. Compare and contrast between an oxygen analyser and a flue gas analyser.

Concept Map



Syllabus

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

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

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

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

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

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

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

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

Reference Books

1. David Lindsley, “Power Plant Control & Instrumentation ”,IEE Publications, London, UK (2001).
2. Sam G.Dukelow, The control of Boilers, Instrument Society of America, 1991.
3. Elonka, S.M. and Kohal A.L.Standard Boiler Operations, McGraw Hill, NewDelhi, 1994.
4. R.K.Jain, Mechanical and Industrial Measurements, Khanna Publishers, New Delhi, 1995.
5. P.K.Nag, ”Power Plant Engineering” Tata McGraw-Hill, NewDelhi, 2005.
6. A.K.Mahalanbias-“Power System Instrumentation”-Tata McGraw Hill.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.0	**OVERVIEW OF POWER GENERATING STATIONS**	
1.1	Brief survey of different methods of conventional power generation (hydro, thermal and nuclear)	1
1.2	Importance of instrumentation in power generating stations	1
2.0	**Basics of steam generation in thermal power plants**	
2.1	Process of power generation in coal-fired and oil fired in thermal power plants	1
2.2	Nature of steam	1
2.3	Thermal efficiency	1
2.4	Gas turbine and combined cycle plants	1
2.5	Steam generation and use	1
2.6	Steam turbine	1
3.0	**Water, fuel, air and flue gas circuits**	
3.1	The condensate and feed water system	1

3.2	Feed pumps and valves	1
3.3	The water and steam circuits in HRSG plant	1
3.4	The air and gas circuits	1
3.5	Fuel and Igniter systems	1
3.6	Burner- management systems	1
4.0	**Setting the demand for the steam generator**	
4.1	Nature of the demand	1
4.2	Setting the demand in power station applications	1
4.3	Master demand in power station applications	1
4.5	Load demand in combined heat and power plants	1
4.6	Waste to energy plants	1
5.0	**Boiler control**	
5.1	The principles of compression control	1
5.2	Draught control	1
5.3	The principles of feed water control	1
5.4	One, two and three elements feed water control	1
5.5	Drum level control	2
5.6	Steam temperature control	1
5.7	Spray-water attemperator	1
5.8	Temperature control with tilting burners,	1
5.9	controlling temperature of reheated steam	1
5.10	Gas Recycling	1

6.0	**CONTROL EQUIPMENT PRACTICE**	
6.1	DCS configuration in power plant	1
6.2	A Typical DCS configuration	1
6.3	Interconnections between systems,	1
6.4	Equipment selection and environment	1
6.5	mechanical factors and ergonomics	1
6.6	Electrical actuators	1
6.7	Hydraulic actuators	1
6.8	Cabling,	1
6.9	Electromagnetic compatibility	1
6.10	Reliability of systems	1
	TOTAL	40

Course Designer

M.Geethanjali mgeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEC	3	1	-	4

KEC Flexible AC Transmission Systems 3:1

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.

Programme Outcomes addressed

a. Ability to apply knowledge of engineering, information technology, mathematics, and science

b. Ability to design and conduct experiments, as well as to analyze and interpret data

c. Ability to design a system or component, or process to meet stated specifications

d. Ability to identify, formulate and solve engineering problems

e. Ability to use techniques, skills, and modern engineering tools to implement and organize engineering works under given constraints

g. Ability to function on multidisciplinary teams

Competencies

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

1. Explain the basic principles of different types of FACTS controllers
2. Explain the characteristics and applications of different controllers
3. Determine the modelling of FACTS controller
4. Choose a particular controller for a given application
5. Analyze and compare the performance of various FACTS controllers

Assessment Pattern

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

Course Level learning objectives

Remember

1. What is the objective of series compensation?
2. Specify the range of firing angle corresponding to inductive and capacitive region of operation in TCSC?
3. What is meant by blocking mode of TCSC operation?
4. Draw the UPFC model used for power flow studies?
5. Draw the phasor diagram for UPFC?

Understand

1. Explain the working of TCR?
2. Explain the characteristics of TCSC?
3. Explain the power flow capability of TCPAR?
4. Explain the working of UPFC?
5. Explain the working of SSSC?

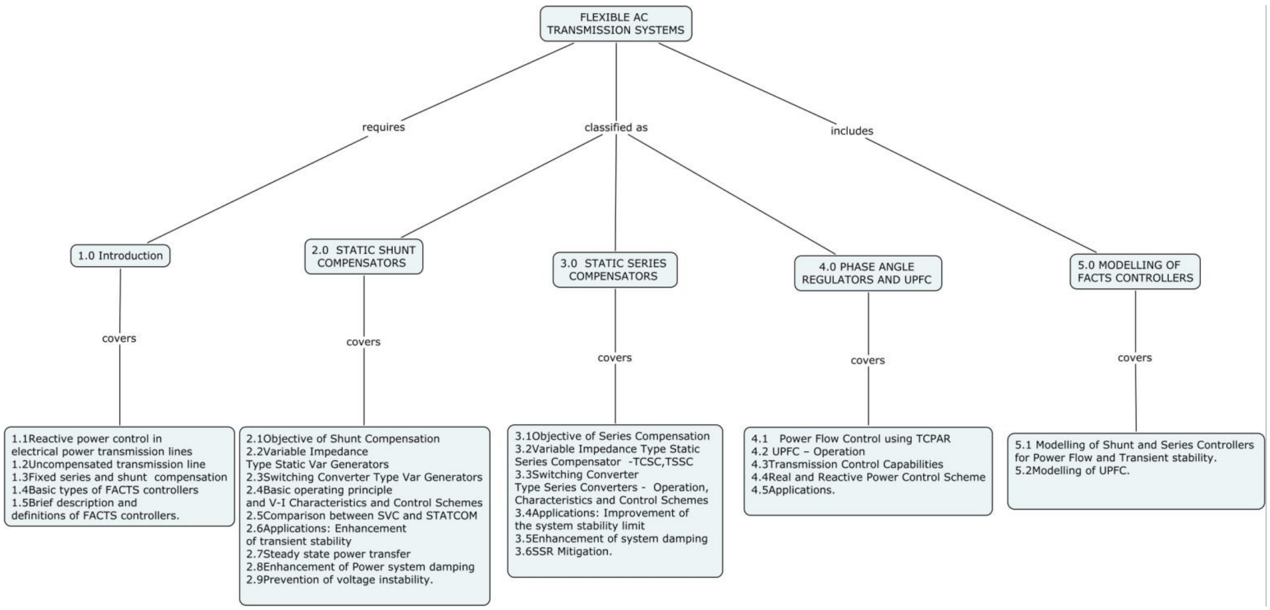
Apply

1. Discuss the application of SVC in the improvement of Transient Stability Improvement
2. How TCSC is used to mitigate SSR.
3. Discuss the application of STATCOM in Power System Damping.
4. UPFC is used for simultaneous control of power system parameters. Justify

Analyze

1. Compare SVC and STATCOM
2. Compare SSSC and TCSC
3. Analyze the modelling of UPFC in power flow control
4. Analyse the Modelling of TCSC in stability studies
5. Analyse the control capabilities of UPFC

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 SVC and STATCOM. Applications: Enhancement of transient stability – Steady state power transfer – Enhancement of Power system damping – Prevention of voltage instability.

STATIC SERIES COMPENSATORS

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

PHASE ANGLE REGULATORS AND UPFC

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

UPQC & IPFC.

MODELLING OF FACTS CONTROLLERS

Modelling of Shunt and Series Controllers for Power Flow and Transient stability.
Modelling of UPFC.
Location and tuning of FACTS devices.

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 Content and Lecture Schedule

S.No.	Topic	No. of Lectures
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 SVC and STATCOM	1
2.6	Applications: Enhancement of transient stability	2
2.7	Steady state power transfer	1
2.8	Enhancement of Power system damping	1
2.9	Prevention of voltage instability.	1
3.0	**STATIC SERIES COMPENSATORS**	
3.1	Objective of Series Compensation	1
3.2	Variable Impedance Type Static Series Compensator - TCSC,TSSC	2
3.3	Switching Converter Type Series Converters - Operation, Characteristics and Control Schemes	2
3.4	Applications: Improvement of the system stability limit	2
3.5	Enhancement of system damping	1
3.6	SSR Mitigation.	2
4.0	**PHASE ANGLE REGULATORS AND UPFC**	
4.1	Power Flow Control using TCPAR	1
4.2	UPFC – Operation	1
4.3	Transmission Control Capabilities	2
4.4	Real and Reactive Power Control Scheme	2
4.5	Applications. UPQC & IPFC	2
5.0	**MODELLING OF FACTS CONTROLLERS**	
5.1	Modelling of Shunt and Series Controllers for Power Flow and Transient stability.	3
5.2	Modelling of UPFC. Location and tuning of FACTS devices	2
	Total	40

Course Designer

S.Latha sleee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KED	3	1	-	4

KED Electrical Transients in Power System 3:1

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.

Programme Outcome Addressed

a. An ability to apply knowledge of engineering, information technology, mathematics and science
b. An ability to design and conduct experiments, as well as to analyze and interpret data
c. An ability to design a system or component, or process to meet stated specifications
d. An ability to identify, formulate and solve engineering problems
e. An ability to use techniques, skills, and modern engineering tools to implement and organize engineering works under given constraints

Competencies

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

1. Understand the various sources of electromagnetic transient.
2. Understand the formation and characteristics of travelling waves in transmission line
3. Be able to use the ATP/EMTP software for transient studies.
4. Be able to model power apparatus under transient conditions
5. Get a detailed knowledge on Insulation co ordination and will be able to determine the proper insulation levels of various components in a power system and their arrangement.

Assessment Pattern

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

Course Level Learning Objectives

Remember

1. What are the various sources of Transient Over voltages?
2. Define Surge impedance loading.
3. What is the use of Bewley lattice diagram?
4. State important properties of co-efficient of Potential, Capacitance and Induction.
5. State important properties of co-efficient of Potential, Capacitance and Induction.
6. What is meant by basic insulation level?
7. How lightning arresters are classified?
8. State the functions of energy management system.
9. Draw the equivalent Π section of a long transmission line.
10. Write the wave equation.

Understand

1. Distinguish between surge absorber and surge diverter.
2. 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).
3. 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

4. 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.
5. Discuss the application of
   a. Ground wires
   b. Surge Diverters

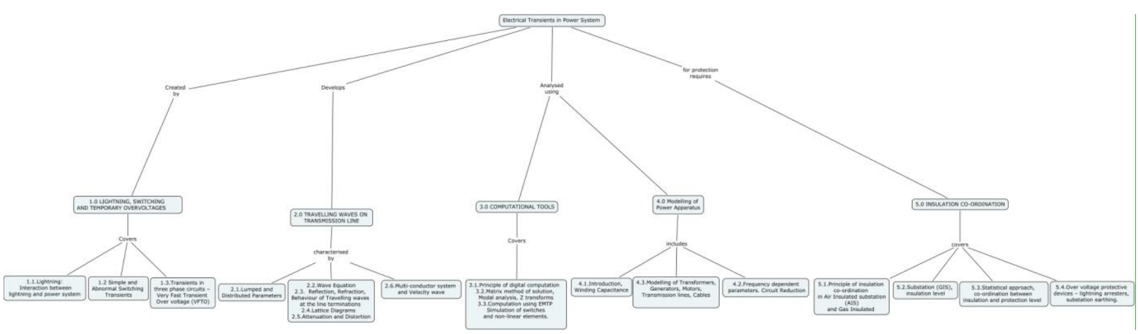
   For the protection of a line against surge voltages.
6. Explain in detail the various types of lightning strokes that can strike a transmission line. Also Derive an expression for the over voltage developed due to lighting stroke.

Apply

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. How do you model a surge diverter for steep fronted waves? Also, explain the steps involved in simulating model sung EMTP.
3. 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.

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 content and Lecture Schedule

S.No.	Topics	No. of lectures
1.0 LIGHTNING, SWITCHING AND TEMPORARY OVERVOLTAGES		

1.1.	Lightning: Physical phenomena of lightning – Interaction between lightning and power system	2
1.2.	Simple and Abnormal Switching Transients	4
1.3.	Transients in three phase circuits – Very Fast Transient Over voltage (VFTO) - IEC standards and wave models.	3
2.0 TRAVELLING WAVES ON TRANSMISSION LINE		
2.1.	Lumped and Distributed Parameters	2
2.2.	Wave Equation	1
2.3.	Reflection, Refraction, Behaviour of Travelling waves at the line terminations	2
2.4.	Lattice Diagrams	2
2.5.	Attenuation and Distortion	1
2.6.	Multi-conductor system and Velocity wave	2
3.0 COMPUTATION OF POWER SYSTEM TRANSIENTS		
3.1.	Principle of digital computation	1
3.2.	Matrix method of solution, Modal analysis, Z transforms	3
3.3.	Computation using EMTP – Simulation of switches and non-linear elements.	3
4.0 MODELLING OF POWER APPARATUS UNDER TRANSIENT CONDITION		
4.1.	Introduction, Winding Capacitance	1
4.2.	Frequency dependent parameters. Circuit Reduction	1
4.3.	Modelling of Transformers, Generators, Motors, Transmission lines, Cables	5
5.0 INSULATION CO-ORDINATION		
5.1.	Principle of insulation co-ordination in Air Insulated substation (AIS) and Gas Insulated	2
5.2.	Substation (GIS), insulation level	2
5.3.	Statistical approach, co-ordination between insulation and protection level	2

5.4.	Over voltage protective devices – lightning arresters, substation earthing.	1
Total		40

Course Designer

R. Rajan Prakash r_rajanprakash@tce.edu

Sub code	Lectures	Tutorial	Practical	Credit
KEE	**3**	**1**	**-**	**3**

KEE Analysis of Electrical Machines 3:1

Preamble

This course "Analysis of Electrical machines" a departmental elective course, is preceded by courses DC machines and transformers and AC machines" in UG which presents the basic and depth concepts of Electrical machines. The course mainly discusses the concepts of torque production in machines as well as the reference frame theories. It also discuses the transformation between reference frames, transformation of a balanced set, balanced steady state phasor and voltage equations from several frames of reference. It also discusses the computer simulation in arbitrary reference frame.

Program Outcomes addressed

a. An ability to apply knowledge of engineering, information technology, mathematics and science.
b. An ability to design and conduct experiments, as well as to analyze and interpret data.
c. An ability to design a system or component, or process to meet stated specifications.

Competencies

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

1. Obtain useful information about the torque production and voltage generation in electrical machines
2. Study and design of electrical machines
3. Study of dynamic performance for load and torque variations in rotating machines
4. Computer simulation of in arbitrary reference for electrical machines

Assessment pattern

	Bloom's Category	Test 1	Test 2	End-semester examination
1	Remember	10	10	10
2	Understand	20	20	20
3	Apply	0	0	0
4	Analyze	70	70	70
5	Evaluate	0	0	0
6	Create	0	0	0

Course Level Learning Objectives

Remember

1. Mention the types of exciting systems.
2. Write the voltage and torque equations of D.C. motor?
3. Give the areas of application of induction motor
4. What is the difference between a synchronous machine and an induction machine?
5. Write the advantages of converting rotating axis to stationary axis transformation?
6. Write is critical clearing time?

Understand

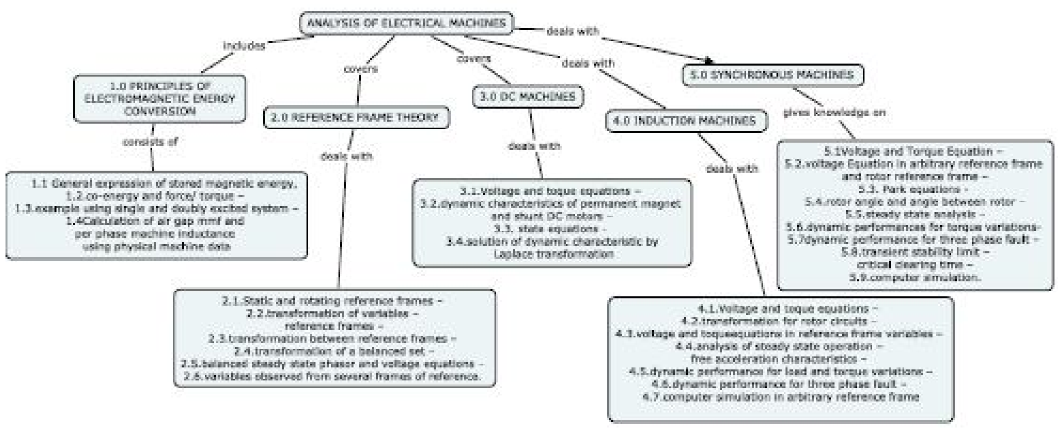
1. Give the difference between steady state stability and transient state stability
2. Draw the free acceleration characteristics of induction machine?
3. Write the state equations of DC motor

4. Derive the general expression of stored electric energy
5. Discuss the variables observed from several frames of reference.

Analyze

1. Analyze Park equations?
2. Write about transformation between reference frames?
3. Discuss the dynamic characteristics of permanent magnet DC motors.
4. With neat diagrams explain steady state operations of induction machines?
5. Explain the calculation of airgap mmf and per phase machine inductance using physical machine data.

Concept Map



Syllabus

PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION

General expression of stored magnetic energy, co-energy and force/ torque – example using single and doubly excited system –Calculation of air gap mmf and per phase machine inductance using physical machine data

REFERENCE FRAME THEORY

Static and rotating reference frames – transformation of variables – reference frames –transformation between reference frames – transformation of a balanced set – balanced steady state phasor and voltage equations – variables observed from several frames of reference.

DC MACHINES

Voltage and toque equations – dynamic characteristics of permanent magnet and shunt DC motors – state equations - solution of dynamic characteristic by Laplace transformation.

INDUCTION MACHINES

Voltage and toque equations – transformation for rotor circuits – voltage and toque equations in reference frame variables – analysis of steady state operation – free acceleration characteristics – dynamic performance for load and torque variations – dynamic performance for three phase fault – computer simulation in arbitrary reference frame.

SYNCHRONOUS MACHINES

Voltage and Torque Equation, voltage Equation in arbitrary reference frame and rotor reference frame, Park equations, rotor angle and angle between rotor, steady state analysis, dynamic performances for torque variations, dynamic performance for three phase fault, transient stability limit and critical clearing time, computer simulation

REFERENCE BOOKS

1. Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, “Analysis of Electric Machinery and Drive Systems”, IEEE Press, Second Edition.
2. R.Krishnan, “Electric Motor Drives, Modeling, Analysis and Control” , Prentice Hall of India, 2002
3. Samuel Seely, “ Eletomechanical Energy Conversion”, Tata McGraw Hill Publishing Company,
4. A.E, Fitzgerald, Charles Kingsley, Jr, and Stephan D, Umanx, “ Electric Machinery”, Tata McGraw Hill, 5th Edition, 1992

Course Contents and Lecture Schedule

S.No	Topics	No. of Lectures
1	**PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION**	
1.1	General expression of stored magnetic energy	1
1.2	co-energy and force/ torque	2
1.3	example using single and doubly excited system	1
1.4	Calculation of air gap mmf and per phase machine inductance using physical machine data	2
2	**REFERENCE FRAME THEORY**	
2.1	Static and rotating reference frames	2
2.2	transformation of variables, reference frames	1
2.3	transformation between reference frames	1
2.4	Transformation of balanced set	2
2.5	balanced steady state phasor and voltage equations –	2
2.6	variables observed from several frames of reference.	1
3	**DC MACHINES**	
3.1	Voltage and torque equation	1
3.2	dynamic characteristics of permanent magnet and shunt DC motors	2
3.3	State Equations	1
3.4	solution of dynamic characteristic by Laplace transformation.	2
4	**INDUCTION MACHINES**	
4.1	Voltage and torque equations	1
4.2	transformation for rotor circuits	1
4.3	voltage and torque equations in reference frame variables	1
4.4	analysis of steady state operation – free acceleration characteristics	1
4.5	dynamic performance for load and torque variations –	1
4.6	dynamic performance for three phase fault	1
4.7	computer simulation in arbitrary reference	1
5	**SYNCHRONOUS MACHINES**	
5.1	Voltage and Torque Equation	2
5.2	voltage Equation in arbitrary reference frame and rotor reference frame	2
5.3	Park equations	2

5.4	rotor angle and angle between rotor	1
5.5	steady state analysis	1
5.6	dynamic performances for torque variations	1
5.7	dynamic performance for three phase fault	1
5.8	transient stability limit and critical clearing time	1
5.9	computer simulation	1
	Total	40

Course designers

P.Reguna preee@tce.edu

S. Arockia Edwin Xavier saexeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEF	**4**	**-**	**-**	**4**

KEF Renewable Energy Sources 4:0

Preamble

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

Programme Outcomes addressed

a. Graduates will demonstrate knowledge of Renewable Energy Sources applications to real life energy requirements.

b. Graduates will able to select a right green energy source for a specify applications.

c. Graduate who can participate and succeed in competitive examinations.

