KANNUR UNIVERSITY

(Abstract)

M-Tech Degree Programme in **Power Electronics** –Scheme ,Syllabus & Model Question Papers -Implemented with effect from **2014** admission - Orders issued.

ACADEMIC BRANCH

No.Acad/C5/ 91/2015 (iii) Dated, Civil Station P.O , 05-05-2015.

Read: 1. U.O. No.Acad/C3/ 10834/2011 dated 22.08.2012
2. U.O. No.Acad/C3/ 10834/2011 (2) dated 07.10.2013
3. Minutes of the meeting of the Board of Studies in Engineering (PG) held on 29.01.2015
4. Letter dated 5-03-2015 from the Convenor of the Expert Committee for framing the Scheme, Syllabus & Pattern of Question Papers for M.Tech Degree Programme in **Power Electronics**
5. Minutes of the meeting of the Board of Studies in Engineering (P.G) held on 5.03.2015.
6. Minutes of the meeting of the Faculty of Engineering held on 21.04.2015.

ORDER

1. The modified Regulations for M-Tech Degree Programmes were implemented in the University with effect from 2011 Admission as per the paper read (1) above, and certain modifications were effected to the same w.e.f 2013 admission vide paper read (2).

2. As per paper read (3) above , an Expert Committee was constituted as recommended by the BOS in Engineering (PG) at its meeting held on 29.01.2015, for framing the Scheme , Syllabus and Model question papers for M-Tech Degree Programme in **Power Electronics** to be implemented in the University with effect from 2014 Admission.

3. The Convenor of the above Committee, vide paper read (4) above has submitted the Scheme , Syllabus & Model Question Papers for M-Tech Degree Programme in **Power Electronics** to the University, for implementation with effect from 2014 Admission.

4. As per paper read (5) above the Board of Studies in Engineering (P.G) finalised the Scheme, Syllabus and Model Question Papers for M. Tech. Programme in **Power Electronics** for implementation w.e.f. 2014 Admission.

5. As per paper read (6) above the meeting of the Faculty of Engineering approved the Scheme, Syllabus and Model Question Papers for M. Tech. Programme in **Power Electronics** for implementation w.e.f. 2014 Admission.

6. The Vice-Chancellor after examining the matter in detail and in exercise of the powers of the Academic Council conferred under Section 11(1) of Kannur University Act 1996 and all other enabling provisions read together with has

i) approved the draft Scheme, Syllabus and Model Question papers for M-Tech Programme in **Power Electronics** prepared by the Expert Committee appointed by the Board of Studies.

Contd….2

ii) accorded sanction to implement the Scheme, Syllabus and Model Question Papers of the M-Tech Degree Programme in **Power Electronics** with effect from 2014 Admission, subject to report to the Academic Council.

7. Orders are issued accordingly.

8. The implemented Scheme, Syllabus & Model Question Papers are appended.

Sd/-
DEPUTY REGISTRAR
FOR REGISTRAR

To

The Principals of Affiliated Engineering Colleges
offering M.Tech. Programme

Copy to

1. The Examination Branch (Through PA to CE)
2.The Chairman,BOS in Engineering (PG) 3.PS to VC/PA to CE/ P.A to Registrar.
4. DR/AR-I (Academic) 5. SF/DF/FC.

Forwarded/By Order

SECTION OFFICER

KANNUR UNIVERSITY
CIVIL STATION P.O.
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Pin-670 002
THAVAKKARA