Competencies

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

1. Discuss the nature of renewable energy sources including solar, geothermal, wind, biomass, tidal and hydro paying attention to energy and environment payback.
2. Explain the basic principles of energy conversion from Renewable Energy Resources
3. Discuss the various viable option for the utilization of renewable energy resources
4. Design renewable energy system for given specification based on current commercially available technologies

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/ End-semester examination
1	Remember	20	20	10
2	Understand	50	50	40
3	Apply	30	30	30
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	20

Course Level Learning Objectives

Remember

1. Define the term Renewable energy source?
2. Mention the Coal, Gas & Fuel oil reserves of India at present rate of consumption in years?
3. Name the green house gases involved in global warming?
4. What is meant by Cut-in and Cut-out speed in wind turbine?
5. What are the factors to be considered while selecting a site for wind power plant?
6. Explain the working principle of a wind electric generator system with a block diagram?
7. Explain the various methods of tidal power generation with a conceptual diagram? What are the limitations?
8. What is meant by Energy Plantation?
9. What is meant by energy economy?
10. What are the factors governing global warming? How it can be minimized?

Understand

1. Specify the limitations of Renewable energy sources?
2. Why tracking/orientation is needed in concentrating type of solar collectors?
3. Specify the needs of energy storage devices? Discuss the various method of energy storage?
4. Explain the operation of binary cycle geothermal power plant?

5. Explain the Anaerobic digestion principle to convert Biomass into biogas?
6. What are the advantages of vertical axis turbine over to horizontal axis wind turbine?
7. List the advantages of biomass gasification compared to biomass combustion
8. Explain the process of pyrolysis to generate biogas from biomass? Also specify the advantages & disadvantages.
9. Why biomass is considered as a renewable energy sources?
10. What do you understand by the term mini hydro power plant?

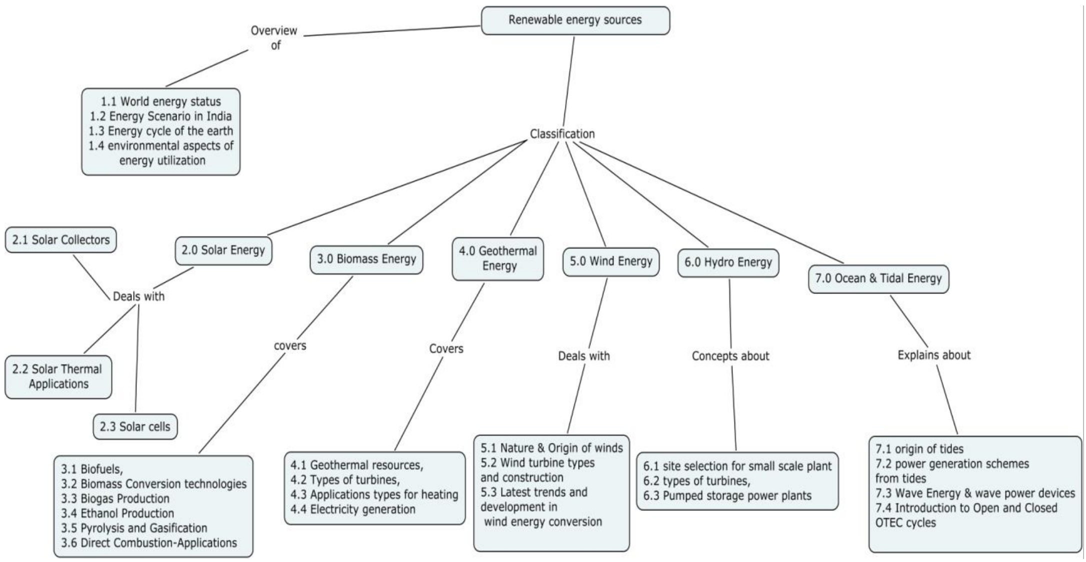
Apply

1. Draw the Energy Consumption pattern of India by using a bar chart graph and also discuss the ways and means to bridge the gap between Demand & Supply of Power in India?
2. List the commercial energy resources?
3. Suggest suitable solar collectors for solar furnace applications?
4. What are the main applications of solar dryer?
5. Discuss the various application of solar energy? Also specify its applicability with respect to economic operation?
6. Discuss the various application of geothermal energy for energy alternative?
7. List the procedure to select a site for wind electric generator installations? Also specify the different types of Wind Turbine along with its application.
8. What are the difficulties encountered in commercializing the renewable energy sources?
9. The ocean surface temperature at a location is 30C and bottom ocean temperature is 10C. Calculate the maximum theoretical efficiency of the OTEC system for energy conversion?

Create

1. Create a Renewable Energy System for an Tea industry energy applications
2. Create a Renewable energy model for preheating water for a power plant application.
3. Create a renewable energy system for desalination of Sea water.

Concept Map



Syllabus

Energy Overview: Classification of Energy Resources, World energy status, Energy Scenario in India-energy cycle of the earth-environmental aspects of energy utilization-renewable energy resources and their importance, Carbon credit.

Solar Energy: Solar collectors, Solar thermal applications, solar cells types, Standalone & Grid Connected Solar PV Cells.

Biomass Energy: Bio-fuels, Biomass Conversion technologies, Biogas Production-Ethanol Production-Pyrolysis and Gasification-Direct Combustion-Biomass power generation status, Applications.

Geothermal Energy: Geothermal resources, basic theory-types of turbines-applications types, applications for heating and electricity generation

Wind Energy: Nature & Origin of winds, Wind turbine types and construction, Latest trends and development in wind energy conversion.

Hydro Energy: Basic concepts site selection and types of turbines for small scale hydropower, Run-off River plant, Role of Pumped storage power plants in Power system for the Voltage and Frequency control.

Ocean & Tidal Energy: origin of tides-power generation schemes-Wave Energy, wave power devices, Introduction to Open and Closed OTEC cycles

Environmental Aspects: Energy Payback period & Environmental Payback period, Potential impacts of harnessing the different renewable energy resources.

Reference Books

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

Course Content and Lecture Schedule

S.No.	Topic	No. of Lectures
1.0	**Energy Overview**	
1.1	Classification of Energy Resources, World energy status	1
1.2	Energy Scenario in India	1
1.3	Energy cycle of the earth	1
1.4	Environmental aspects of energy utilization	1
1.5	Renewable energy resources and their importance	1
2.0	**Solar Energy**	
2.1	Solar collectors	1
2.2	Solar thermal applications	1
2.3	solar cells, Standalone & Grid Connected Solar PV Cells.	2
3.0	**Biomass Energy**	
3.1	Biofuels	1
3.2	Biomass Conversion technologies	1
3.3	Biogas Production	1
3.4	Ethanol Production	1
3.5	Pyrolysis and Gasification	2
3.6	Direct Combustion-Applications	1

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

Course Designer

V.Saravanan vseee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEG	**4**	**0**	**-**	**4**

KEG Power Quality 4 : 0

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 electric power that drives an electrical load and the load's ability to function properly with that electric power. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power.

The electric power industry comprises electricity generation (AC power), electric power transmission and ultimately electricity distribution to an electricity meter located at the premises of the end user of the electric power. The electricity then moves through the wiring system of the end user until it reaches the load. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised.

While "power quality" is a convenient term for many, it is the quality of the voltage—rather than power or electric current—that is actually described by the term. Power is simply the flow of energy and the current demanded by a load is largely uncontrollable.

The quality of electrical power may be described as a set of values of parameters, such as: Continuity of service, Variation in voltage magnitude, Transient voltages and currents and Harmonic content in the waveforms etc.

It is often useful to think of power quality as a compatibility problem: is the equipment connected to the grid compatible with the events on the grid, and is the power delivered by the grid, including the events, compatible with the equipment that is connected. Compatibility problems always have at least two solutions: in this case, either clean up the power, or make the equipment tougher. Considering all the above issues, the course **Power Quality** is designed.

Program Outcomes addressed

a. An ability to apply knowledge of engineering, information technology, mathematics, and science
c. An ability to design a system or component, or process to meet stated specifications
d. An ability to identify, formulate and solve engineering problems

Competencies

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

1. Understand & analyze various electrical power quality issues in the generation, transmission and distribution systems
2. Evaluate & Design filters such as harmonic filter for mitigating power quality problems
3. Design custom power devices like DVR, D-STATCOM, UPQC etc.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/End-semester examination
1	Remember	20	20	15
2	Understand	20	20	15
3	Apply	0	0	0
4	Analyze	30	30	40
5	Evaluate	30	30	30
6	Create	0	0	0

Course level learning objectives

Remember

1. List the various power quality issues.
2. Draw the CBEMA and ITIC power acceptability curves.
3. List the sources of nonlinear load which generates PQ problems.
4. Define, the harmonic indices THD & DIN.
5. Brief the concept of solid state current limiter.
6. Define, harmonic distortion.
7. Draw the CBEMA and ITIC power acceptability curves.
8. List some of the non linear loads.

Understand

1. What is the role of PQ standards? List some of the PQ standards.

2. What are the causes for voltage sag?
3. How fluorescent light creates power quality problems?
4. What is wavelet transform?
5. What are the causes for voltage sag?
6. How voltage unbalance can be eliminated?
7. What is the role of custom power devices?
8. What is active harmonic filter?

Analyze

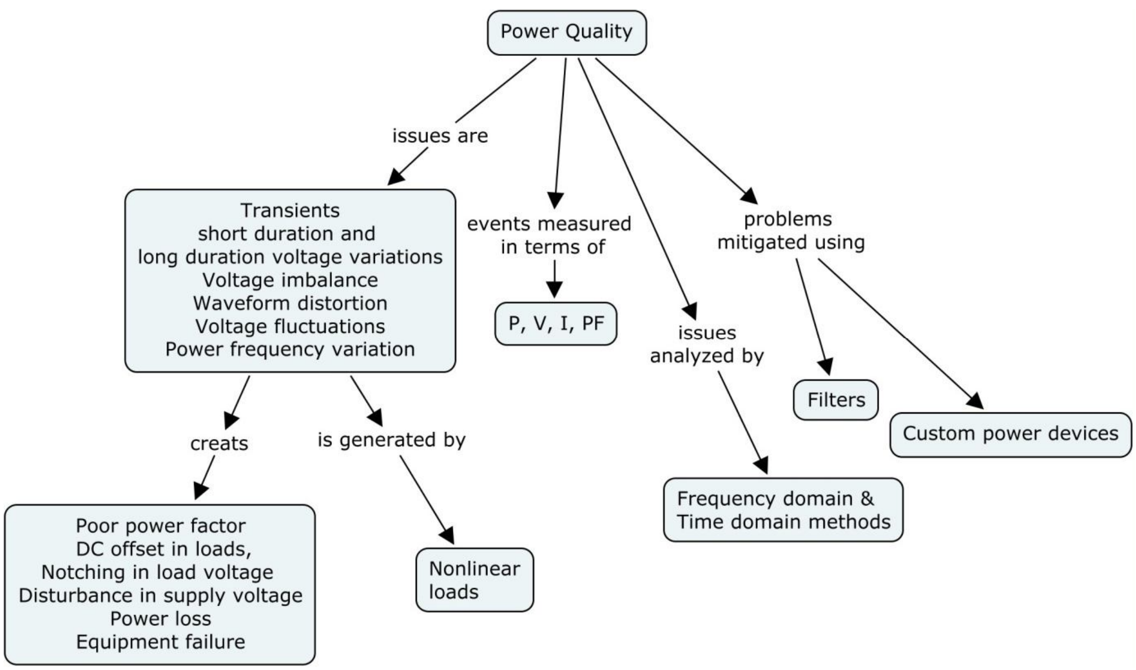
1. Explain how unbalance is analyzed using symmetrical components. Also discuss how unbalance is eliminated.
2. Discuss the working principle and operation of the followings
    a) Active filter
    b) Network reconfiguring devices
3. Explain the following electrical power quality issues in detail with examples.
    a) Voltage variations (short & long)
    b) Waveform distortions
4. Discuss the following electrical power quality issues in detail with examples.
    a) Voltage imbalance
    b) Flickers
    c) Transients
5. Discuss any three types of nonlinear load which create power quality issues.
6. Explain working principle and construction of D-STATCOM and also discuss how it is used for load compensation and voltage regulation in power system.
7. Discuss the issues related to voltage, current, power, energy and power factor measurements.
8. Describe the operation of UPQC and DVR. Also discuss how UPQC and DVR are used to mitigate power quality problems.

Evaluate

1. Evaluate the harmonic distortion produced by different PWM converter based adjustable speed drives.
2. Evaluate various methods used for analyzing voltage sag in power systems.
3. Explain how the following electrical power quality issues are evaluated using various indexes.
    a) Power outage
    b) Voltage sag

4. Explain working principle and construction of UPQC and also discuss how it is used for load compensation and voltage regulation in power system.
5. Evaluate different types of time domain and frequency domain methods used for analyzing various PQ indices.
6. Evaluate different mathematical transformation techniques available for analyzing power quality events.

Concept Map



Syllabus

Introduction

Characterization of Electric Power Quality: Transients, short duration and long duration voltage variations, Voltage imbalance, waveform distortion, Voltage fluctuations, Power frequency variation, Power acceptability curves – Power quality problems: Poor load power factor, Non linear and unbalanced loads – DC offset in loads, Notching in load voltage – Disturbance in supply voltage – Power quality standards.

Nonlinear loads

Single phase static and rotating AC/DC converters - Three phase static AC/DC converters- Battery chargers- Arc furnaces- Fluorescent lighting- DC/AC converters - Adjustable speed drives.

Measurement of PQ Events

Voltage, Current, Power and Energy measurements- power factor measurements - event recorders, Measurement Error

Analysis of PQ events

Analysis in the periodic steady state –Frequency domain methods: Laplace, Fourier and Hartley transform – Wavelet Transform- Time domain methods- Analysis of power outages- Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers- Analysis of distortion :On-line extraction of fundamental sequence components from measured samples, Harmonic indices – Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index (VSLEI) – Analysis of voltage flicker

Power Quality Improvement

Utility-Customer interface- Harmonic filters: Passive, Active and Hybrid filters – Custom power devices: DSTATCOM, DVR & UPQC – Status of application of custom power devices.

Reference Books

1. Arindam Ghosh and Gerald Ledwich: Power Quality Enhancement Using Custom Power Devices, Kluwer Academic Publishers, 2002
2. G.T.Heydt: Electric Power Quality, 2nd edition, Stars in a Circle Publications, 1994
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
8. Short.T.A., “Distribution Reliability and Power Quality”, CRC Press Taylor and Francis Group, 2006

Course Content and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Introduction to Electric Power Quality**	
1.1	Transients, short duration and long duration voltage variations, Voltage imbalance	2
	waveform distortion, Voltage fluctuations, Power frequency variation	2
1.2	Power quality problems: Poor load power factor, Non linear and unbalanced loads – DC offset in loads, Notching in load voltage – Disturbance in supply voltage	3
1.3	Power quality standards	1
2.	**Nonlinear loads**	
2.1	Single phase static and rotating AC/DC converters **-** Three phase static AC/DC converters **-** DC/AC converters –Multilevel converters	2
2.2	Battery chargers**-** Arc furnaces**-** Fluorescent lighting	2
2.3	Adjustable speed drives	1
3.	**Measurement of PQ Events**	
3.1	Voltage, Current**,** Power and Energy measurements**-** power factor measurements	2
3.2	Event recorders, Measurement Error	2
4.	**Analysis of PQ events**	
4.1	Analysis in the periodic steady state – Frequency domain methods: Laplace,	2
	Fourier and Hartley transform – Wavelet Transform**-** Time domain methods	2
4.2	Analysis of power outages**-** Analysis of unbalance: Symmetrical components of phasor quantities, Instantaneous symmetrical components, Instantaneous real and reactive powers	3
4.3	Analysis of distortion :On-line extraction of fundamental sequence components from measured samples**,** Harmonic indices	3
4.4	Analysis of voltage sag: Detorit Edison sag score, Voltage sag energy, Voltage Sag Lost Energy Index	2
4.5	Analysis of voltage flicker	2
5.	**Power Quality Improvement**	
5.1	Harmonic filters: Passive, Active and Hybrid filters	3
5.2	Custom power devices: DSTATCOM	2
5.3	DVR	2
5.4	UPQC	2
	Total	40

Course Designer

V. Suresh Kumar vskeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEH	**4**	**-**	**-**	**4**

KEH Soft Computing Techniques 4:0

Preamble

Soft computing is a discipline that deals with the design of intelligent systems, which is in contrast to classical hard computing technique. A consortium of computing methodologies that provides a foundation for the conception, design, and deployment of intelligent systems and aims to formalize the human ability to make rational decisions in an environment of uncertainty, imprecision, partial truth, and approximation. The main constituents of soft computing involve fuzzy logic, neuro computing, neuro-fuzzy and genetic algorithms and its applications.

Students acquire knowledge of soft computing theories, fundamentals and so they will be able to design program systems using approaches of these theories for solving various real-world problems. Students also awake the importance of tolerance of imprecision and uncertainty for design of robust and low-cost intelligent machines.

Program outcomes addressed

a. An ability to apply knowledge of engineering, information technology, mathematics and science

b. An ability to design and conduct experiments, as well as to analyze and interpret data

c. An ability to identify, formulate and solve engineering problems

d. An ability to use techniques, skills and modern engineering tools to implement and organize engineering works under given constraints

Competencies

After successfully completing the course, students will be able to:

1. Acquire the ideas of fuzzy sets, fuzzy logic, Neuro-Fuzzy and use of heuristics based on human experience
2. Acquire the knowledge of neural networks that can learn from available examples and generalize to form appropriate rules for inferencing systems
3. Provide the mathematical background for carrying out the optimization associated with neural network learning
4. Acquire knowledge of various optimization techniques and genetic algorithm procedures useful while seeking global optimum in self-learning situations

5. Detailed case studies utilizing the above and illustrate the intelligent behavior of programs based on soft computing

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/End semester examination
1	Remember	20	20	10
2	Understand	40	40	30
3	Apply	40	40	40
4	Analyze	0	0	0
5	Evaluate	0	0	20
6	Create	0	0	0

Course level learning objectives

Remember

1. What are the different paradigms of soft-computing?
2. What are the various learning rules used for training the neural network?
3. Give some common applications of fuzzy logic?
4. What are the different methods of De-fuzzification?
5. What are the parameters to be considered for the design of membership function?
6. Define: optimization.
7. Mention the different methods selection.
8. What are the genetic operators used in GA?
9. Mention the linear and non-linear activation functions used in ANN.
10. What is perceptron?
11. Mention the special features of Boltzman machine.
12. Define a fuzzy inference system.

Understand

1. Explain Sugeno fuzzy model.
2. Explain the construction of fuzzy model for a nonlinear equation.
3. Explain Widrow-Hoff LMS Learning Algorithms.
4. Explain multilayer perceptron with its architecture. How is it used to solve XOR Problem?
5. What do you mean by supervised and unsupervised learning?
6. Explain back propagation algorithm in detail.
7. Describe the learning expressions in the back propagation network.
8. What is competitive learning? How does it differ from signal Hebbrian learning?
9. Explain the basic idea behind SVM with suitable illustrations.
10. Explain the various steps involved in GA in detail.
11. Explain Classification and regression trees.
12. Describe Neuro-Fuzzy controls.

Apply

1. Compute the centroid defuzzifier for

   $\overline{A} = \left\{ \frac{0.9}{-3}, \frac{0.7}{-2}, \frac{0}{-1}, \frac{0.3}{1}, \frac{1}{2}, \frac{0.2}{3} \right\}$

   Let $X = \{0,1,2,3,4,5\}$ and $\overline{A} = \left\{ \frac{0.9}{-3}, \frac{0.7}{-2}, \frac{0}{-1}, \frac{0.3}{1}, \frac{1}{2}, \frac{0.2}{3} \right\}$, $\overline{B} = \left\{ \frac{0.9}{-3}, \frac{0.7}{-2}, \frac{0}{-1}, \frac{0.3}{1}, \frac{1}{2}, \frac{0.2}{3} \right\}$

   Find the fuzzy max and fuzzy min of $\overline{A}$ and $\overline{B}$

2. Let A={(x1,0.2),(x2,0.7),(x3,0.4)} and B={(y1,0.5),(y2,0.6)} be two fuzzy sets defined on the universe of discourse X={x1,x2,x3} and Y={y1,y2,y3} respectively. Find the Cartesian product of the A and B and fuzzy relation R.
   3. Describe the structure and operation of continuous Hopfield network. & Construct an auto associative BAM using the following training vectors. X1 = $(1,-1,-1,1,-1,1)^T$ and x2 = $(1,1,1,-1,-1,-1)^T$. Determine the output using xo $=(1,1,1,1,-1,1)^T$

3. Find the optimal layer associative memory (OLAM) matrix M for the association given below

   A1 = $(1\ 2\ 3)^T$ B1 = $(4\ 3\ 2\ )^T$

   A2 = $(2\ 3\ 4)^T$ B2 = $(3\ 5\ 2\ )^T$

   A3 = $(3\ 4\ 6)^T$ B3 = $(2\ 2\ 1)^T$

   Determining whether Ai= M - Bi

4. Perform two generations of simple binary coded genetic algorithm to solve the following optimization problem. Maximize f(x) = x^2 ; 0≤ x≤ 31, x is an integer. Use proportionate selection, single point crossover, binary mutation and population size of six.

Evaluate

1. Perform two generations of simple binary coded and real coded genetic algorithm to solve the following optimization problem.

   Maximize f(x) = |x| sin(x); -5≤ x≤ 5, x is real number.