FOR MORE DETAILS : LOG ON www.kannuruniversity.ac.in

CURRICULUM, SCHEME OF EXAMINATIONS AND SYLLABI FOR M.TECH DEGREE PROGRAMME WITH EFFECT FROM ACADEMIC YEAR 2014-2015

KANNUR UNIVERSITY

FACULTY OF ENGINEERING

ELECTRICAL AND ELECTRONICS ENGINEERING

M Tech in

POWER ELECTRONICS

M.TECH IN POWER ELECTRONICS

The world today is reeling from severe power shortage. The conventional power resources are on the verge of extinction. Efforts are being made to find alternative sources. Renewable energy has become the most sought alternative. But the proper harnessing of this energy was very difficult till the advancement of Power Electronics. Today Power electronics based Researches on Renewable Energy is the most sought stream. The M.Tech Programme on Power Electronics offered has a holistic approach focusing upon imparting the students with application based knowledge on mastering all the areas related to design development, analysis and implementation of power electronics in all aspects of engineering. The first two semesters cover course work facilitating the students to learn both fundamentals and recent advances in various core and elective subjects supported by laboratory courses, which include Power Electronics Hardware based Laboratory and Power Electronics Control Laboratory thereby enabling the students to gain an overall perspective about the design of power electronic circuits and their control. The third and fourth semesters are earmarked for Dissertation Work. Students are generally encouraged to do their projects on their own thereby making the students gain in depth knowledge on their research material. The research work done are published in journals or conferences of repute. The students are also brought into close contact with industries and eminent personalities which enables the students to be well informed on the current need and aspirations of the engineering world.

ADMISSION PREREQUISITES:-

B. E/ B. Tech.in Electrical and Electronic Engineering, with a First Class with or without valid GATE score.

SCHEME:

FIRST SEMESTER

Code	Subject	Hours/Week			Sessional Marks	University Examination		Credit
		L	T	P		Hrs	Marks	
PEL 101	Mathematical Methods for Power Engineering	3	-	-	50	3	100	3
PEL 102	System Theory	3	-	-	50	3	100	3
PEL 103	Power Electronic Drives	3	-	-	50	3	100	3
PEL 104	Power Converters- I	3	-	-	50	3	100	3
PEL 105	Elective I	3	-	-	50	3	100	3
PEL 106	Elective II	3	-	-	50	3	100	3
PEL 107 (P)	Power Electronics Lab	-	-	2	50	3	100	2
PEL 108 (P)	Seminar	-	-	2	50			2
TOTAL		**18**	**-**	**4**	**400**		**700**	**22**

SECOND SEMESTER

Code	Subject	Hours/Week			Sessional Marks	University Examination		Credit
		L	T	P		Hrs	Marks	
PEL 201	Switched Mode Power Conversion	3	-	-	50	3	100	3
PEL 202	Power Converters- II	3	-	-	50	3	100	3
PEL 203	Dynamics of Electrical Machines	3	-	-	50	3	100	3
PEL 204	Elective III	3	-	-	50	3	100	3
PEL 205	Elective IV	3	-	-	50	3	100	3
PEL 206	Elective V	3	-	-	50	3	100	3
PEL 207 (P)	Power Electronics and Control Lab	-	-	2	50	3	100	2
PEL 208 (P)	Term Paper	-	-	2	50	-	-	2
TOTAL		**18**	**-**	**4**	**400**		**800**	**22**

THIRD SEMESTER

Code	Subject	Hours/Week			Marks					Credit
					Internal		University		Total	
		L	T	P	Guide	Evaluation Committee	Thesis	Viva		
PEL 301 (P)	Thesis Preliminary			22	200	200	---	---	400	8
TOTAL				**22**	**200**	**200**			**400**	**8**

FOURTH SEMESTER

Code	Subject	Hours/Week			Marks					Credit
					Internal		University		Total	
		L	T	P	Guide	Evaluation Committee	Thesis	Viva		
PEL 401 (P)	Thesis			22	200	200	100	100	600	12
TOTAL				**22**	**200**	**200**	**100**	**100**	**600**	**12**

FIRST SEMESTER

Code	Subject	Hours/Week			Sessional Marks	University Examination		Credit
		L	T	P		Hrs	Marks	
PEL 101	Mathematical Methods for Power Engineering	3	-	-	50	3	100	3
PEL 102	System Theory	3	-	-	50	3	100	3
PEL 103	Power Electronic Drives	3	-	-	50	3	100	3
PEL 104	Power Converters- I	3	-	-	50	3	100	3
PEL 105	Elective I	3	-	-	50	3	100	3
PEL 106	Elective II	3	-	-	50	3	100	3
PEL 107 (P)	Power Electronics Lab	-	-	2	50	3	100	2
PEL 108 (P)	Seminar	-	-	2	50			2
TOTAL		**18**	**-**	**4**	**400**		**700**	**22**

ELECTIVE I -PEL 105	
PEL 105(A)	Distribution Systems Management and Automation
PEL 105 (B)	Special Machines
PEL 105 (C)	Advanced Digital Signal Processing
PEL 105 (D)	Custom Power Devices
PEL 105 (E)	Power Semiconductor Devices