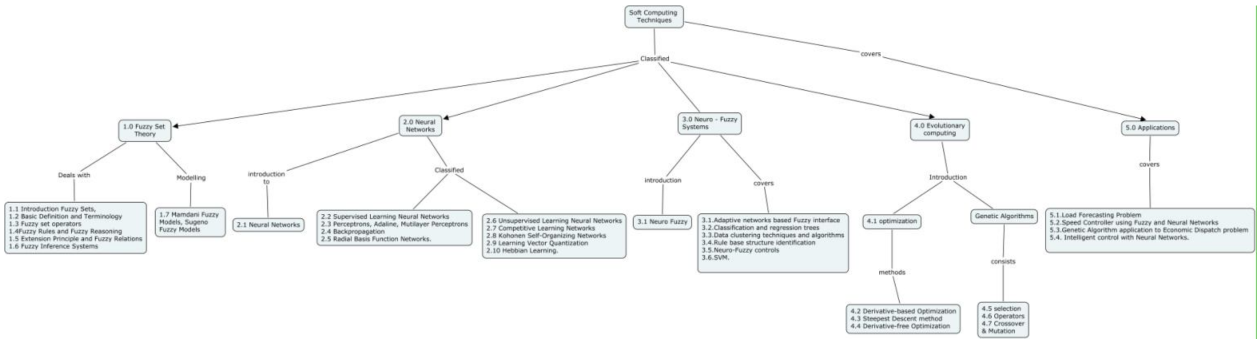
   Use proportionate selection, single point crossover, and binary mutation for simple GA and proportionate selection, Arithmetic crossover, and Gaussian mutation for RGA .Use population size of six for both SGA and RGA. Evaluate the performance of SGA and RGA after two generations

2. For the following data set, generate a suitable simple fuzzy and perceptron neuron model

```
OriginalData = {{1, 20}, {2, 12}, {3, 9}, {4, 6},
  {5, 5}, {6, 4}, {7, 5}, {8, 6}, {9, 9}, {10, 12}, {11, 20}};
```

Evaluate their performance.

Concept Map



Syllabus

FUZZY SET THEORY

Introduction to Soft Computing, Fuzzy Sets, Fuzzy set operators, Fuzzy Rules and Fuzzy Reasoning, Extension Principle and Fuzzy Relations, Fuzzy Inference Systems, Mamdani Fuzzy Models, Sugeno Fuzzy Models, Fuzzy Modeling.

NEURAL NETWORKS

Introduction, Supervised Learning Neural Networks, Perceptrons, Adaline, Multilayer Perceptrons, Back propagation, Radial Basis Function Networks, Unsupervised Learning Neural Networks, Competitive Learning Networks, Kohonen Self-Organizing Networks, Learning Vector Quantization, Hebbian Learning, Support vector Machines.

NEURO-FUZZY SYSTEMS

Introduction, Adaptive networks based Fuzzy interface, Classification and regression trees, Data clustering techniques and algorithms, Rule base structure identification, Neuro-Fuzzy controls.

GENETIC ALGORITHMS

Introduction to optimization techniques, Derivative-based Optimization, Steepest Descent Method, Derivative-free Optimization, Genetic Algorithms, Selection, Genetic operators, Crossover and Mutation, Simple binary coded GA-Real coded GA.

APPLICAIONS

Load Forecasting Problem, Speed Controller using Fuzzy and Neural Networks, Genetic Algorithm application to Economic Dispatch problem, Intelligent control with Neural Networks, Power system protection using FUZZY/ANN/ANFIS, Power Quality Assessment using GA.

REFERENCE BOOKS

1. J.S.R.Jang, C.T.Sun and E.Mizutani, "Neuro-Fuzzy and Soft Computing", PHI, 2004, Pearson Education 2004.
2. Timothy J.Ross, "Fuzzy Logic with Engineering Applications", McGraw-Hill, 1997.
3. Davis E.Goldberg, "Genetic Algorithms: Search, Optimization and Machine Learning", Addison Wesley, N.Y., 1989.
4. Simon Haykin, "Neural Networks A comprehensive foundation", PHI, Second Edition,1999.
5. Naresh.K.Sinha, Madan.M.Gupta, "Soft Computing and Intellegent Systems – Theory and Applications", Academic Press, Elsevier, 2000.

Course contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.0 FUZZY SET THEORY		
1.1	Introduction to Soft Computing	2
1.2	Fuzzy Sets	1
1.3	Fuzzy set operators	1
1.4	Fuzzy Rules and Fuzzy Reasoning	1
1.5	Extension Principle and Fuzzy Relations	1
1.6	Fuzzy Inference Systems	1
1.7	Mamdani Fuzzy Models Sugeno Fuzzy Models	2
2.0 NEURAL NETWORKS		
2.1	Introduction	1
2.2	Supervised and unsupervised Learning Neural Networks	2
2.3	Perceptrons, Adaline, Mutilayer Perceptrons	1
2.4	Backpropagation	1
2.5	Radial Basis Function Networks	1
2.6	Competitive Learning Networks	1

2.7	Kohonen Self-Organizing Networks	2
2.8	Learning Vector Quantization	1
2.9	Hebbian Learning	1
2.10	Support vector machines	2
3.0 NEURO-FUZZY SYSTEMS		
3.1	Introduction	1
3.2	Adaptive networks based Fuzzy interface	1
3.3	Classification and regression trees	1
3.4	Data clustering techniques and algorithms	1
3.5	Rule base structure identification	1
3.6	Neuro-Fuzzy controls	1
4.0 GENETIC ALGORITHMS		
4.1	Introduction to optimization techniques	1
4.2	Derivative-based Optimization	1
4.3	Steepest Descent method and Derivative-free Optimization	1
4.4	Genetic Algorithms- Selection	1
4.5	Genetic operators	1
4.6	Crossover and Mutation schemes	1
4.7	Simple binary coded GA	1
4.8	Real coded GA	1
5.0 APPLIATIONS		
5.1	Load Forecasting Problem	2
5.2	Speed Controller using Fuzzy and Neural Networks	2
5.3	Genetic Algorithm application to Economic Dispatch problem.	1
5.4	Intelligent control with Neural Networks	2
5.5	Power system protection using FUZZY/ANN/ANFIS, Power Quality Assessment using GA.	2
	Total	45

Course Designer

P.S.Manoharan psmeee@tce.edu

Sub code	Lectures	Tutorial	Practical	Credit
KEI / CN EA	**3**	**1**	**-**	**4**

KEI / CN EA Control of Electric drives 3:1

(Common to M.Tech. C &I)

Preamble

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

Program Outcomes addressed

a) An ability to apply knowledge of engineering, information technology, mathematics and science

c) An ability to design a system or component, or process to meet stated specifications

d) An ability to identify, formulate and solve engineering problems.

e) An ability to use techniques, skills, and modern engineering tools to implement and organize engineering works under given constraints

Competencies

At end of the course the graduates will be able to:

1. Analyze and characterize various control strategies for DC & AC motor Drives.
2. Analyze the role of power electronic converters in drives.
3. Classify the choice of electrical drives for practical applications.
4. Able to design the controller for an application.
5. Able to build an efficient drive system to meet the increasing demands in industry.

Assessment pattern

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

Course level Learning Objectives

Remember

1. Name the various blocks in closed loop drives.
2. What is meant by v/f control?
3. List the advantages of variable frequency drives.

4. Name the types of stepper motor drive.
5. List the advantages of load commutated inverter fed BLDC drive.
6. Identify the blocks in digital position control.

Understand

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

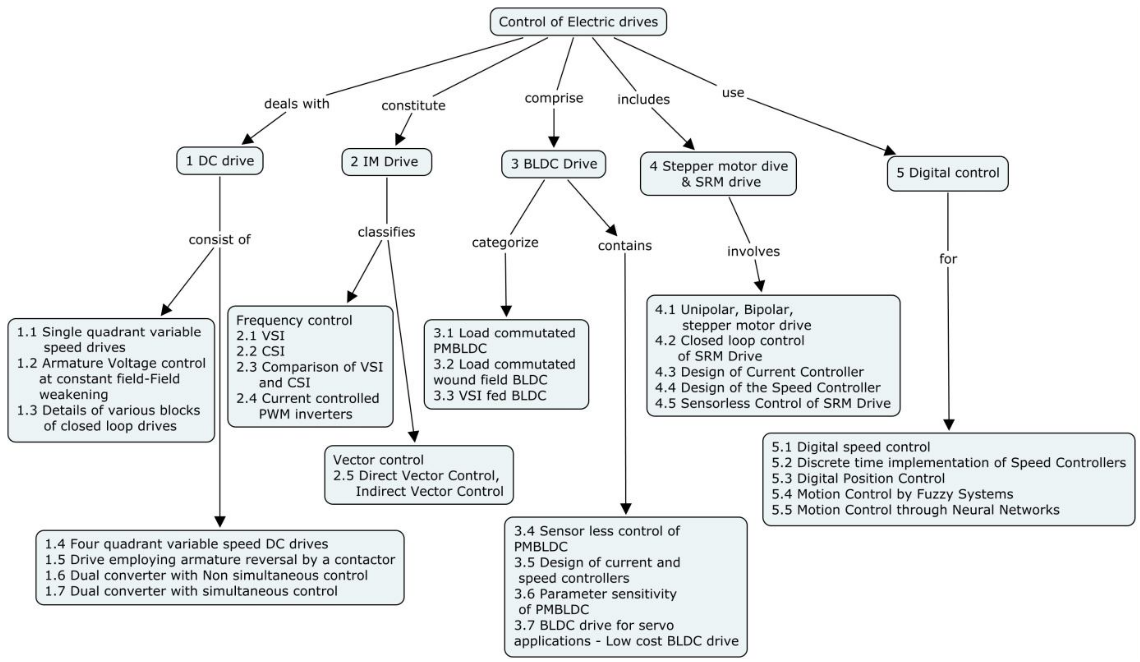
Apply

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

Analyze

1. Differentiate between single quadrant and four quadrant drives.
2. Compare and contrast CSI and VSI fed induction motor drives.
3. Devise a control scheme to maximize the efficiency of the induction motor drive operating with a vector control strategy.
4. Analyze the issues related to sensor less control of PMBLDC drive scheme.
5. Organize the steps involved in closed loop speed control of SRM drive.
6. Inspect the role of the digital controller within a speed control system.

Concept map



Syllabus

CONTROL OF DC DRIVES

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

CONTROL OF INDUCTION MOTOR DRIVES

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

CONTROL OF BLDC DRIVES

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

STEPPER MOTOR DRIVE AND SRM DRIVE

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

DIGITAL CONTROL OF DRIVES

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

Reference Books

1. G.K. Dubey, 'Power Semiconductor Controlled Drives', Prentice Hall, N. Jersey, 1989.

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

Course content and Lecture Schedule

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

5.4	Motion Control by Fuzzy Systems	2
5.5	Motion Control through Neural Networks	2
Total		40

Course Designers

L.Jessi Sahaya Shanthi ljseee@tce.edu
T.Prathiba tpeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEU / CN EO	**3**	**1**	**-**	**4**

KEU / CN EO SCADA **3:1**

(Common to M.Tech. C & I)

Preamble

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

Program Outcomes addressed

a. Graduates will demonstrate knowledge of mathematics, science and engineering.

b. Graduates will demonstrate an ability to identify, formulate and solve engineering problems.

c. Graduates will demonstrate an ability to design a system, component or process as per needs and specifications.

d. Graduate will demonstrate skills to use modern engineering tools, softwares and equipment to analyze problems.

e. Graduate who can participate and succeed in competitive examinations.

Competencies

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

1. Demonstrate about various LANs.
2. Explain the design of SCADA systems.
3. Apply the distributed and programmable controllers for industrial requirements
4. Identify the problems in practical installation of SCADA systems.

Assessment Pattern

Sl.No.	Bloom's Category	Test 1	Test 2	Test 3/ End-semester examination
1	Remember	10	10	20
2	Understand	20	20	40
3	Apply	20	20	40
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course level Learning Objectives

Remember

1. Draw the typical RTU hardware structure.
2. List the components of analog input module.
3. What are the specifications of A/D converter?
4. Name some high speed Ethernet systems.
5. What is the principle of Huff man encoding?
6. What are the different trivial alarms?

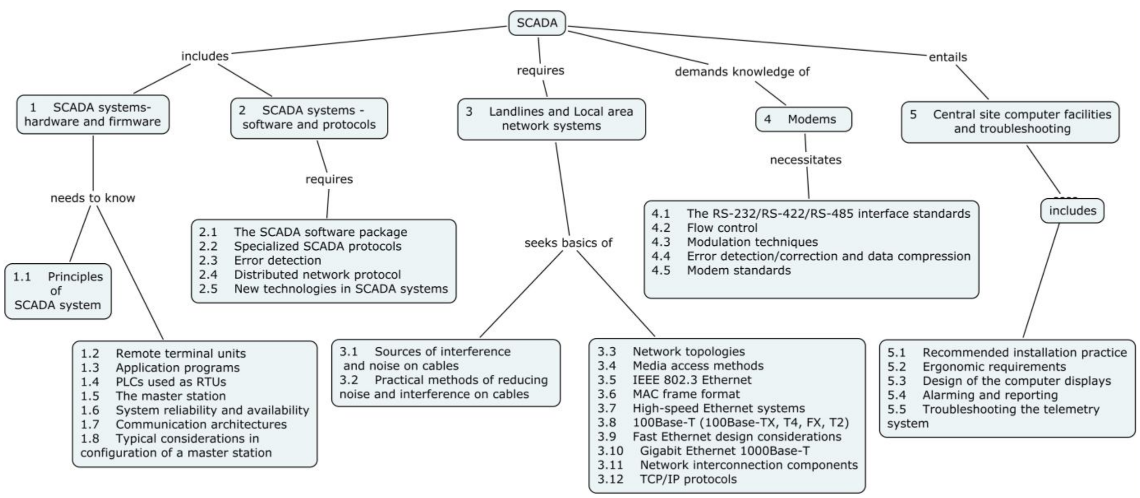
Understand

1. Why mixed digital and analog modules are used?
2. What are the requirements of RTU system?
3. What are the ways of transferring control of the ladder logic program?
4. Discuss the communication architecture of SCADA.
5. How noises and interferences are reduced by shielding and twisting wires?
6. How IP messages are routed?
7. What are the various distributed system protocols?

Apply

1. Develop PLC ladder program for ON/OFF control.
2. How SCADA system can be designed for a power industry?
3. Select a modem for a particular telemetry application. Justify the selection.
4. Design a simple SCADA system for a tank filling device.
5. How to troubleshoot the system if CPU module is not running?
6. Compare the performance of different Ethernet systems.

Concept Map



Syllabus

SCADA systems- hardware and firmware

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

SCADA systems - software and protocols

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

Landlines and Local area network systems

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

Modems

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

Central site computer facilities and troubleshooting

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

Reference Books

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

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

Course contents and Lecture Schedule

Sl.No.	Topic	No. Of Lectures
1	**SCADA systems- hardware and firmware**	
1.1	Principles of SCADA system	1
1.2	Remote terminal units	1
1.3	Application programs	1
1.4	PLCs used as RTUs	2
1.5	The master station	1
1.6	System reliability and availability	1
1.7	Communication architectures	2
1.8	Typical considerations in configuration of a master station	1
2	**SCADA systems - software and protocols**	
2.1	The SCADA software package	1
2.2	Specialized SCADA protocols	2
2.3	Error detection	2
2.4	Distributed network protocol	1
2.5	New technologies in SCADA systems	1
3	**Landlines and Local area network systems**	
3.1	Sources of interference and noise on cables	1
3.2	Practical methods of reducing noise and interference on cables	1

3.3	Network topologies	2
3.4	Media access methods	1
3.5	IEEE 802.3 Ethernet	1
3.6	MAC frame format	1
3.7	High-speed Ethernet systems	1
3.8	100Base-T (100Base-TX, T4, FX, T2)	1
3.9	Fast Ethernet design considerations	1
3.10	Gigabit Ethernet 1000Base-T	1
3.11	Network interconnection components	1
3.12	TCP/IP protocols	1
4	**Modems**	
4.1	The RS-232/RS-422/RS-485 interface standards	1
4.2	Flow control	1
4.3	Modulation techniques	1
4.4	Error detection/correction and data compression	1
4.5	Modem standards	1
5	**Central site computer facilities and troubleshooting**	
5.1	Recommended installation practice	1
5.2	Ergonomic requirements	1
5.3	Design of the computer displays	1
5.4	Alarming and reporting	1
5.5	Troubleshooting the telemetry system	1
	Total	40

Course Designers

S.Sivakumar siva@tce.edu
D.Kavitha dkavitha@tce.edu

CURRICULUM AND DETAILED SYLLABI

FOR

M.E. DEGREE (Power System Engineering) PROGRAM

III & IV SEMESTER SUBJECTS

&

ELECTIVE SUBJECTS

FOR THE STUDENTS ADMITTED FROM THE ACADEMIC YEAR 2011-2012

THIAGARAJAR COLLEGE OF ENGINEERING

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

MADURAI – 625 015, TAMILNADU

Phone: 0452 – 2482240, 41

Fax: 0452 2483427

Web: www.tce.edu

Email:hodeee@tce.edu

Passed in BOS meeting held on 7-4-2012 Approved in 44th Academic Council meeting on 9th June 2012

Department of Electrical and Electronics Engineering

Graduating Students of M.E. program of Power System Engineering will be able to:

1. Specify, architect, design and analyze systems that efficiently and economically generate, transmit, distribute and utilize electrical power to meet the present power market strategy.
2. Specify, design, prototype and test modern Power Systems using various simulation packages and soft computing tools.
3. Work in a team using common tools and environments to achieve project objectives.

Thiagarajar College of Engineering: Madurai-625015

Department of Electrical and Electronics Engineering

Scheduling of Courses

Sem.	Theory Courses						Practical / Project
4th (12)							K41 Project 0:12
3rd (16)	K31 Electricity Deregulation 3:1	KEX Elective -V 3:1	KEX Elective -VI 3:1				K34 Project 0:4
2nd (24)	K21 Power System Security 3:0	K22 Power System Operation and Control 3:1	KEX Elective -I 3:1	KEX Elective -II 3:1	KEX Elective -III 3:1	KEX Elective -IV 3:1	K 27 Power System Laboratory - II 0:1
1st (24)	K11 Applied Mathematics for Electrical Engineers 3:1	K12 Systems Theory 3:1	K13 Power System Modelling and Analysis 3:1	K14 Digital Protection for Power System 3:1	K15 Power System Dynamics and Stability 3:1	K16 Power Converters for Distributed Generation Systems 3:0	K17 Power System Laboratory - I 0:1

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Power System Engineering) PROGRAM

SUBJECTS OF STUDY

(For the candidates admitted from 2011-2012)

FIRST SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
K11	Applied Mathematics for Electrical Engineers	BS	3	1	-	4
K12	Systems Theory	DC	3	1	-	4
K13	Power System Modelling and Analysis	DC	3	1	-	4
K14	Digital Protection for Power System	DC	3	1	-	4
K15	Power System Dynamics and Stability	DC	3	1	-	4
K16	Power Converters for Distributed Generation Systems	DC	3	-	-	3
PRACTICAL						
K17	Power System Laboratory - I	DC	-	-	3	1
	Total		**18**	**5**	**3**	**24**

SECOND SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
K21	Power System Security	DC	3	-	-	3
K22	Power System Operation and Control	DC	3	1	-	4
KEx	Elective-I	DE	3	1	-	4
KEx	Elective-II	DE	3	1	-	4
KEx	Elective-III	DE	3	1	-	4
KEx	Elective-IV	DE	3	1	-	4
PRACTICAL						
K17	Power System Laboratory - II	DC	-	-	3	1
	Total		**18**	**5**	**3**	**24**

THIRD SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week L	T	P	Credits C
THEORY						
K31	Electricity Deregulation	DC	3	1	-	4
KEx	Elective-V	DE	3	1	-	4
KEx	Elective-VI	DE	3	1	-	4
PRACTICAL						
K34	Project	DC	-	-	12	4
Total			**9**	**3**	**12**	**16**

FOURTH SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week L	T	P	Credits C
PRACTICAL						
K41	Project	DC	-	-	36	12
Total			**-**	**-**	**36**	**12**

Total credits: 76

BS : Basic Science
DC : Department Core
DE : Departmental Elective
L : Lecture
T : Tutorial
P : Practical

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2/3 Hours Practical is equivalent to 1 credit

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

SCHEME OF EXAMINATIONS
(For the candidates admitted from 2011-2012)

FIRST SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	K11	Applied Mathematics for Electrical Engineers	3	50	50	100	25	50
2	K12	Systems Theory	3	50	50	100	25	50
3	K13	Power System Modelling and Analysis	3	50	50	100	25	50
4	K14	Digital Protection for Power System	3	50	50	100	25	50
5	K15	Power System Dynamics and Stability	3	50	50	100	25	50
6	K16	Power Converters for Distributed Generation Systems	3	50	50	100	25	50
PRACTICAL								
7	K27	Power System Laboratory - I	3	50	50	100	25	50

SECOND SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	K21	Power System Security	3	50	50	100	25	50
2	K22	Power system Operation and Control	3	50	50	100	25	50
3	KEx	Elective-I	3	50	50	100	25	50
4	KEx	Elective-II	3	50	50	100	25	50
5	KEx	Elective-III	3	50	50	100	25	50
6	KEx	Elective-IV	3	50	50	100	25	50
PRACTICAL								
7	K27	Power System Laboratory - II	3	50	50	100	25	50

THIRD SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	K31	Electricity Deregulation	3	50	50	100	25	50
2	KEx	Elective-V	3	50	50	100	25	50
3	KEx	Elective-VI	3	50	50	100	25	50
PRACTICAL								
4	K34	Project	-	150	150	300	75	150

FOURTH SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
PRACTICAL								
1	K41	Project	-	150	150	300	75	150

* CA evaluation pattern will differ from subject to subject 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.

** Terminal Examination will be conducted for maximum marks of 100/300 and subsequently be reduced to 50/150 marks for the award of terminal examination marks

List of Electives – M.E. Power System Engineering

Departmental Electives			
Sub. Code KEx	Subject Name	Pre/Co requisites	Credits
KEA	Power System Optimization	Power System Analysis	4
KEB /CNEH	Power Plant Instrumentation and Control	Measurement and Instrumentation	4
KEC	Flexible AC Transmission Systems	Power System Analysis Power Electronics	4
KED	Electrical Transients in Power system	Power System Analysis	4
KEE	Analysis of Electrical Machines	Electrical Machines	4
KEF	Renewable Energy Sources	Generation, Power Plant Engineering	4
KEG	Power Quality	Power System Analysis, Power Electronics	4
KEH	Soft Computing Techniques	Fuzzy Logic, Neural Networks	4
KEI / CN EA	Control of Electric Drives	Electrical machines, power Electronics	4
KEJ	Power System Reliability	Power System Analysis	4
KEK	Power System Voltage Stability	Power System Stability	4
KEL	High Voltage Testing Techniques	High voltage Engineering	4
KEM	Distributed Generation Systems	Generation, Transmission & Distribution	4
KEN	Energy Resources Management	Energy Conservation & Audit	4
KEP	Smart Grid	Power system Analysis	4
KEQ	Custom Power Devices	Power System Analysis, Power Electronics	4
KER	Gas Insulated Substations	Power System Protection	4
KES/ CN EP	Real Time Operating Systems	Micro Processors / Micro controllers	4
KEU/ CN EO	SCADA	Micro Processors , Instrumentation, DSP	4
KEV	Electromagnetic Field Computation and Modelling	Electromagnetic fields	4
KEW	Modern Transformer Design	AC machines , Machine design	4

Sub Code	Lectures	Tutorial	Practical	Credit
K31	**3**	**1**	**-**	**4**

K31 Electricity Deregulation 3:1

Preamble

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

Competencies

At the end of the course, students will be able to:

1. Acquire the knowledge of restructuring process, different new entities in the power market and reason for benefit of restructuring
2. Acquire the knowledge of changes in the power system operation and control in the restructured environment
3. Know the various methods in congestion management
4. Acquire the knowledge of transmission open access and pricing issues and ways to calculate the market price
5. Acquire the knowledge of Indian power system, issues, regulatory and policy developments and acts.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/End semester examination
1	Remember	20	20	20
2	Understand	20	20	20
3	Apply	60	60	60
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course level learning objectives

Remember

1. Explain electricity deregulation?
2. What are all the benefits from competitive electricity market?
3. What is an ISO?
4. What is meant by double auction power pool?
5. What is power wheeling?
6. What is meant by firm transaction?

Understand

1. Explain the difference between vertically integrated utility and deregulated market
2. Explain any one transmission pricing method with suitable example.
3. Explain the terms related with ATC?
4. Explain time line of Indian power sector.
5. What are interruptible load options?
6. What are the root causes in congestion management?

Apply

1. What are all the different entities in deregulated electricity market and explain them in brief?
2. Explain the structure of power market in any one developed country with details.
3. Consider four utilities joined together for dispatch. The generation capacity and cost function are given in the table.

Utilities	a_o($/Mwh)	b_o($/Mwh)	c_o $	P_{max} (MW)	P_{min} (MW)	P_D (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

Let each transmission line has a power carrying capacity of 15MW. Examine the optimum interchange schedule obtained through joint dispatch.

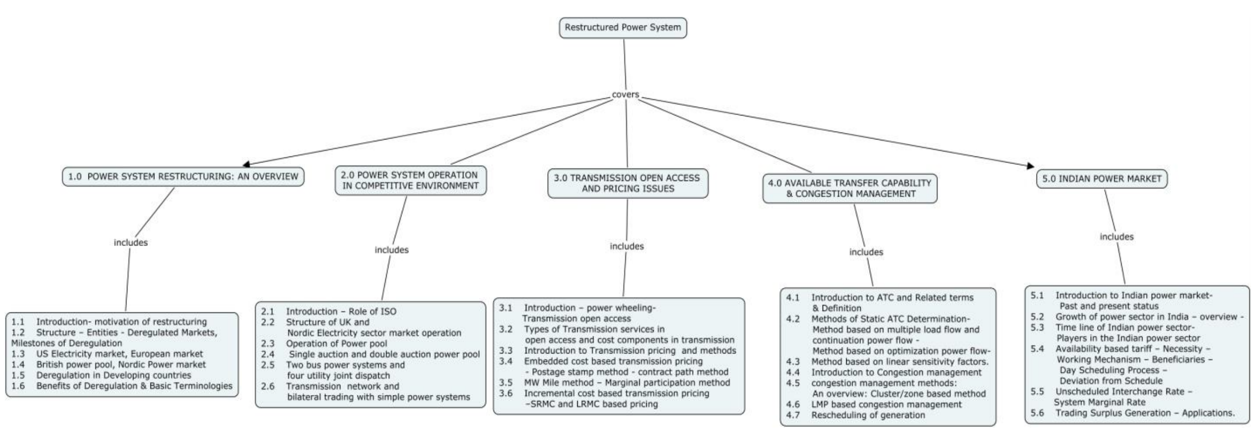
4. The electricity pool of one company has received the bids and offers shown ion the table below for the period is given in table between 9 and 10 a.m on a particular day. Determine the system marginal price.

Table: Company bid and offer

Bids	Company	Quantity (MWh)	Price ($ /Mwh)
Supply	Red	200	12.00
	Red	50	15.00
	Red	50	20.00
	Green	150	16.00
	Green	50	17.00
	Blue	100	13.00
	Blue	50	18.00
Demand	Yellow	50	13.00
	Yellow	100	23.00
	Purple	50	11.00
	Purple	150	22.00
	Orange	50	10.00
	Orange	200	25.00

5. Describe the steps involved in MW-mile method of transmission pricing scheme?
6. Explain any one method of incremental cost based transmission pricing scheme and give the advantage involved in it?

Concept Map



Course contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.0 POWER SYSTEM RESTRUCTURING: AN OVERVIEW		
1.1	Introduction- motivation of restructuring	1
1.2	Structure – Entities - Deregulated Markets, Milestones of Deregulation	2
1.3	US Electricity market, European market	2
1.4	British power pool, Nordic Power market	2
1.5	Deregulation in Developing countries	1
1.6	Benefits of Deregulation & Basic Terminologies	1
2.0 POWER SYSTEM OPERATION IN COMPETITIVE ENVIRONMENT		
2.1	Introduction – Role of ISO	1
2.2	Structure of UK and Nordic Electricity sector market operation	1
2.3	Operation of Power pool	1
2.4	Single auction and double auction power pool	2
2.5	Two bus power systems and four utility joint dispatch	2
2.6	Transmission network and bilateral trading with simple power systems	2
3.0 TRANSMISSION OPEN ACCESS AND PRICING ISSUES		
3.1	Introduction – power wheeling-Transmission open access	1
3.2	Types of Transmission services in open access and cost components in transmission	2
3.3	Introduction to Transmission pricing and methods	1
3.4	Embedded cost based transmission pricing - Postage stamp method - contract path method	1
3.5	MW Mile method – Marginal participation method	2
3.6	Incremental cost based transmission pricing –SRMC and LRMC based pricing	2
4.0 AVAILABLE TRANSFER CAPABILITY & CONGESTION MANAGEMENT		
4.1	Introduction to ATC and Related terms & Definition	1
4.2	Methods of Static ATC Determination-Method based on multiple load flow and continuation power flow - Method based on optimization power flow-	2
4.3	Method based on linear sensitivity factors.	2
4.4	Introduction to Congestion management	1
4.5	congestion management methods: An overview: Cluster/zone	2

	based method	
4.6	LMP based congestion management	1
4.7	Rescheduling of generation	1
5.0 INDIAN POWER MARKET		
5.1	Introduction to Indian power market- Past and present status	2
5.2	Growth of power sector in India – overview -	1
5.3	Time line of Indian power sector- Players in the Indian power sector	1
5.4	Availability based tariff – Necessity – Working Mechanism – Beneficiaries – Day Scheduling Process – Deviation from Schedule	2
5.5	Unscheduled Interchange Rate – System Marginal Rate	1
5.6	Trading Surplus Generation – Applications.	1
	Total	45

Syllabus

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

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

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

AVAILABLE TRANSFER CAPABILITY & CONGESTION MANAGEMENT

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

INDIAN POWER MARKET

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

Reference books

1. Kankar Bhattacharya Maath H.J. Bollen and Jaap E.Daalder, "Operation of restructured power systems", Kluwer academic publishers, USA ,first edition, 2001.
2. Daniel Kirschen and Goran Strbac ,"Fundamentals of power system economics", John Wiley sons, 2004.
3. Loi Lei Lai, "Power system Restructuring and regulation" John Wiley sons, 2001.
4. M.Shahidepour, and Almoush.M, "Restructuring electrical power systems", Marcel Decker Inc., 2001.
5. M.Shahidepour, Hatim Tamin and Zuyi Li, "Market operations in electric power system forecasting, scheduling and risk management", John Wiley sons, 2002.

Course Designer

P.Venkatesh pveee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEJ	**3**	**1**	**0**	**4**

KEJ Power System Reliability 3:1

Preamble

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

Competencies

At the end of the course the students will be able to:

1. demonstrate the knowledge of Power System Reliability engineering.
2. familiar with the different types of reliability indices evaluation methods.
3. understand the process of probability measurement to apply in power system design and planning.
4. demonstrate the process of probability measurement to apply in power system design and planning.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/End-semester examination
1	Remember	10	10	10
2	Understand	20	20	20
3	Apply	70	70	70
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course Level Learning Objectives

Remember

1.Obtain the system reliability when 'n' components connected in series.

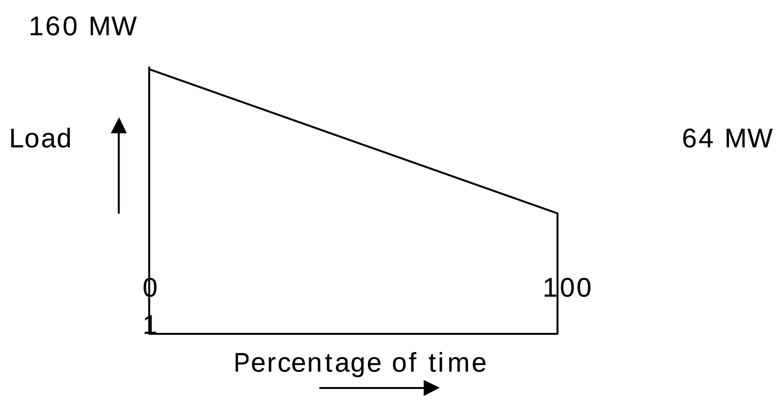
2.If 'i' and 'j' are two identical capacity states and 'k' designated as the merged state, for C_k , write the values P_k, and F_k.
3. What is the difference between capacity outage and loss of load?
4. Give the advantages and disadvantages of average interruption rate method.
5. Write the benefits of interconnection.
6.Draw the state space diagram for a single bridge.

Understand

1. Derive the general reliability function.
2. Describe recursive technique used in reliability studies
3.Evaluate the equivalent model parameters λ and r for two components in series.
4.Discuss the methods used to evaluate de-rated capacity levels
5 Give the advantages and disadvantages of average interruption rate method
6. "Determination of a reliability index based upon service quality involves more effort" why?

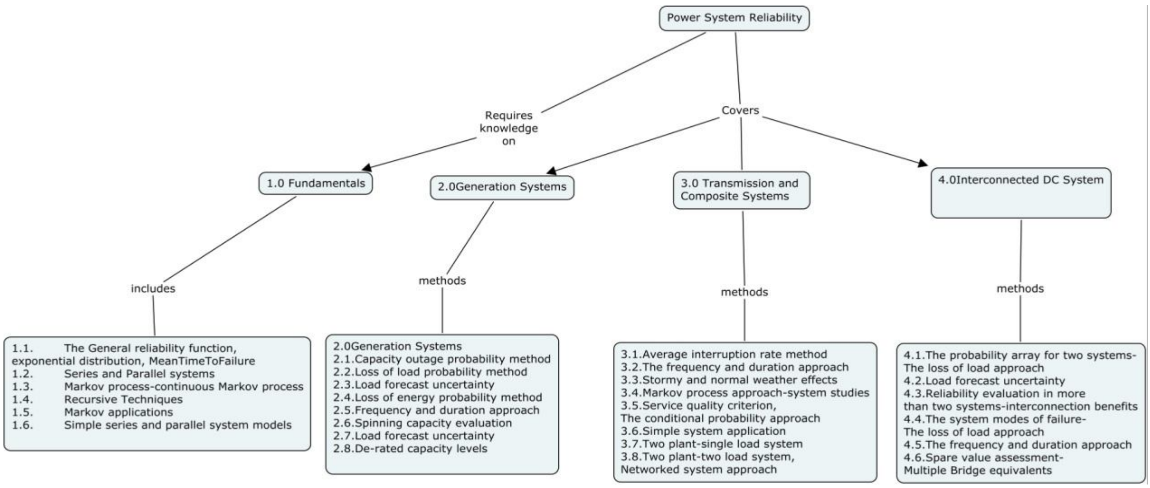
Apply

1. 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



2.With an example explain the procedure to obtain capacity outage probability table
3.Draw schematic diagram of two plant single load system and give the procedure for reliability evaluation of system failure.
4.Interconnection between systems improves the overall level of system reliability. By loss of load approach, prove the above statement using three areas.
5. Illustrate the step by step procedure to obtain multiple bridge equivalents

Concept Map



Course contents and Lecture Schedule

S. No	Topics	No. of periods
1.0	**Fundamentals**	
1.1	The General reliability function, exponential distribution, Mean Time To Failure	3
1.2	Series and Parallel systems	1
1.3	Markov process-continuous Markov process	3
1.4	Recursive Techniques	2
1.5	Markov applications	2
1.6	Simple series and parallel system models	2
2.0	**Generation Systems**	
2.1	Evaluation of Power Generation systems reliability indices – LOLP, LOLE, EENS, Power Interruption Frequency and Duration & System minutes.	2
2.2	Capacity outage probability method	2
2.3	Loss of load probability method	2
2.4	Load forecast uncertainty	1
2.5	Loss of energy probability method	2
2.6	Frequency and duration approach	2
2.7	Spinning capacity evaluation	2
2.8	Load forecast uncertainty	1
2.9	De-rated capacity levels	2
3.0	**Transmission and Composite Systems**	
3.1	Average interruption rate method	1
3.2	The frequency and duration approach	2

3.3	Stormy and normal weather effects	1
3.4	Markov process approach-system studies	1
3.5	Service quality criterion, The conditional probability approach	1
3.6	Simple system application	1
3.7	Two plant-single load system	1
3.8	Two plant-two load system, Networked system approach	1
4.0	**Interconnected System and HVDC System**	
4.1	The probability array for two systems-The loss of load approach	1
4.2	Load forecast uncertainty	1
4.3	Reliability evaluation in more than two systems-interconnection benefits	2
4.4	The system modes of failure-The loss of load approach	1
4.5	The frequency and duration approach	1
4.6	Spare value assessment-Multiple Bridge equivalents	1
	Total	45

Syllabus

Fundamentals

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

Generation Systems

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

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

Transmission and Composite Systems

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

Interconnected System and HVDC System

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

Reference Books

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

Course Designers

P.Renuga preee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEK	**3**	**1**	**0**	**4**

KEK Power system voltage stability 3:1

Preamble

Voltage stability, however, is now a major concern in planning and operating electric power systems. More and more electric utilities are facing voltage stability-imposed limits. Voltage instability and collapse have resulted in several major system failures. Voltage stability will remain a challenge for the foreseeable future and, indeed, is likely to increase in importance. One reason is the need for more intensive use of available transmission facilities. Based on this, the course aims at giving an adequate exposure in physical phenomenon of voltage collapse, Transmission system, Generation, load aspects and Static voltage stability methods.

Competencies

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

1. Understand the time frames for voltage instability.
2. Know the working principles of compensating devices.
3. Understand the limiting devices affecting voltage stability.
4. Identify the saddle node point.
5. Addressing the voltage dependence of loads.
6. Description of frequency and voltage controllers.
7. Understand and apply the Continuation power flow method.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	20	20	20
2	Understand	40	40	40
3	Apply	40	40	40
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course level Learning Objectives

Remember

1. Define voltage stability?
2. Classify PS stability problems based on time scale?
3. What do you mean by critical voltage?
4. What do you mean by compensation?
5. Define SIL of transmission system?

6. Draw the block diagram of AVR?

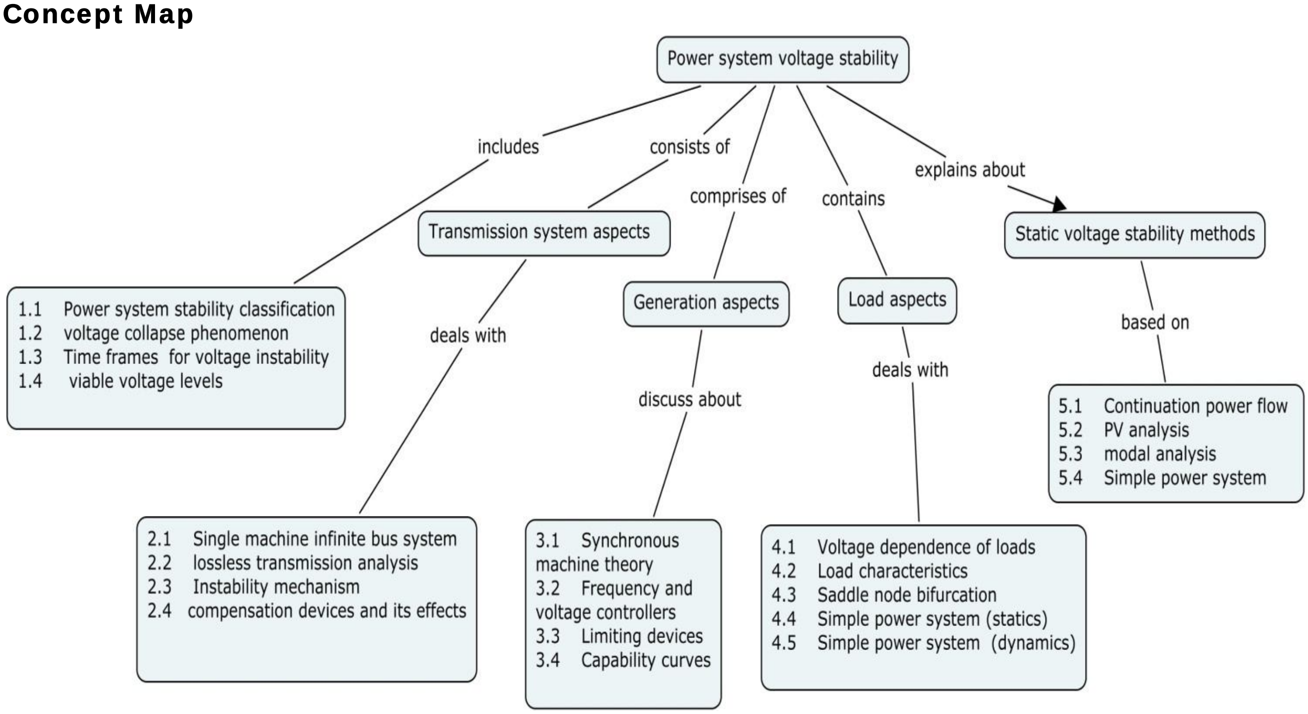
Understand

1. Why does frequency problem arise in Power System?
2. Voltage Instability results from the attempt of loads to draw more power that can be delivered by the transmission and generation systems. Justify this statement.
3. Comment on the location of series capacitors in transmission system?
4. Compare the operation of series and shunt capacitors as compensating devices.
5. Discuss the effects of adjustable transformer ratio on voltage control?
6. What do you understand from Capability characteristics of Synchronous generator.

Apply

1. Discuss in detail about the typical scenario of voltage collapse and its general characterization?
2. Draw network and load PV curves and write a note on it.
3. Discuss in detail about the physical and mathematical description of Synchronous machine?
4. With a neat figure, give an overview of sub-transmission and distribution networks and discuss the impact of its components on voltage stability?
5. Explain in detail about saddle node bifurcation with suitable example.
6. What is continuation power flow? Formulate its mathematical modeling and explain the method?