ELECTIVE II -PEL 106	
PEL 106 (A)	Digital System Design
PEL 106 (B)	Advanced Microcontroller Based Systems
PEL 106 (C)	Power Quality Issues and Remedial Measures
PEL 106 (D)	HVDC Transmission System
PEL 106 (E)	Digital Signal Processors and Applications

Sessional marks for all the Theory based Subjects

The marks allotted for internal continuous assessment and end-semester university examinations shall be 50 marks and 100 marks respectively with a maximum of 150 marks for each theory subject. The weightage to award internal assessment marks should be as follows:

Test papers (two tests) : 25 marks
Assignments and/or class performance : 25 marks

SECOND SEMESTER

Code	Subject	Hours/Week			Sessional Marks	University Examination		Credit
		L	T	P		Hrs	Marks	
PEL 201	Switched Mode Power Conversion	3	-	-	50	3	100	3
PEL 202	Power Converters- II	3	-	-	50	3	100	3
PEL 203	Dynamics of Electrical Machines	3	-	-	50	3	100	3
PEL 204	Elective III	3	-	-	50	3	100	3
PEL 205	Elective IV	3	-	-	50	3	100	3
PEL 206	Elective V	3	-	-	50	3	100	3
PEL 207 (P)	Power Electronics and Control Lab	-	-	2	50	3	100	2
PEL 208 (P)	Term Paper	-	-	2	50	-	-	2
TOTAL		**18**	**-**	**4**	**400**		**800**	**22**

ELECTIVE

ELECTIVE III - PEL 204	
PEL 204 (A)	Electro-Mechanical Systems
PEL 204 (B)	Smart Grid Technologies
PEL 204 (C)	Embedded System Design
PEL 204 (D)	Process Control and Automation
PEL 204 (E)	FACTS Controller

ELECTIVE IV - PEL 205	
PEL 205 (A)	Static VAr controllers and Harmonic Filtering
PEL 205 (B)	Industrial Control Electronics
PEL 205 (C)	Power Electronic Applications in Renewable Energy Systems
PEL 205 (D)	Energy Conservation
PEL 205 (E)	Computer Controlled Systems

ELECTIVE V- PEL 206	
PEL 206(A)	Artificial Neural Networks and Fuzzy systems
PEL 206 (B)	Robotics and Automation
PEL 206 (C)	Energy Management
PEL 206 (D)	Data Acquisition and Signal Control
PEL 206 (E)	Electric Vehicles

THIRD SEMESTER

Code	Subject	Hours/Week			Marks					Credit
		L	T	P	Internal		University		Total	
					Guide	Evaluation Committee	Thesis	Viva		
PEL 301 (P)	Thesis Preliminary			22	200	200	---	---	400	8
TOTAL				**22**	**200**	**200**			**400**	**8**

THESIS PRELIMINARY

This shall comprise of two seminars and submission of an interim thesis report. This report shall be evaluated by the evaluation committee. The fourth semester Thesis- Final shall be an extension of this work in the same area. The first seminar would highlight the topic, objectives, methodology and expected results. The first seminar shall be conducted in the first half of this semester. The second seminar is presentation of the interim thesis report of the work completed and scope of the work which is to be accomplished in the fourth semester.

FOURTH SEMESTER

Code	Subject	Hours/Week			Marks					Credit
		L	T	P	Internal		University		Total	
					Guide	Evaluation Committee	Thesis	Viva		
PEL 401 (P)	Thesis			22	200	200	100	100	600	12
TOTAL				**22**	**200**	**200**	**100**	**100**	**600**	**12**

Towards the middle of the semester there shall be a pre submission seminar to assess the quality and quantum of the work by the evaluation committee. This shall consist of a brief presentation of Third semester interim thesis report and the work done during the fourth semester. The comments of the examiners should be incorporated in the work and at least one technical paper is to be prepared for possible publication in journals / conferences. The final evaluation of the thesis shall be an external evaluation.

PEL 101 MATHEMATICAL METHODS FOR POWER ENGINEERING

3 hours lecture per week

Objective: *To familiarize with mathematical aspect of Power Engineering.*

Vector spaces, subspaces, Linear dependence, Basis and Dimension, Linear transformations, Kernels and Images , Matrix representation of linear transformation, Change of basis, Eigen values and Eigen vectors of linear operator

Mathematical formulation of Linear Programming Problems, Simplex Method, Duality in Linear Programming, Dual Simplex method.