Concept Map



Course contents and Lecture schedule

Sl.No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Voltage stability - Power system stability classification	02
1.2	Physical phenomenon of voltage collapse	02
1.3	Time frames for voltage instability, mechanisms	01
1.4	Maintaining viable voltage levels	01
1.4.1	Introduction to standards	
2.0	**Transmission system aspects**	
2.1	Single machine infinite bus system	02
2.2	Maximum deliverable power, lossless transmission	02
2.2.1	Power voltage relationships, generator reactive power requirement	02
2.3	Instability mechanism	02
2.4	Effect of compensation	01
2.4.1	Line series compensation, shunt compensation,Static VAR compensator, VQ curves, Effect of adjustable transformer ratio, FACTS devices	03
3.0	**Generation aspects**	
3.1	A review of Synchronous machine theory	02
3.2	Frequency and voltage controllers	02
3.3	Limiting devices affecting voltage stability	01
3.3.1	Over excitation limiters, field current, armature current limiters	02
3.4	P and Q Expressions, Capability curves	01
4.0	**Load aspects**	
4.1	Voltage dependence of loads	02
4.2	Load characteristics, exponential load, polynomial load	02
4.3	Saddle node bifurcation	02
4.4	Simple power system example (statics)	02
4.5	Simple power system example (dynamics)	02
5.0	**Static voltage stability methods**	
5.1	Continuation power flow methods	03
5.2	PV analysis, VQ analysis	02
5.3	Time domain analysis, modal analysis	02
5.4	Simple power system example	02
	Total	45

Syllabus

Introduction

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

Transmission system aspects

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

Generation aspects

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

Load aspects

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

Static voltage stability methods

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

Reference Books

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

Course Designer

K. Selvi kseee@tce.edu

Sub code	Lectures	Tutorial	Practical	Credit
KEL	**3**	**1**	**0**	**4**

KEL High Voltage Testing Techniques 3:1

Preamble

High voltage testing is a special field of electrical power engineering with high importance to find the reliability of the components of power system. It gives information about the quantity of insulation system. Non Destructive Testing on insulation system is used to detect and quantify the partial discharge. Consequently the knowledge of the principles of HV testing and its standards is important for both designers and users of HV equipment. The purpose is to teach students the fundamentals of high voltage laboratory techniques and to provide an understanding of high voltage phenomena and to present the basics of high voltage insulation and design. This subject deals with the various testing techniques for insulation failure of high voltage equipments such as circuit breakers, transformers surge diverters etc. Under all conditions which the equipment is likely to encounter.

Competencies

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

1. Explain the various types of high voltage testing methods.
2. Understand the standards and specifications used during testing.
3. Analyse the life data of the equipment due to aging
4. Explain the insulation testing methodology for Electrical Equipment.
5. Understand the Non destructive Testing on insulation system based on the detection of partial discharge.
6. Explain the salt fog pollution test.

Assessment Pattern

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

Course level Learning Objectives

Remember

1. What are the objectives of high voltage testing?

2. State the importance on online measurement.
3. Define multi stress ageing.
4. Mention the different power frequency tests involved in testing of insulators.
5. What are the different tests carried on cables?
6. State the dynamic properties of dielectrics.

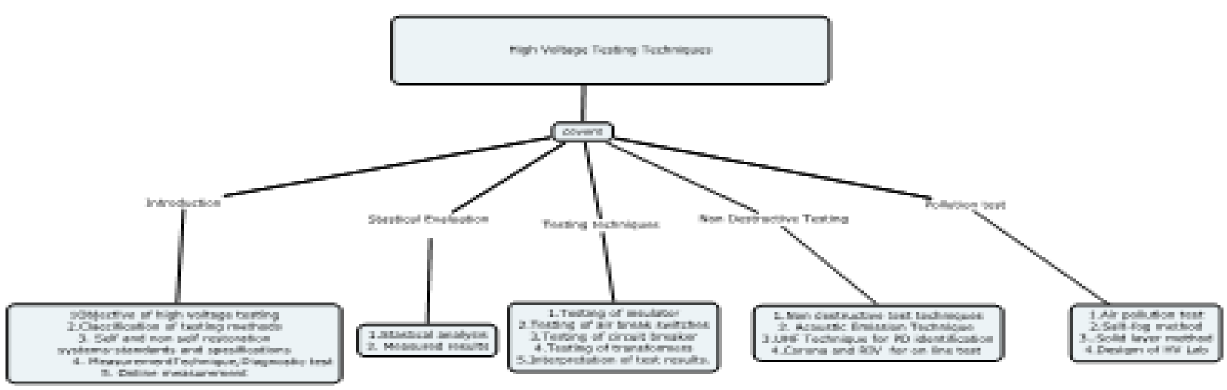
Understand

1. Briefly explain self restoration and non-self restoration system with its standards and specifications.
2. Explain 'Up and Down' method for determining the 50% disruptive discharge voltage.
3. What are the significances of power factor test and partial discharge tests on bushings? How they are conducted in laboratory?
4. Explain the testing methodology for an electrical equipment and interpret the test results obtained from oscillogram
5. Explain the high voltage schering bridge for the dielectric loss and capacitance measurements of insulators.
6. Explain in brief about the corona and RIV measurements a line hardware.

Apply

1. Find the ability of the insulation of transformer to withstand transient voltage due to lightning using impulse test.
2. How to use standards and specifications during on line measurement.
3. Give the statistical analysis for the discharge voltage due to ageing
4. How to adopt acoustic emission technique for partial discharge identification.
5. Design a high voltage laboratory including fencing earthing and shielding with suitable dimensions.
6. Design a grid earthing for a HV substation.

Concept Map



Course Plan and Lecture schedule

S.No	Topic	No.of Lectures
1.0	**INTRODUCTION**	
1.1	Objectives of high voltage testing	1
1.2	Classification of testing methods	1
1.3	Self restoration and non-self restoration systems-standards and specifications	2
1.4	Measurement techniques, Diagnostic testing	3
1.5	Online measurement	2
2.0	**STATISTICAL EVALUTION OF MEASURED RESULTS**	
2.1	Determination of probability values	1
2.2	Distribution function of a measured quantity	2
2.3	Confidence limits of the mean values of disruptive discharges	2
2.4	Up and Down' method for determining the 50% disruptive discharge voltage	2
2.5	Multi stress ageing , life data analysis	2
3.0	**TESTING TECHNIQUES FOR ELECTRICAL EQUIPMENT**	
3.1	Testing of insulators , bushings	1
3.2	Air break switches , isolators , circuit breakers	2
3.3	Power transformers –voltage transformers –Current transformers	2
3.4	Surge diverters, cable	1
3.5	Testing methodology	1
3.6	Recording of oscillograms	1
3.7	Interpretation of test results	1
4.0	**NON- DESTRUCTIVE INSULATION TEST TECHNIQUES**	
4.1	Dynamic properties of dielectrics loss	1
4.2	Capacitance measurement- partial discharge measurements	1
4.3	Basic partial discharge(PD) circuit	1
4.4	PD currents- PQ quantities	2
4.5	Digital PD instruments and measurements	1
4.6	Acoustic emission techniques and UHF Techniques for PD identification	2
4.7	Corona and RIV measurements on line hardware	1
5.0	**POLLUTION TESTS AND DESIGN OF HIGH VOLTAGE LAB**	
5.1	Artificial pollution tests	1
5.2	Salt –fog method	1
5.3	Solid layer method	1
5.4	Dimensions of High voltage laboratory	2
5.5	Equipment- fencing , earthing and shielding	2
5.6	Circuits for high voltage equipments	2
	Total	45

Syllabus

INTRODUCTION

Objectives of high voltage testing, classification of testing methods – self restoration and non-self restoration systems-standards and specifications, measurement techniques, Diagnostic testing – online measurement .

STATISTICAL EVALUTION OF MEASURED RESULTS

Determination of probability values, Distribution function of a measured quantity, confidence limits of the mean values of disruptive discharges – 'Up and Down' method for determining the 50% disruptive discharge voltage, multi stress ageing, life data analysis.

TESTING TECHNIQUES FOR ELECTRICAL EQUIPMENT

Testing of insulators, bushings , air break switches , isolators , circuit breakers , power transformers –voltage transformers –current transformers, surge diverters, cable – testing methodology – recording of oscillograms- interpretation of test results.

NON- DESTRUCTIVE INSULATION TEST TECHNIQUES

Dynamic properties of dielectrics loss and capacitance measurement- partial discharge measurements – basic partial discharge(PD) circuit – PD currents- PQ quantities – Digital PD instruments and measurements , acoustic emission techniques and UHF Techniques for PD identification , corona and RIV measurements on line hardware.

POLLUTION TESTS AND DESIGN OF HIGH VOLTAGE LAB

Artificial pollution tests –salt –fog method, solid layer method, Dimensions of High voltage laboratory, equipment- fencing , earthing and shielding circuits for high voltage equipments.

REFERENCE BOOKS

1. Diter Kind, Kurt Feser, "High Voltage test techniques", SBA Electrical Engineering Series, New Delhi, 1999
2. Naidu M.S and Kamaraju V, "High Voltage engineering", Tata McGraw Hill Publishing Company , New-Delhi, 2004.
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4. Gallagher,T.J., and Pearmain A., "High voltage measurements ,Testing and Design",John Willy & Sons,New York,1983.
5. IS,IEC and IEEE standards for "Dielectric Testing of High Voltage Apparatus" W.Nelson, Applied Life Data Analysis, John Willy & Sons,New York,1982.
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Course Designer

K.Selvi kseee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEM	**3**	**1**	**0**	**4**

KEM Distributed Generation Systems 3:1

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 nonpolluting. It provides adequate emergency power for major metropolitan load centers, remote villages and would safeguard in preventing the complete blackout of the interconnected power systems due to man-made events and environmental calamity and would provide the ability to break up the interconnected power systems into the cluster smaller regions. Based on this, the course aims at giving an adequate exposure in Distributed Generation system, Modelling of Wind and solar systems, Economics of Distributed Resources, Wind Power Systems, and Photovoltaic Systems, State of the art of hybrid systems & major issues of connecting DG into the system.

Competencies

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

1. Understand the need of Distributed Generation Systems.
2. Determine the economic attributes of the technologies that can most efficiently utilize Renewable resources.
3. Identify the suitable potential sources to develop Distributed Generation systems.
4. Do first-order calculations on how the Distributed generation systems will actually perform.
5. Understand the operation of Hybrid Systems.
6. Model the DG systems and analyse various issues of Distributed Generation.

Assessment Pattern

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

Course level Learning Objectives

Remember

1. What is meant by Micro Turbine?
2. What is meant by HHV and LHV?
3. Define cost of conserved energy (CCE)?

4. What is meant by singly fed induction generator?
5. What is meant by singly fed induction generator?
6. What are the main components of Hybrid systems?
7. What is meant by cogeneration or CHP?

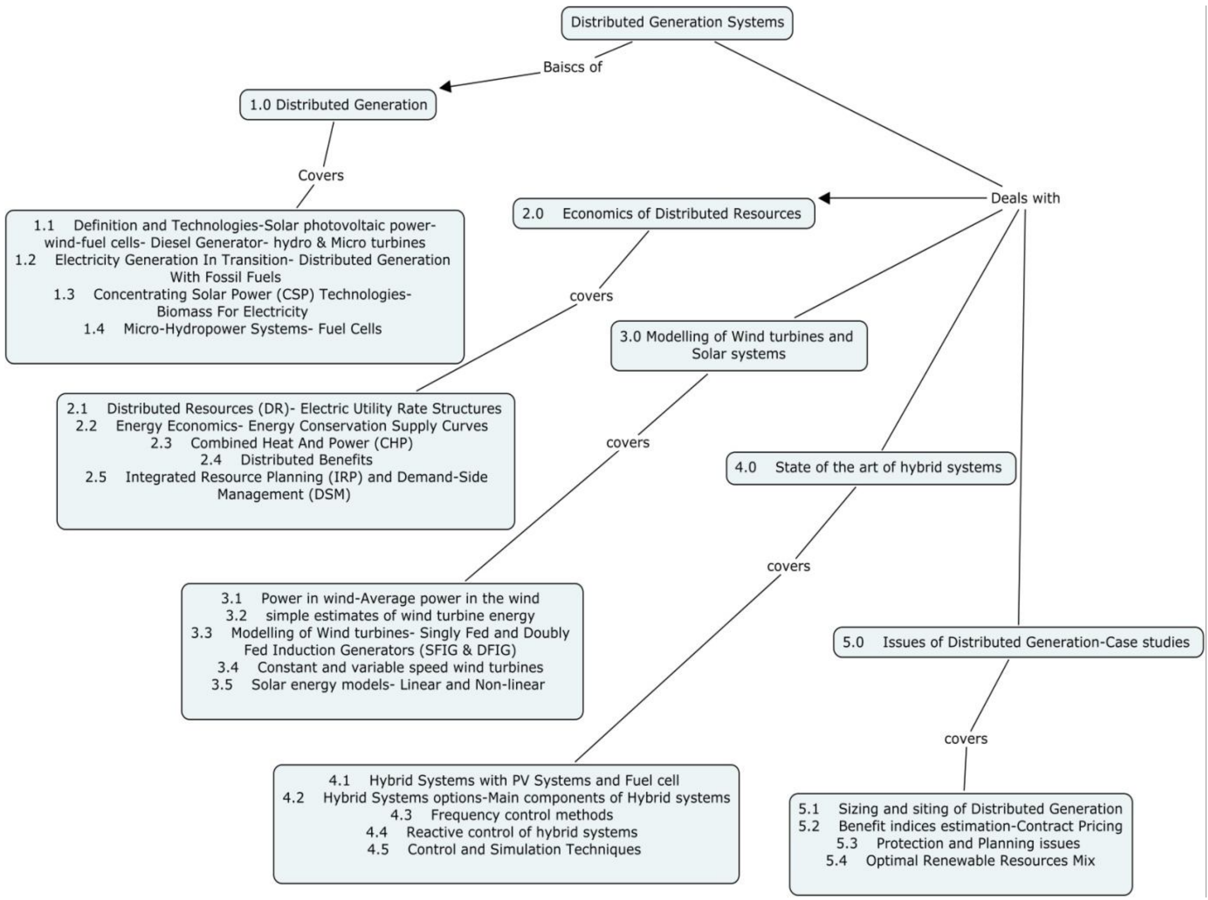
Understand

1. Explain the Bio mass Gasification process?
2. Explain the benefits of Distributed Generation Systems?
3. What are the various configurations in an autonomous hybrid system?
4. Why the reactive power is need to control in a hybrid systems?
5. Distinguish among singly fed and doubly fed induction generators.
6. List out the difference between constant and variable speed wind turbines.

Apply

1. A microturbine has a natural gas input of 13,700 Btu (LHV) per kWh of electricity generated. Find its LHV efficiency and its HHV efficiency?
2. Draw the schematic diagram for a general isolated wind –diesel hybrid power systems.
3. How will you control the reactive power of hybrid system using static synchronous compensator?
4. An ideal PEM fuel cell with an efficiency of 83% needs 30.35 g of hydrogen to generate 1 kWh. For a real cell with half that efficiency, how much hydrogen per day would be needed to power a house that uses 25 kWh per day?
5. Two customers each use 100,000 kWh/mo. One (customer A) has a load factor of 15% and the other (customer B) has a 60% load factor. Using a rate structure with energy charges of $0.06/kWh and demand charges of $10/kW-mo, compare their monthly utility bills.
6. Draw the block diagram of singly fed induction generator and explain its function.

Concept Map



Course contents and Lecture schedule

Sl. No.	Topic	No. of Lectures
1.0	**Distributed Generation**	
1.1	Definition and Technologies-Solar photovoltaic power-wind-fuel cells- Diesel Generator- hydro & Micro turbines	2
1.2	Electricity Generation In Transition- Distributed Generation With Fossil Fuels	1
1.3	Concentrating Solar Power (CSP) Technologies- Biomass For Electricity	2
1.4	Micro-Hydropower Systems- Fuel Cells	2
2.0	**Economics of Distributed Resources**	
2.1	Distributed Resources (DR)- Electric Utility Rate Structures	2
2.2	Energy Economics- Energy Conservation Supply Curves	2
2.3	Combined Heat And Power (CHP)	2
2.4	Distributed Benefits	2
2.5	Integrated Resource Planning (IRP) and Demand-Side Management (DSM)	2
3.0	**Modelling of Wind turbines and Solar systems**	
3.1	Power in wind-Average power in the wind	2

3.2	simple estimates of wind turbine energy	2
3.3	Modelling of Wind turbines- Singly Fed and Doubly Fed Induction Generators (SFIG & DFIG)	3
3.4	Constant and variable speed wind turbines	2
3.5	Solar energy models- Linear and Non-linear	3
4.0	**State of the art of hybrid systems**	
4.1	Hybrid Systems with PV Systems and Fuel cell	2
4.2	Hybrid Systems options-Main components of Hybrid systems	2
4.3	Frequency control methods	1
4.4	Reactive control of hybrid systems	2
4.5	Control and Simulation Techniques	1
5.0	**Issues of Distributed Generation-Case studies**	
5.1	Sizing and siting of Distributed Generation	2
5.2	Benefit indices estimation-Contract Pricing	2
5.3	Protection and Planning issues	2
5.4	Optimal Renewable Resources Mix	2
	Total	45

Syllabus

Distributed Generation

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

Economics of Distributed Resources

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

Modelling of Wind turbines and Solar systems

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

State of the art of hybrid systems

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

Issues of Distributed Generation-Case studies

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

Reference Books

1. Gilbert M.Masters, “Renewable and Efficient Electric Power Systems”, John Wiley & Sons,Inc.,Hoboken,New Jersey,2004.
2. Bansal.R, Bhatti.T.S, “ Small signal Analysis of isolated Hybrid power systems”, Narosa Publishing House Pvt.Ltd.New Delhi,2008.
3. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright,Mike Hughes, “Wind Energy Generation Modelling and Control” John Wiley & Sons, Ltd,2009.
4. Zekai Sen “Solar Energy Fundamentals and Modeling Techniques” Springer-Verlag London Limited, 2008.
5. Tomas Petru and Torbjorn Thiringer, “Modeling of Wind Turbines for Power System Studies” IEEE Transactions on Power Systems, vol. 17, No.4, November 2002.
6. Paul Breeze, “Power Generation Technologies”, Newnes, An imprint of Elsevier, Linacre House, Jordan Hill, Oxford OX2 8DP,2005.
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8. Thomas Ackermann, Goran Andersson, and Lennart Soder: “Distributed generation: a definition”, Electric Power System Research, 51, 2001, pp.195-204.
9. Sachin Jain, Vivek Agarwal, “An Integrated Hybrid Power Supply for Distributed Generation Applications Fed by Nonconventional Energy Sources”, IEEE Transactions on Energy Conversion, vol. 23, no. 2, June 2008.
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11. Pathomthat Chiradeja*,* and R. Ramakumar, “An Approach to Quantify the Technical Benefits of Distributed Generation”, IEEE Transactions on energy conversion, Vol. 19,No. 4, December 2004, pp.764-73.
12. Jesus Maria Lopez-Lezama*, A*ntonio Padilha-Feltrin*,* Javier Contreras and Jose Ignacio Munoz, “Optimal Contract Pricing of Distributed Generation in Distribution Networks” IEEE Transaction on Power Systems, Vol. 26, No. 1, February 2011, pp.128-136.
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14. Y.M.Atwa, E.F.EI-Saadany, M.M.A.Salama and R.Seethapathy, “Optimal Renewable Resources Mix for Distribution System Energy Loss minimization”, IEEE Transactions on Power Systems, Vol.24, No.1, Feb.2010, PP.360-370.

Course Designer

N.Shanmuga Vadivoo nsveee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEN	**4**	**-**	**-**	**4**

KEN Energy Resources Management 4:0

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.

Competencies

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

1. Explain the basic principle of Energy Management and Conservation
2. Select Energy Efficient gadgets for domestic, commercial and industrial applications
3. Estimate the energy performance of Electrical Equipment
4. Get familiar about the energy conservation practice
5. Capable to carryout preliminary energy audit

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	20	20	20
2	Understand	50	50	40
3	Apply	30	30	40
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course Level Learning Objectives

Remember

1. What is an Energy audit?
2. List down the objective of energy management
3. Define contracted demand and billing demand.
4. Name three types of motors in industrial practice.
5. List the factors affecting energy efficiency in air compressors.

6. What are the types of commonly used lamps?

Understand

1. Explain the implications of part load operation of energy equipment with examples.
2. What are the effects of moisture on compressed air?
3. Discuss the various energy conservation opportunities in a refrigeration plant.
4. Explain what do you understand by static head and friction head.
5. What are the effects of over sizing a pump?
6. List down few energy conservation opportunities in pumping system.

Apply

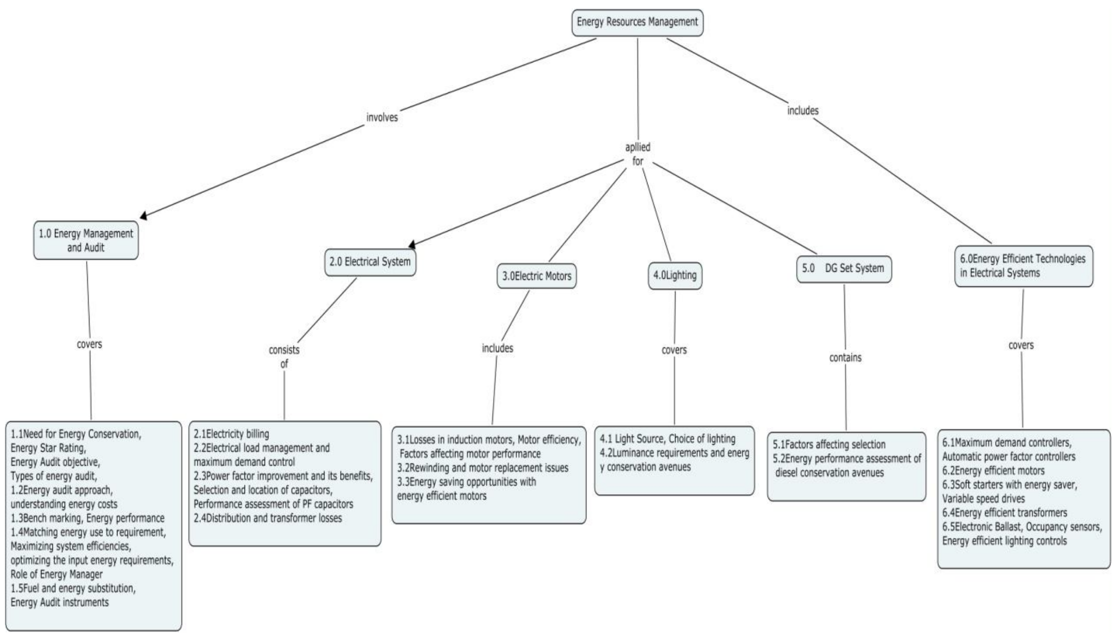
1. A textile mill operates with a load of 1800kVA demand at 0.85 power factor lagging. If the power factor is improved from 0.85 to 0.95 lagging by adding additional capacitors, calculate the reduction in demand. The demand charge is Rs.300 per kVA demand per month. Calculate the demand cost saving per year due to the power factor improvement.
2. In a factory shop floor lighting 60Nos. of 400Watts High Pressure Mercury Vapour (HPMV) lamps are replaced with 250Watts Metal Halide Lamps to reduce energy consumption. The luminous efficacy of HPMV Lamp and Metal Halide lamp are 60 & 100 Lumens per watt. Calculate the Annual energy saving potential and payback period for the above energy saving proposal, if the lamps are used for 12 Hours daily for 330Days in a year. The cost per fitting of Metal halide lamp is Rs.6000/- and cost per kWh energy is Rs.5/-.
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.
4. A 100kW rated Electrical oven consumes 750000kWh per year was replaced with a Diesel fired oven to minimize the energy cost. The efficiency of energy conversion of Electric oven and Diesel fired oven are 98% and 88% respectively. Calculate the saving in energy cost in the above energy saving proposal considered the following data.

Calorific value of Electrical Energy	- 860kilocalories / kWh
Calorific value of Diesel	- 10000kilocalories /Litre
Cost of Electrical Energy	- Rs.5.5 per kWh
Cost of Diesel	- Rs. 42 per Litre

Concept Map



Course contents and Lecture Schedule

No.	Topic	No. of Lectures
1.0	**Energy Management and Audit**	
1.1	Need for Energy Conservation, Energy Star Rating, Energy Audit objective, Types of energy audit,	3
1.2	Energy audit approach, understanding energy costs	2
1.3	Bench marking, Energy performance	2
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	2
2.0	**Electrical System**	
2.1	Electricity billing	2
2.2	Electrical load management and maximum demand control	2
2.3	Power factor improvement and its benefits, Selection and location of capacitors, Performance assessment of PF capacitors	3

2.4	Distribution and transformer losses	2
3.0	**Electric Motors**	
3.1	Losses in induction motors, Motor efficiency, Factors affecting motor performance	2
3.2	Rewinding and motor replacement issues	2
3.3	Energy saving opportunities with energy efficient motors	2
4.0	**Lighting**	
4.1	Light Source, Choice of lighting	2
4.2	Luminance requirements and energy conservation avenues	2
5.0	**DG Set System**	
5.1	Factors affecting selection	2
5.2	Energy performance assessment of diesel conservation avenues	2
6.0	**Energy Efficient Technologies in Electrical Systems**	
6.1	Maximum demand controllers, Automatic power factor controllers	3
6.2	Energy efficient motors	2
6.3	Soft starters with energy saver, Variable speed drives	2
6.4	Energy efficient transformers	2
6.5	Electronic Ballast, Occupancy sensors, Energy efficient lighting controls	2
	Total	45

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.

Electric Motors

Losses in induction motors, Motor efficiency, Factors affecting motor performance, Rewinding and motor replacement issues, Energy saving opportunities with energy efficient motors.

Lighting

Light Source, Choice of lighting, Luminance requirements and energy conservation avenues.

DG Set System

Factors affecting selection, Energy performance assessment of diesel conservation avenues.

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.

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

Course Designers

V.Saravanan vseee@tce.edu

Sub code	Lectures	Tutorial	Practical	Credit
KEP	**3**	**1**	**0**	**4**

KEP Smart Grid 3:1

Preamble

This course covers the fundamentals of smart power grids , operation and control of Micro grids, Voltage variation and load frequency control of Micro grids, Intelligent Power Management of Hybrid Fuel Cell/Energy Storage Distributed Generator.

Competencies

At the end of the course the students will be able to:

1. Understand the fundamentals of smart power grids.
2. Understand the operation and control of Micro grids.
3. Analyze the various aspects of micro grids such as voltage variation and load frequency control.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test3 / End-semester examination
1	Remember	30	30	30
2	Understand	40	40	40
3	Apply	0	0	0
4	Analyze	30	30	30
5	Evaluate	0	0	0
6	Create	0	0	0

Course Level Learning Objectives

Remember

1. Define - Smart grid.
2. List the various mitigation methods of voltage regulation in microgrid.
3. Define – Fuel cell.
4. Write short notes on microgrid black start.
5. Describe the power quality enhanced operation of a microgrid.
6. State the methods of voltage mitigation in microgrids.

Understand

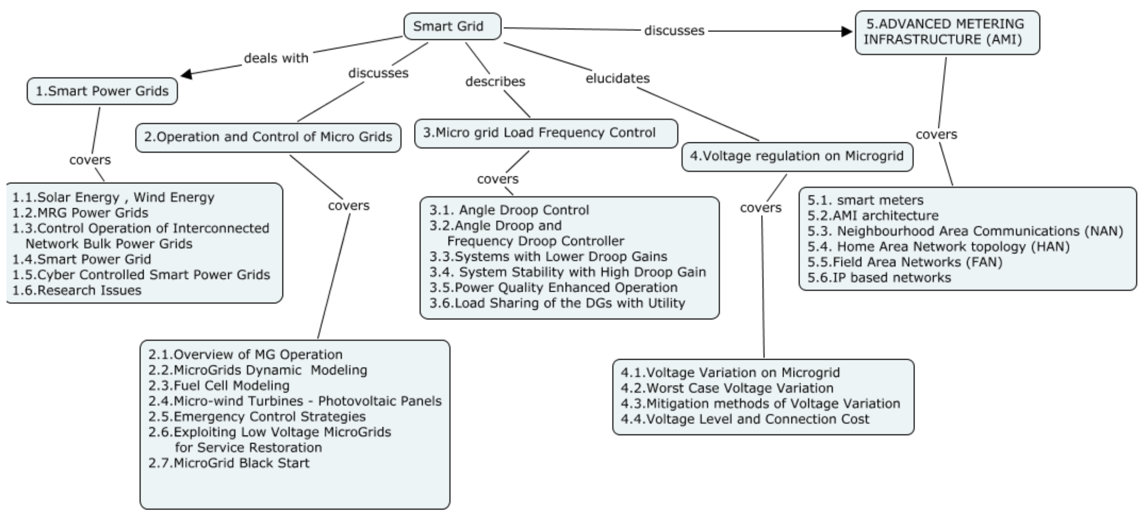
1. Explain the control operation of Interconnected Network Bulk Power Grids.
2. Explain the various emergency control strategies in microgrid.
3. Explain the dynamic modeling of a Hybrid Distributed Generation (HDG) System.
4. Describe the general requirements and sequence of actions for microgrid Black Start
5. What is the significance of droop setting in frequency control?

6. Discuss in detail the Neighborhood Area Communications and Home Area Network topology.

Analyze

1. Distinguish between conventional grid and smart grid.
2. Analyze the system stability of microgrid with high droop gain .
3. Compare the voltage regulation in microgrid and conventional distribution network.
4. Analyze the different network topologies in smart grid.
5. Enumerate the role of advanced metering in smart grid.

Concept Map



Course content and Lecture schedule

No.	Topic	No. of Lectures
1.0	**Smart Power Grids**	
1.1	Introduction to smart grid - Solar Energy , Wind Energy	2
1.2	Micro grid of Renewable and Green (MRG) Power Grids	1
1.3	Control Operation of Interconnected Network Bulk Power Grids	2
1.4	Smart Power Grid	1
1.5	Cyber Controlled Smart Power Grids	2
1.6	Research Issues	1
2.0	**Operation and Control of Micro Grids**	
2.1	Introduction - Overview of MG Operation	1
2.2	MicroGrids Dynamic Modeling	1
2.3	Fuel Cells - Solid Oxide Fuel Cell Modeling	1
2.4	Micro-wind Turbines - Photovoltaic Panels	2
2.5	MicroGrids Emergency Control Strategies - Frequency Control	2

2.6	Exploiting Low Voltage MicroGrids for Service Restoration	1
2.7	MicroGrid Black Start -General Requirements & Sequence of Actions for MicroGrid Black Start.	1
3.0	**Micro grid Load Frequency Control**	
3.1	Introduction - Angle Droop Control for VSC Interfaced DGs	1
3.2	Angle Droop Control and Power Sharing - Angle Droop and Frequency Droop Controller	2
3.3	Systems with Lower Droop Gains	1
3.4	System Stability with High Droop Gain	1
3.5	Power Quality Enhanced Operation of a Microgrid	1
3.6	Load Sharing of the DGs with Utility- Change in Power Supply from Utility - Power Supply from Microgrid to Utility	2
4.0	**Voltage regulation on Microgrid**	
4.1	Introduction - Voltage regulation in Conventional Distribution Network - Voltage Variation on Microgrid	2
4.2	Worst Case Voltage regulation - Mitigation of Voltage Variation Based on Worst Case Scenario.	2
4.3	Mitigation methods of Voltage regulation : Regulating Primary DS Voltage (VS), Reducing Line Resistance, using Reactive Power Control .	2
4.4	Voltage Level and Connection Cost	1
5.0	**ADVANCED METERING INFRASTRUCTURE (AMI)**	
5.1	smart meters – benefits and applications of smart metering	1
5.2	AMI architecture – components overview	1
5.3	smart meter requirements and technology: Neighborhood Area Network (NAN)	1
5.4	Home Area Network topology (HAN) – power line carriers – HAN gateways	2
5.5	Field Area Networks (FAN)- requirements	1
5.6	IP based networks – overview of smart metering	1
	Total	40

Syllabus

Smart Power Grids
Introduction - Solar Energy - Wind energy -Micro grid of Renewable and Green (MRG) Power Grids - Control Operation of Interconnected Network Bulk Power Grids - Smart Power Grid - Cyber Controlled Smart Power Grids - Research Issues.

Operation and Control of MicroGrids

Introduction - Overview of MG Operation - MicroGrids Dynamic Modeling- Fuel Cells - Solid Oxide Fuel Cell Modeling- Micro-wind Turbines - Photovoltaic Panels - MicroGrids Emergency Control Strategies - Frequency Control - Exploiting Low Voltage MicroGrids for Service Restoration - MicroGrid Black Start - General Requirements & Sequence of Actions for MicroGrid Black Start .

Micro grid Load Frequency Control
Introduction - Angle Droop Control for VSC Interfaced DGs - Angle Droop Control and Power Sharing - Angle Droop and Frequency Droop Controller - Systems with Lower Droop Gains - System Stability with High Droop Gain - Power Quality Enhanced Operation of a Microgrid - Load Sharing of the DGs with Utility- Change in Power Supply from Utility - Power Supply from Microgrid to Utility.

Voltage Regulation on Microgrid
Introduction - Voltage regulation in Conventional Distribution Network - Voltage regulation on Microgrid - Worst Case Voltage regulation - Mitigation of Voltage Variation Based on Worst Case Scenario – Mitigation methods of Voltage regulation**:** Regulating Primary DS Voltage (VS), Reducing Line Resistance, using Reactive Power Control - Voltage Level and Connection Cost .

Advanced Metering Infrastructure (AMI)
Smart meters – benefits and applications of smart metering – AMI architecture – components overview – **Smart meter requirements and technology:** Neighborhood Area Network (NAN) – Home Area Network topology (HAN) – power line carriers – HAN gateways – Field Area Networks (FAN) - requirements , IP based networks – overview of smart metering.

Reference Books

1. Ali Keyhani and Muhammad Marwali , "Smart Power Grids 2011" , Springer Publications , 2011.
2. Fereidoon.P.sioshansi, "Smart grid – integrating renewable, distributed and efficient energy", academic press 2011.
3. Janaka Ekanayake , Nick Jenekins , "Smart grid : technology and applications", John wiley and sons Canada ,2011.
4. Christine Hertzog, "Smart Grid Dictionary" , Springer publications, 2009.
5. Tony Flick, Justin morehouse ,"Securing the smart grid : Next generation power grid security", Elsevier ,2010.

Course Designer

R.Medeswaran medes@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEQ	**4**	**0**	**-**	**4**

KEQ Custom Power Devices 4:0

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 course addresses various solutions to mitigate power quality problems. Before going deeper details of the course the students should understand the basic definition and terms used in power system in order to define and characterize its features. Power systems are ideally designed to operate three-phase balanced load at fundamental frequency. When there is deviation from these ideal conditions, the efficiency of power system comes down. This is due to increased losses, heating of electric machines, transformers and appliances. The consequences of power quality problems will be discussed and an effort will be made to understand their mitigation using custom power devices such as distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR). For that the basic step involves to know the reference parameters say voltage and current in order to make system well behaved. A good number of lectures are devoted for this. Once reference quantities are known using discussed algorithms, these have to be synthesized using suitable topologies of the voltage source inverters. These converter topologies and their applications will be discussed. The switching control strategies then will be presented in order to control the inverter to synthesize desired voltage and current quantities. Here modeling and analysis aspects of three phase compensated system will be presented. Considering all the above issues, the course Custom Power Devices is designed.

Competencies

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

1. Evaluate need for custom power devices.
2. Understand & analyze performance characteristics of different custom power devices
3. Design custom power devices like DVR, D-STATCOM, UPQC.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/End-semester examination
1	Remember	20	20	15
2	Understand	20	20	15
3	Apply	0	0	0
4	Analyze	40	40	60
5	Evaluate	20	20	10
6	Create	0	0	0

Course level learning Objectives

Remember

1. Distinguish between FACTS & custom power devices.

2. List the various power quality issues.
3. List the sources of nonlinear load which generates PQ problems.
4. Define, voltage sag.
5. Brief the concept of solid state current limiter.
6. Define, harmonic distortion.

Understand

1. What is the role of PQ standards? List some of the PQ standards.
2. What are the causes for voltage swell?
3. How fluorescent light creates power quality problems?
4. What are the causes for voltage sag?
5. How voltage unbalance can be eliminated?
6. What is the role of custom power devices?

Analyze

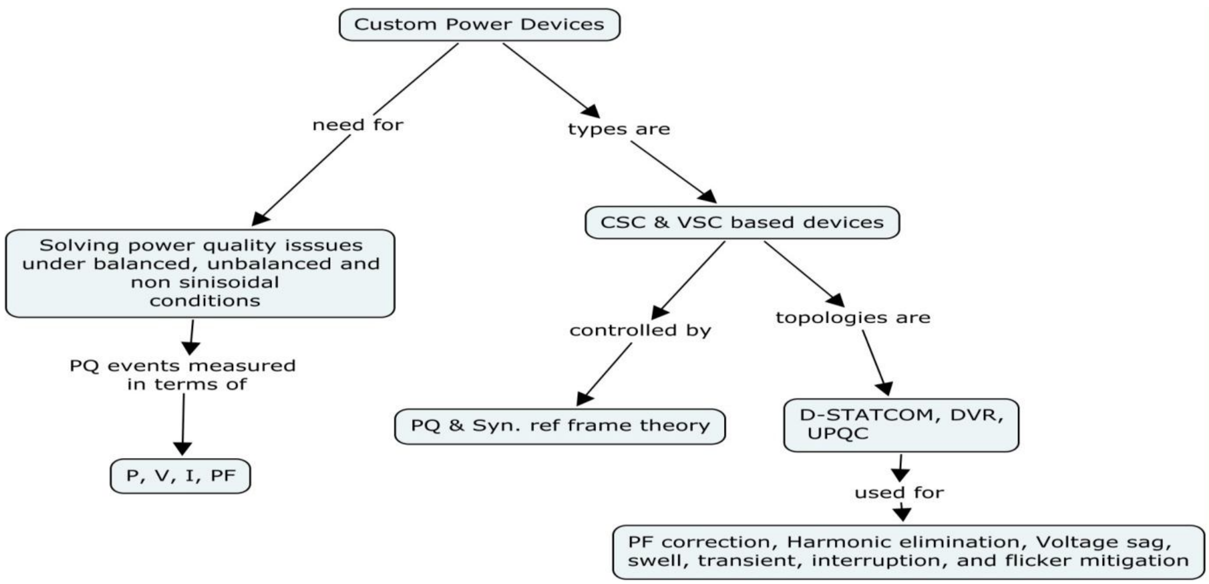
1. Explain the following electrical power quality issues in detail with examples.
    a) Voltage variations (short & long)
    b) Waveform distortions
2. Discuss the following electrical power quality issues in detail with examples.
    a) Voltage imbalance
    b) Flickers
    c) Transients
3. Explain working principle and construction of D-STATCOM and also discuss how it is used for load compensation and voltage regulation in power system.
4. Discuss the ride through capability of adjustable speed drives using custom power devices.
5. Describe the operation of UPQC Also discuss how UPQC is used to mitigate power quality problems.
6. Describe the operation of DVR. Also discuss how DVR is used to mitigate power quality problems.

Evaluate

1. Evaluate the harmonic distortion produced by different PWM converter based adjustable speed drives.
2. Evaluate various methods used for analyzing voltage sag in power systems.
3. Explain how the following electrical power quality issues are evaluated using various indexes.
    a) Power outage
    b) Voltage sag

4. Explain working principle and construction of D-SATCOM and also discuss how it is used for load compensation and voltage regulation in power system.
5. Evaluate different mathematical transformation techniques available for analyzing power quality events.
6. Evaluate different converter topologies used in DVR.

Concept Map



Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Introduction to Power Quality**	
1.1	Definitions of various powers, power factor	2
1.2	Other figures of merit under balanced, non-sinusoidal conditions	3
1.3	Other figures of merit under unbalanced conditions	3
2.	**Custom power devices (CPD)**	
2.1	Introduction to custom power devices	2
2.2	Their applications in power system	2
2.3	Voltage source converters	2
2.4	current source converters	3
2.5	IPQC	3
3.	**Control algorithms for CPD**	
3.1	Instantaneous PQ theory	3
3.2	Synchronous reference frame theory	3
4.	**Topologies**	
4.1	Detailed modeling, analysis and design aspects of custom power devices - DSTATCOM	4
4.2	DVR	3
4.3	UPQC	3
5.	**Compensators to mitigate PQ problems**	

No.	Topic	No. of Lectures
5.1	PF correction, Harmonic elimination	3
5.2	Voltage sag, swell, transient	1
5.3	Flicker, interruption mitigation	1
5.4	Case studies	4
	Total	45

Syllabus

Introduction to power quality
Definitions of various powers, power factor and other figures of merit under balanced, unbalanced and non-sinusoidal conditions.

Custom power devices (CPD)
Introduction to custom power devices and their applications in power system- Voltage source converters and current source converters in CPDs – Improved power quality converters

Control algorithms for CPD
Instantaneous PQ theory & Synchronous reference frame theory.

Topologies
Detailed modeling, analysis and design aspects of different custom power devices - DSTATCOM, DV and UPQC.

Compensators to mitigate PQ problems
PF correction, Harmonic elimination, Voltage sag, swell, transient, interruption, and flicker mitigation and Case studies.

Reference Books

1. Arindam Ghosh and Gerald Ledwich: Power Quality Enhancement Using Custom Power Devices, Kluwer Academic Publishers, 2002
2. G.T.Heydt: Electric Power Quality, 2nd edition, Stars in a Circle Publications, 1994
3. Sankaran.C: Power Quality, CRC Press, Washington D.C., 2002
4. Roger C. Dugan, Mark F. McGranaghan and H.Wayne Beaty: Electrical Power System Quality, McGraw-Hill, New York, 2nd Edition, 2002
5. Instantaneous power theory and application to power conditioning, H. Akagi et al., IEEE Press, 2007.

Course Designer

V. Suresh Kumar vskeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KER	**3**	**1**	**-**	**4**

KER Gas Insulated Substations 3:1

Preamble

The increase in demand for electricity and the growing energy density in metropolitan cities have made it necessary to extend the existing high voltage network right up to the consumer. Stepping down the voltage from transmission to distribution level at the substation located near the actual consumers not only yield economic advantages, but also ensures reliable power supply. The development of completely enclosed substations or otherwise known as Gas Insulated Substations (GIS) and Gas Insulated Transmission Lines (GITL) towards the end of the last century has come as a boon to the power engineers. GIS of up to 800kV have been developed and are being widely used.

With ever increasing use of GIS, a student of Electrical Engineering is expected to possess knowledge of GIS. This subject is designed to give a comprehensive introduction to GIS.

Competencies

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

1. Explain the properties of Gas insulations.
2. Understand the concept of components and its arrangements in GIS
3. Design a GIS Station
4. Explain the various tests to be carried on GIS
5. Understand the quality assurance during the testing of GIS components
6. Explain Various Problems in GIS and Diagnostics.

Assessment Pattern

S.No.	Bloom's Category	Test 1	Test 2	Test 3 / End-semester examination
1	Remember	40	30	20
2	Understand	60	50	50
3	Apply	0	20	30
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course Level Learning Objectives

Remember

1. What are the advantages of GIS?
2. Mention the important characteristics of SF_6 recycling unit?
3. List the major components of GIS.
4. What the are the major requirements for planning and Installation of GIS?

5. What are the various design features of GIS
6. What are the various type test involved in the testing of GIS?

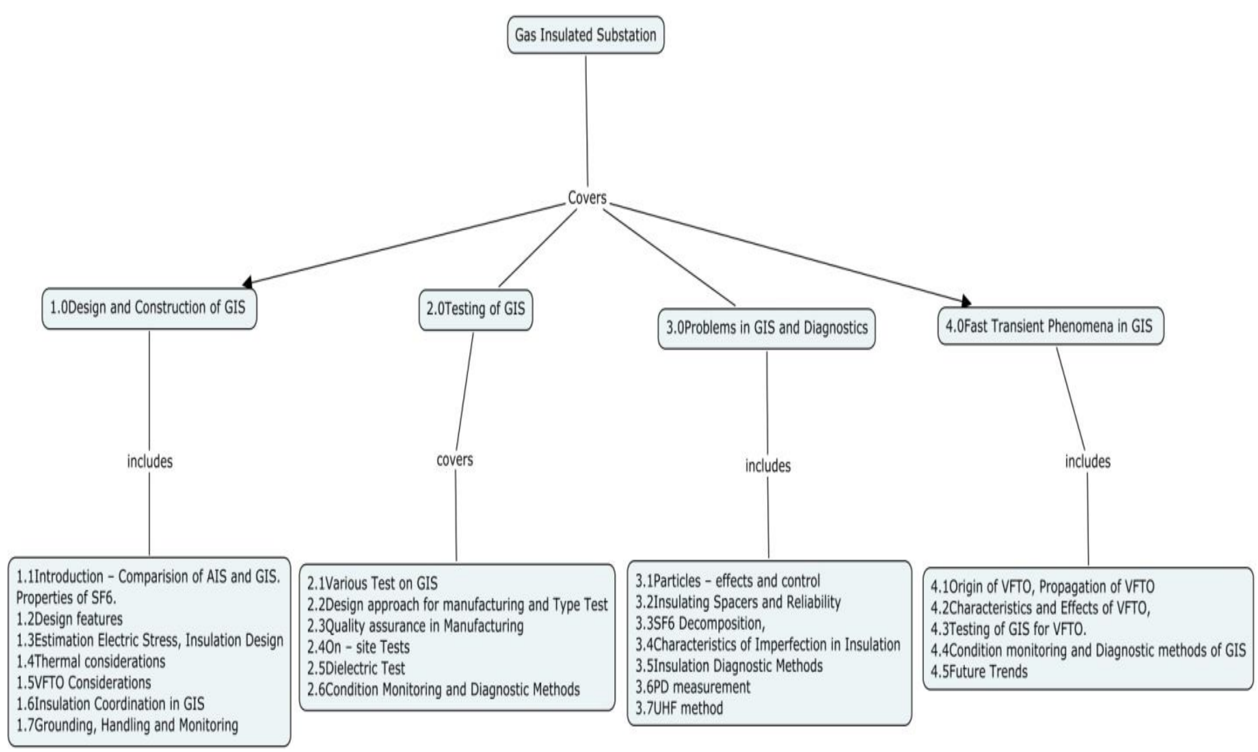
Understand

1. Justify SF_6 as a Green Gas.
2. Compare AIS and GIS.
3. Explain in detail the Basic requirement for the choice of Equipment.
4. Explain in detail the various components of GIS.
5. Briefly explain the various test carried out in GIS.
6. In detail explain the various causes for SF_6 decomposition.

Apply

1. Find the Insulation level between Breaker and LA using Insulation Co – ordination in a 400 KV GIS.
2. Give a schematic design of Gas Handling and Monitoring Systems of a GIS.
3. How do adopt Standards during the testing of GIS?
4. What kind of insulation Diagnostic Methods preferred for finding cavity in an Insulator ?
5. Apply VHF and UHF methods to detect the partial discharge signals in a GIS.
6. How do analyze the discharge in GIS by condition monitoring?

Concept Map



Course contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.0	**Design and Construction of GIS**	
1.1	Introduction – Comparison of AIS and GIS. Properties of SF_6.	1
1.2	Design features	1
1.3	Estimation Electric Stress, Insulation Design	2
1.4	Thermal considerations	1
1.5	VFTO Considerations	1
1.6	Insulation Coordination in GIS	1
1.7	Grounding, Handling and Monitoring	2
2.0	**Testing of GIS**	
2.1	Various Test on GIS	1
2.2	Design approach for manufacturing and Type Test	2
2.3	Quality assurance in Manufacturing	2
2.4	On – site Tests	2
2.5	Dielectric Test	2
2.6	Condition Monitoring and Diagnostic Methods	2
3.0	**Problems in GIS and Diagnostics**	
3.1	Particles – effects and control	2
3.2	Insulating Spacers and Reliability	2
3.3	SF_6 Decomposition,	2
3.4	Characteristics of Imperfection in Insulation	1
3.5	Insulation Diagnostic Methods	2
3.6	PD measurement	1
3.7	UHF method	2
4.0	**Fast Transient Phenomena in GIS**	
4.1	Origin of VFTO, Propagation of VFTO	2
4.2	Characteristics and Effects of VFTO	2
4.3	Testing of GIS for VFTO.	2
4.4	Condition monitoring and Diagnostic methods of GIS	1
4.5	Future Trends	1
	Total	40

Syllabus

Design and Construction of GIS

Introduction – Comparison of AIS and GIS. Properties of SF_6.

Design features, Estimation Electric Stress, Insulation Design, Thermal considerations, VFTO Considerations, Insulation Coordination in GIS, Grounding, Handling and Monitoring.

Testing of GIS

Various Test on GIS, Design approach for manufacturing and Type Test, Quality assurance in Manufacturing, On – site Tests, Dielectric Tests, Condition Monitoring and Diagnostic Methods.

GIS Problems and Diagnostics

Particles effects and control, Insulating Spacers and Reliability, SF_6 Decomposition, Characteristics of Imperfection in Insulation, Insulation Diagnostic Methods, PD measurement, UHF method, Future Trends.

Fast Transient Phenomena in GIS

Origin of VFTO, Propagation of VFTO, Characteristics and Effects of VFTO, Testing of GIS for VFTO, condition monitoring and Diagnostic methods of GIS, future trends.

Reference Books

1. M.S. Naidu, "Gas Insulated Substations", I. K. International, New Delhi, 2008.
2. L.L. Alston, "High Voltage Insulation Technology", Oxford university Press, London, 1996.

Course Designers

N. Kamaraj nkeee@tce.edu
R. Rajan Prakash r_rajanprakash@tce.edu

Sub code	Lectures	Tutorial	Practical	Credit
KES / CNEP	**3**	**1**	**0**	**4**

KES / CNEP Real Time Operating System 3:1

(Common to M.Tech. Control and Instrumentation)

Preamble

Real-time systems are complex embedded systems that operate with real time constraints. Examples of real-time systems include automotive electronics, air traffic control, nuclear power plants, telecommunications, and robotics. Real time systems use a real time operating system (RTOS) that determines which applications should run in what order and how much time should be allowed for each application before giving processor access to another process. The functions of the RTOS are to manage the sharing of internal memory among multiple tasks, to handle input and output to and from attached hardware devices such as serial ports, buses, and I/O device controllers and to send messages about the status of operation and any errors that may have occurred.

Competencies

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

1. Make use of different program models for embedded system programming
2. Explain interprocess communication and synchronization in embedded system
3. Understand the OS services, file, I/O and memory management, interrupt handling and scheduling mechanism in RTOS
4. Explain the RTOS Programming concepts
5. Design an Embedded System by programming using RTOS µCOS-II

Assessment pattern

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

Course level Learning Objectives

Remember

1. What is the role of RAM in an embedded system?
2. What are the different steps in the design process an embedded system?
3. Define critical section of a task?

4. What is the advantage and disadvantage of disabling interrupts during running of a critical section of a process?
5. Write the operation done when the function OSSemPend ( ) is executed.
6. How is an anonymous object denoted in UML?

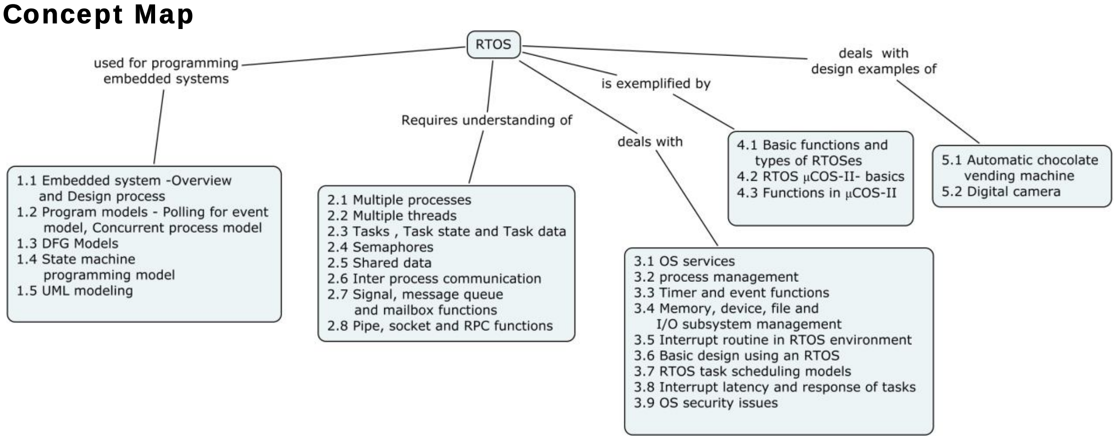
Understand

1. Explain the different hardware components in embedded system.
2. Explain the DFG model of programming with an example.
3. Why RTOS is required in an embedded system?
4. Why polled waiting loop method is not preferred in many applications?
5. How semaphore is used to execute critical section of a task in a multitasking system?
6. Describe any three task related functions in µCOS-II.

Apply

1. Show how the timer functions can be applied
   a) to reduce the light level in a mobile phone with full brightness
   b) to switch off the LCD display in a mobile phone after 15 seconds from the time it was switched on.
2. Draw an FSM model of an automatic chocolate-vending machine program. The machine permits only one type of coin, Rs. 1, one chocolate at a time and one chocolate cost is Rs. 8.
3. Illustrate the class diagram and state diagram for the automatic chocolate vending machine.
4. How will you create and display SMS message in T9 keypad of a mobile phone? Use the states, FSM model and state tables for all keys 0, 1 to 9 with T9 keypad. Use suitable templates.
5. Write exemplary codes for using the µCOS-II functions for time delay and semaphore.
6. How will you create, remove, open, close a device by applying RTOS functions? Take an example of a pipe delivering an I/O stream from a network device.

Concept Map



Course contents and Lecture Schedule

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

Syllabus

Introduction and Programming of embedded systems

Embedded system – Overview and Design process- Program modeling concepts-
Polling for events model – Concurrent process model- DFG models – State machine programming model - UML modeling

Interprocess communication and synchronization
Multiple processes - Multiple threads – Tasks, Task state and Task data – Semaphores – Shared data – Interprocess communication – Signal, message queue and mailbox functions – Pipe, socket and RPC functions.

Real time operating systems

OS services- process management – Timer and event functions – Memory, device, file and I/O subsystem management, Interrupt routine in RTOS environment – Basic design using an RTOS – RTOS task scheduling models-Interrupt latency and response of tasks – OS security issues.

RTOS programming

Basic functions and types of RTOSes – RTOS μCOS-II- basics - Functions in μCOS-II

Design examples with μCOS-II

Automatic chocolate vending machine - Digital Camera

Reference Books

1. Raj Kamal, "Embedded Systems- Architecture, Programming and Design" Second edition , Tata McGraw Hill, 2008.
2. David E.Simon, "An Embedded Software Primer", Pearson Education, 2006
3. C.M. Krishna, Kang, G.Shin, "Real Time Systems", McGraw Hill, 1997.
4. Phillip A. Laplante, Real Time Systems Design and Analysis, An Engineer's Handbook, Second Edition, PHI India, 1997.

Course designers

M.Saravanan mseee@tce.edu

L.Jessi Sahaya Shanthi ljseee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEV	**3**	**1**	**-**	**4**

KEV Electromagnetic Field Computation and Modelling 3:1

Preamble

Electromagnetic field computation is a discipline that deals with electric field resulting from electric charges, magnetic field, electromagnetic field, electrostatic field, and electrodynamics. The main constituents of electromagnetic field computation and modelling involve basic field theory, solution of field equations I and II, field computation for basic configurations and design applications. It provides foundation for acquiring knowledge in the field theory, which is most important in the design of both rotating and static electrical machines.

Competencies

At the end of the course, the student will be able to:

a) solve field equations by analytical method i.e., Direct Integration method, Variable separable method and by numerical method Finite Difference Method.

b) apply FEM for solving any electromagnetic field problems.

c) design any electrical apparatus using ANSOFT software.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/End semester examination
1	Remember	40	40	30
2	Understand	40	40	30
3	Apply	20	20	40
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Course level learning objectives

Remember

1. Give the following equations

   a. Electrostatics Poisson's and Laplace equation

   b. Magnetostatics Poisson's and Laplace equation

c. Helmoltz equation – eddy current solver
d. Electromagnetic wave equations
e. Maxwell's equations from the fundamental laws

2. Define scalar and vector potential and give the relation between them.
3. Discuss the AT required to establish a constant B in the core.
   a) with no air gap, b) with air gap (no fringing) c) with air gap (with fringing)
4. What is the principle of numerical methods?
5. What is the basic concept of finite element method?
6. Define skin depth

Understand

1. Explain the procedure for defining a problem/ problem formulation for solving EM fields in general with suitable practical examples.
2. Explain the concept of method of images with examples and applicability.
3. Explain finite difference method.
4. Explain electro thermal formulation with an algorithm.
5. Starting from the governing equation with the given boundary conditions, derive the FEM equations for the following problems.

Governing equation	**1D**		**2D**		Typical examples (comparison with analytical solutions)
Laplace's	Planar	Axial symmetry	planar	Axial symmetry	
Poisson's	Planar	Axial symmetry	planar	Axial symmetry	
Time harmonic diffusion	Planar	Axial symmetry	planar	Axial symmetry	

a) Equation with boundary condition method
b) Weighted residual method
c) Weak formulation
d) Galerkins' approximation
e) Shape function
f) Formulation of element matrices and vectors
g) Formulation of global matrix and vector

h) Primary variables solution

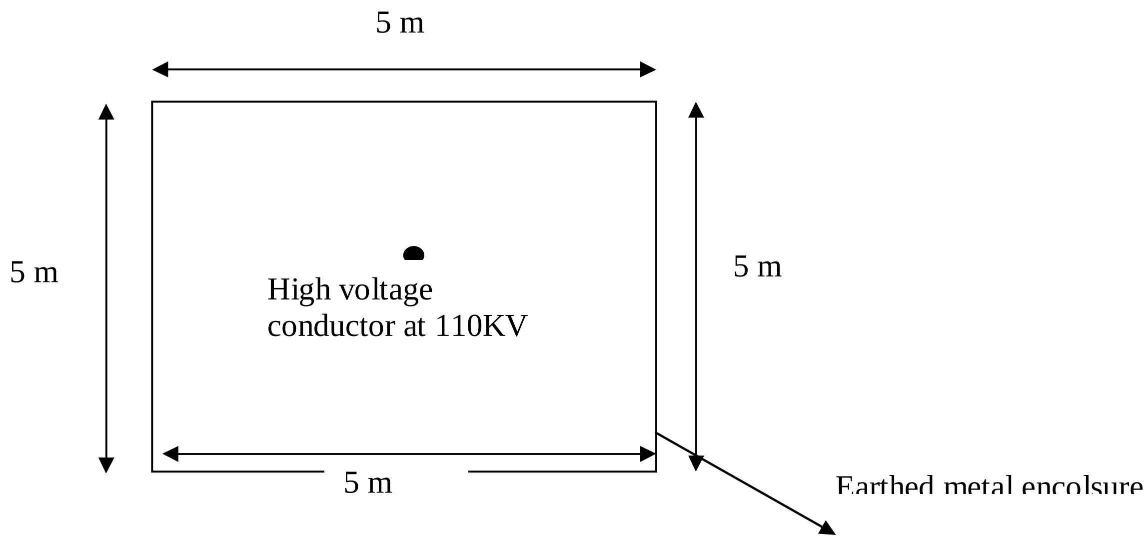
i) Secondary variables

j) Examples

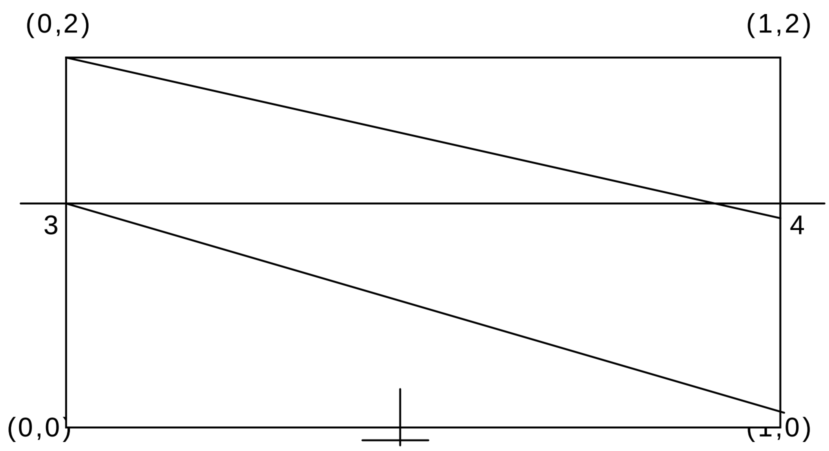
6. Comparison of FEM and FDM.

Apply

1. Compute the voltage distribution in the bus duct shown to check the dimension using finite difference method. Also derive the FDM equations.



2. Using Finite element method solve for unknown potential at 3 and 4 shown in figure. If Y=o, V=0 and y=2, V=100.



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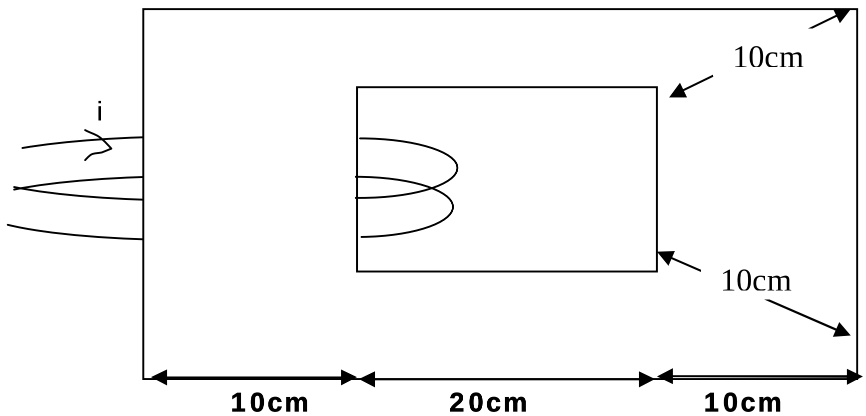
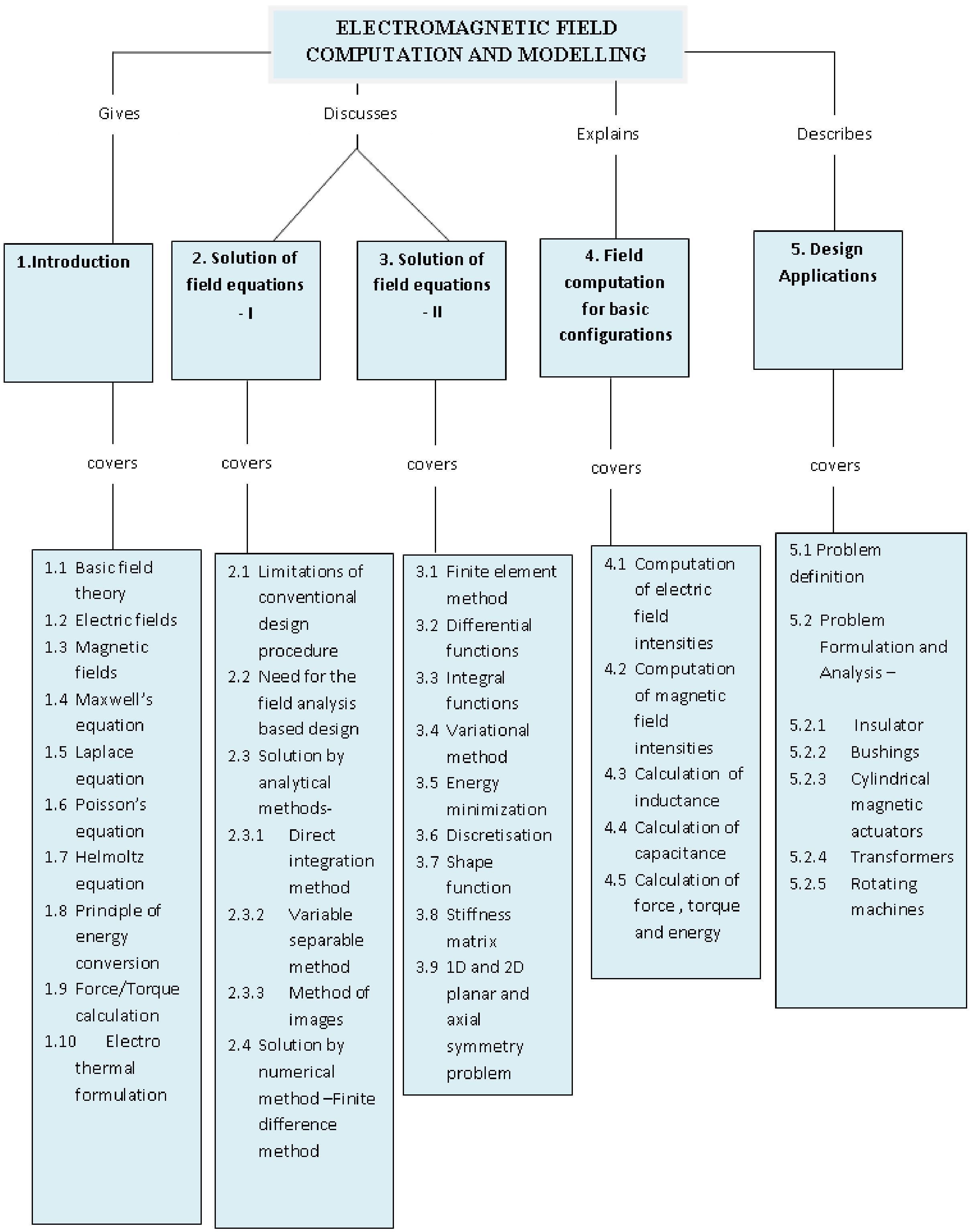
3. The magnetic circuit shown has a core of relative permeability = 2000, coil has 400 turns and carries current of 1.5A. Depth of the core is 5cm. Find the flux and flux density in the core. Also find the inductance of the coil.



Concept Map


ELECTROMAGNETIC FIELD COMPUTATION AND MODELLING
Gives
Discusses
Explains
Describes
1.Introduction
2. Solution of field equations - I
3. Solution of field equations - II
4. Field computation for basic configurations
5. Design Applications
covers
covers
covers
covers
covers
1.1 Basic field theory
1.2 Electric fields
1.3 Magnetic fields
1.4 Maxwell's equation
1.5 Laplace equation
1.6 Poisson's equation
1.7 Helmoltz equation
1.8 Principle of energy conversion
1.9 Force/Torque calculation
1.10 Electro thermal formulation
2.1 Limitations of conventional design procedure
2.2 Need for the field analysis based design
2.3 Solution by analytical methods-
2.3.1 Direct integration method
2.3.2 Variable separable method
2.3.3 Method of images
2.4 Solution by numerical method –Finite difference method
3.1 Finite element method
3.2 Differential functions
3.3 Integral functions
3.4 Variational method
3.5 Energy minimization
3.6 Discretisation
3.7 Shape function
3.8 Stiffness matrix
3.9 1D and 2D planar and axial symmetry problem
4.1 Computation of electric field intensities
4.2 Computation of magnetic field intensities
4.3 Calculation of inductance
4.4 Calculation of capacitance
4.5 Calculation of force , torque and energy
5.1 Problem definition
5.2 Problem Formulation and Analysis –
5.2.1 Insulator
5.2.2 Bushings
5.2.3 Cylindrical magnetic actuators
5.2.4 Transformers
5.2.5 Rotating machines

Course contents and Lecture schedule

No	Topic	No. of Lectures
1.0	**INTRODUCTION**	
1.1	Basic field theory, Electric and magnetic fields	1
1.2	Maxwell's equation	1
1.3	Laplace equation	1
1.4	Poisson's equation	1
1.5	Helmoltz equation	1
1.6	Principle of energy conversion	1
1.7	Force/Torque calculation	1
1.8	Electro thermal formulation	1
2.0	**SOLUTION OF FIELD EQUATIONS I**	
2.1	Limitations of conventional design procedure, Need for the field analysis based design	2
2.2	Variable separable method	2
2.3	Method of images	2
2.4	Solution by numerical method –Finite difference method	2
3.0	**SOLUTION OF FIELD EQUATIONS II**	
3.1	Finite element method and Differential functions	2
3.2	Integral functions and Variational method	2
3.3	Energy minimization and Discretisation	1
3.4	Shape function and Stiffness matrix	1
3.5	1D and 2D planar and axial symmetry problem	2
4.0	**FIELD COMPUTATION FOR BASIC CONFIGURATIONS**	
4.1	Computation of electric field intensities	2
4.2	Computation of magnetic field intensities	2
4.3	Calculation of inductance and capacitance	2
4.4	Calculation of force , torque and energy	2
5.0	**DESIGN APPLICATIONS**	
5.1	Insulators and Bushings design	2
5.2	Cylindrical magnetic actuators design	2
5.3	Transformer design	2
5.4	Rotating machines design	2
	Total	40

Syllabus

INTRODUCTION

Review of basic field theory – electric and magnetic fields – Maxwell's equations – Laplace, Poisson and Helmoltz equations – principle of energy conversion – force/torque calculation – Electro thermal formulation.

SOLUTION OF FIELD EQUATIONS I

Limitations of the conventional design procedure, need for the field analysis based design, problem definition , solution by analytical methods-direct integration method – variable separable method – method of images, solution by numerical methods- Finite Difference Method.

SOLUTION OF FIELD EQUATIONS II
Finite element method (FEM) – Differential/ integral functions – Variational method – Energy minimization – Discretisation – Shape functions –Stiffness matrix –1D and 2D planar and axial symmetry problem.

FIELD COMPUTATION FOR BASIC CONFIGURATIONS
Computation of electric and magnetic field intensities– Capacitance and Inductance – Force, Torque, Energy for basic configurations.

DESIGN APPLICATIONS
Insulators- Bushings – Cylindrical magnetic actuators – Transformers – Rotating machines.

REFERENCE BOOKS

1. K.J.Binns, P.J.Lawrenson, C.W Trowbridge, “The analytical and numerical solution of Electric and magnetic fields”, John Wiley & Sons, 1993.
2. Nathan Ida, Joao P.A.Bastos , “Electromagnetics and calculation of fields”, Springer-Verlage, 1992.
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4. S.J Salon, “Finite Element Analysis of Electrical Machines”, Kluwer Academic Publishers, London, 1995, distributed by TBH Publishers & Distributors, Chennai, India.
5. User manuals of MAGNET, MAXWELL & ANSYS software.
6. Silvester and Ferrari, “Finite Elements for Electrical Engineers”, Cambridge University press, 1983.

Course designer

S.Baskar sbeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
KEW	**3**	**1**	**-**	**4**

KEW Modern Transformer Design 3:1

Preamble

The proposed course is offered as a subject for course work and its main purpose is:

1. To elaborate on the theoretical and practical aspects in the field of transformer design and also the applications of transformers in real life and in industries.
2. To explain new methodologies for transformer design optimization (TDO) and also to apply and extend the methodologies to the optimization of different types of transformers.
3. To impart knowledge about real and accurate data of transformer, since all transformer design examples are from actual constructed and tested transformers.
4. To apply artificial intelligence and numerical techniques to transformer design and also illustrate the use of the techniques for a variety of real-world transformer designs with numerical examples.
5. To explain power engineering professionals the design methodologies and also help them in their transformer purchasing decisions. In particular, they can save money by purchasing the most cost-effective and energy-efficient transformers.
6. To help the graduate and postgraduate students in electric power engineering devices, researchers in the design and implementation of power transformers, transformer designers and power engineering professionals.

Competencies

At the end of the course the students will be able to:

1. understand the transformer design.
2. apply various optimization techniques for the problem of transformer design.
3. design real time practical transformer.

Assessment Pattern

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

Course Level Learning Objectives

Remember

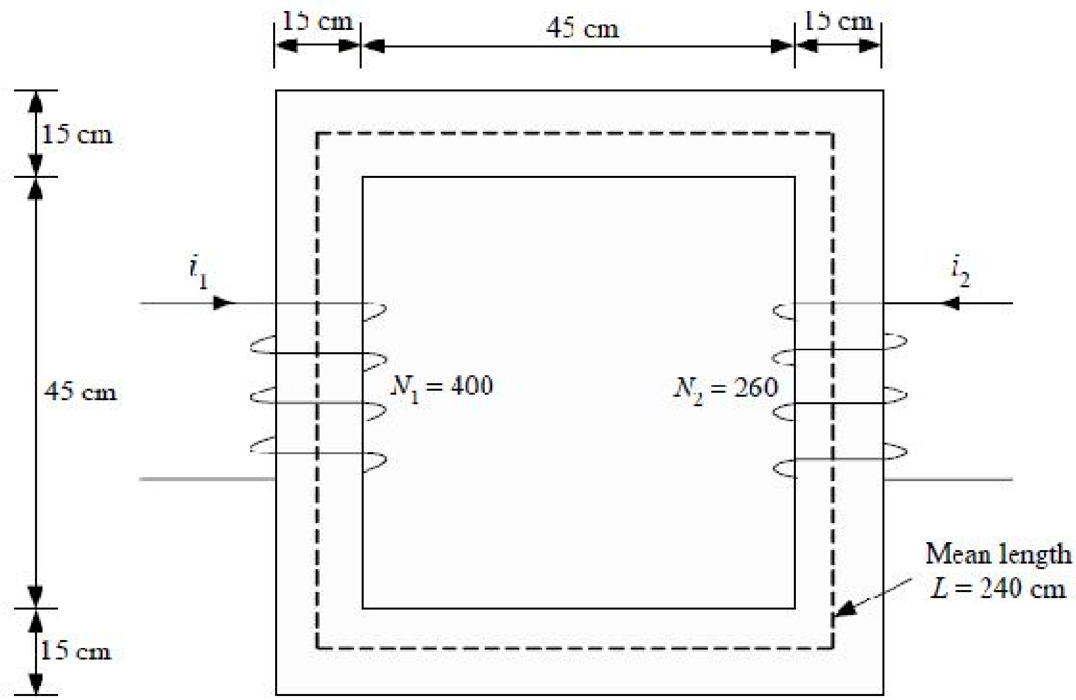
1. List the electrical characteristics of transformer.
2. Classify transformer tests.
3. Differentiate distribution transformer and power transformer.
4. What are the objective functions and constraints for transformer design optimization?
5. Formulate TDO problem.
6. What is sales margin?

Understand

1. Explain the equivalent circuit model of transformer.
2. Explain in steps the design of layer insulation.
3. Explain in detail the calculation of short circuit impedance of transformer.
4. Illustrate the evaluation of no load loss of transformer using finite element method.
5. Explain the evaluation of technical characteristics of transformer using artificial neural networks.
6. What are transformer design variables?

Apply

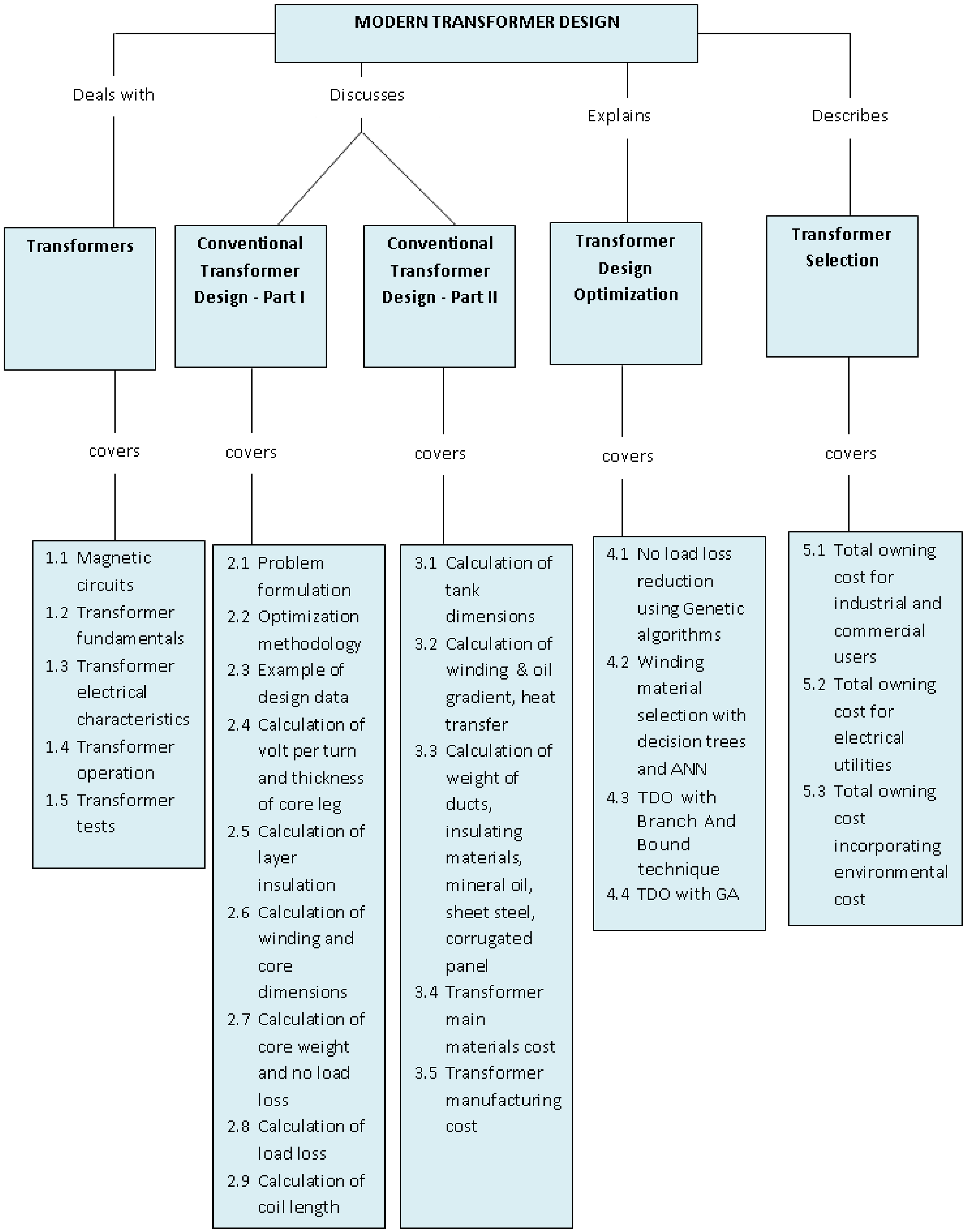
1. A three-phase transformer with rated power 630 kVA, rated primary voltage 20 kV and rated secondary voltage 0.4 kV, has 1200 W no-load losses, 9300 W load losses, and 6% short-circuit impedance. Determine the voltage regulation at full load and at 75% load for power factor 0.8 lagging.
2. A three transformers operate in parallel. The first transformer has 800 kVA rated power and 4.4% short-circuit impedance. The rated power and the short-circuit impedance of the other two transformers is 500 kVA and 4.8%, and 315 kVA and 4.0%, respectively. Calculate the maximum total load of the three transformers.
3. A two-legged core is shown in Fig. 1.2. The winding on the left leg of the core has N_1 = 400 turns and the winding on the right has N_2 = 260 turns. The core depth is 15 cm. Calculate the flux that will be produced by currents i_1 = 0.5A and i_2 = and 0.75 A . Assume μ_r = 1000 and is constant.



4. Design a 630 kVA distribution transformer having the following input data. Compute the volts per turn and thickness of the core leg.

- 50 Hz Frequency
- Δ - Connection of HV winding
- Y - Connection of LV winding
- 630 kVA Rated power
- First rated line voltage of HV winding = 20000 V
- Second rated line voltage of HV winding = 6600 V
- Rated line voltage of LV winding = 400 V
- Number of turns of LV winding = 15
- Width of core leg = 220mm
- Max flux density = 1.7Tesla
- Core stacking factor = 0.965

Concept Map


MODERN TRANSFORMER DESIGN
Deals with
Discusses
Explains
Describes
Transformers
Conventional Transformer Design - Part I
Conventional Transformer Design - Part II
Transformer Design Optimization
Transformer Selection
covers
covers
covers
covers
covers
1.1 Magnetic circuits
1.2 Transformer fundamentals
1.3 Transformer electrical characteristics
1.4 Transformer operation
1.5 Transformer tests
2.1 Problem formulation
2.2 Optimization methodology
2.3 Example of design data
2.4 Calculation of volt per turn and thickness of core leg
2.5 Calculation of layer insulation
2.6 Calculation of winding and core dimensions
2.7 Calculation of core weight and no load loss
2.8 Calculation of load loss
2.9 Calculation of coil length
3.1 Calculation of tank dimensions
3.2 Calculation of winding & oil gradient, heat transfer
3.3 Calculation of weight of ducts, insulating materials, mineral oil, sheet steel, corrugated panel
3.4 Transformer main materials cost
3.5 Transformer manufacturing cost
4.1 No load loss reduction using Genetic algorithms
4.2 Winding material selection with decision trees and ANN
4.3 TDO with Branch And Bound technique
4.4 TDO with GA
5.1 Total owning cost for industrial and commercial users
5.2 Total owning cost for electrical utilities
5.3 Total owning cost incorporating environmental cost

Course contents and Lecture schedule

No.	Topic	No. of Lectures
1.0	**TRANSFORMERS**	
1.1	Magnetic circuits	1
1.2	Transformer fundamentals	2
1.3	Transformer electrical characteristics	2
1.4	Transformer operation	2
1.5	Transformer tests	2
2.0	**CONVENTIONAL TRANSFORMER DESIGN - PART I**	
2.1	Problem formulation and Optimization methodology	2
2.2	Example of design data and Calculation of volt per turn and thickness of core leg	2
2.3	Calculation of layer insulation and winding and core dimensions	2
2.4	Calculation of core weight and no load loss and load loss	2
2.5	Calculation of coil length	1
3.0	**CONVENTIONAL TRANSFORMER DESIGN - PART II**	
3.1	Calculation of tank dimensions	1
3.2	Calculation of winding & oil gradient, heat transfer, weight of ducts, insulating materials, mineral oil, sheet steel, corrugated panel	2
3.3	Transformer main materials cost	2
3.4	Transformer manufacturing cost	2
4.0	**TRANSFORMER DESIGN OPTIMIZATION**	
4.1	No load loss reduction using Genetic algorithms	2
4.2	Winding material selection with decision trees and ANN	3
4.3	TDO with Branch and Bound technique	2
4.4	TDO with GA	2
5.0	**TRANSFORMER SELECTION**	
5.1	Total owning cost for industrial and commercial users	2
5.2	Total owning cost for electrical utilities	2
5.3	Total owning cost incorporating environmental cost	2
	Total	40

Syllabus

TRANSFORMERS

Introduction, Magnetic Circuits – Analysis – Flux Linkage – Magnetic Materials , Transformer Fundamentals – Equivalent Circuit Parameters – Voltage Regulation - Efficiency, Transformer Electrical Characteristics – Rated Power – Temperature Rise – Ambient Temperature – Altitude of Installation - Impedance voltage - No Load Losses – Load Losses - Rated voltages – Vector Group – Frequency – Noise – Short Circuit Current – No Load Current, Transformer Operation, Transformer Standards and Tolerances, Transformer Tests, Transformer Types.

CONVENTIONAL TRANSFORMER DESIGN - PART I

Introduction, Problem Formulation – Objective function – Constraints – Characteristics of the TDO problem, Conventional Transformer Design Optimization Method, Transformer Design data - Description variables – Special variables, Default variables, Cost variables, Calculation of Volts per turn and Thickness of core leg – example, Calculation of Layer Insulation – LV winding – HV winding – example, Calculation of Winding and Core Dimensions – example, Calculation of Core Weight and No-Load Loss – example, Calculation of Inductive Part of Impedance Voltage - Calculation of Load Loss - Calculation of Impedance Voltage – Calculation of Coil Length.

CONVENTIONAL TRANSFORMER DESIGN - PART II
Calculation of Tank Dimensions - Calculation of Winding Gradient and Oil Gradient - Calculation of Heat Transfer - Calculation of Weight of Insulating Materials - Calculation of Weight of Ducts - Calculation of Weight of Oil - Calculation of Weight of Sheet Steel - Calculation of Weight of Corrugated Panels - Calculation of Cost of Transformer Main Materials - Calculation of Transformer Manufacturing Cost - example

TRANSFORMER DESIGN OPTIMIZATION
Introduction, No Load Loss Reduction with Genetic Algorithms, Winding Material Selection with Decision Trees and Artificial Neural Networks, Transformer Design Optimization with Branch and Bound technique - MIP-FEM Methodology, Transformer Design Optimization with Genetic Algorithms - Recursive GA-FEM Methodology.

TRANSFORMER SELECTION

Introduction, Total Owning Cost for Industrial and Commercial Users - Cost Evaluation Method - example, Total Owning Cost for Electric Utilities - Cost Evaluation Method - example, Proposed Total Owning Cost Incorporating Environmental Cost - Cost Evaluation Method - example.

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Course Designer

S.Baskar sbeee@tce.edu