Non Linear Programming preliminaries, Unconstrained Problems ,Search methods , Fibonacci Search, Golden Section Search, Constrained Problems , Lagrange method ,Kuhn-Tucker conditions

Random Variables, Distributions and Density functions, Moments and Moment generating function, Independent Random Variables, Marginal and Conditional distributions, Conditional Expectation, Elements of stochastic processes, Classification of general stochastic processes.

References:

1. Kenneth Hoffman and Ray Kunze, Linear Algebra,2nd Edition, PHI, 1992.
2. Erwin Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons, 2004.
3. Irwin Miller and Marylees Miller, John E. Freund’s Mathematical Statistics, 6th Edn, PHI, 2002.
4. J. Medhi, Stochastic Processes, New Age International, New Delhi., 1994
5. A Papoulis, Probability, Random Variables and Stochastic Processes, 3rd Edition, McGraw Hill, 2002
6. John B Thomas, An Introduction to Applied Probability and Random Processes, John Wiley, 2000
7. Hillier F S and Liebermann G J, Introduction to Operations Research, 7th Edition, McGraw Hill, 2001
8. Simmons D M, Non Linear Programming for Operations Research, PHI, 1975

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 102 SYSTEM THEORY

3 hours lecture per week

Objective: *To develop an understanding about the application of controllers in real time.*

State variable representation of system -concept of state -Equilibrium points –Stability-Solution of state equation -eigen values -eigen vectors –modes -modal decomposition -eigen value and stability-State space representation of discrete time systems -Discretization of continuous time state equation.

Lyapunov stability -definition of stability, asymptotic stability and instability -Lyapunov's second method -Lyapunov's stability analysis of LTI continuous time and discrete time systems-stability analysis of non linear system -Krasovski's theorem -variable gradient method.

Concepts of controllability and observability -controllability and observability tests for continuous time and discrete time systems -controllability and observability studies based on canonical forms of state model -effect of state feedback on controllability and observability -pole placement by state feedback for continuous and discrete time systems -Design of full order and reduced order observer for continuous time and discrete time systems

Optimal control -formulation of optimal control problem -Minimum time control problem -minimum energy problem -minimum fuel problem -state regulator problem -output regulator problem –tracking problem -choice of performance measure -optimal control based on quadratic performance measure –optimal control system design using second method Lyapunov –solution of reduced Riccatti equation.

Robust control systems –introduction -sensitivity analysis of robustness -system with uncertain parameters -design of robust PID controlled systems.

References:

1. Thomas Kailath, Linear systems, Prentice Hall Inc
2. OgataK., Modern control Engg (Second Edition), Prentice Hall Inc, 1990
3. Ogata K,Discrete time control systems, P.H.I
4. Gopal M.,Digital Control and State Variable methods, TMH, 1997
5. Gopal M.Modern Control System Theory
6. Chen C.T., Linear system theory and design, New York,Holt Rinechart and Winston , 1984
7. Richard.C.Dorf and Bishop R.T, Modern Control System, P.H.I publishers

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 103 POWER ELECTRONIC DRIVES

3 hours lecture per week

Objective: *To gain knowledge on application of power electronics in control of industrial drives.*

Introduction to Motor Drives - Components of Power Electronic Drives - Criteria for selection of Drive components - Match between the motor and the load - Thermal consideration - Match between the motor and the Power Electronics converter - Characteristics of mechanical systems - stability criteria

D.C Motor Drives - System model motor rating - Motor-mechanism dynamics - Drive transfer function – Drives control-speed controller design-Effect of armature current waveform - Torque pulsations Adjustable speed dc drives - Chopper fed and 1-phase converter fed drives - Effect of field weakening.

Induction Motor Drives - Basic Principle of operation of 3 phase motor - Equivalent circuit - MMF space harmonics due to fundamental current - Fundamental spatial mmf distributions due to time harmonics - Simultaneous effect of time and space harmonics - Speed control by varying stator frequency and voltage Impact of nonsinusoidal excitation on induction motors - Variable frequency converter classifications - Variable frequency PWM-VSI drives - Variable frequency square wave VSI drives - Variable frequency CSI drives - Comparison of variable frequency drives - Line frequency variable voltage drives - Soft start of induction motors - Speed control by static slip power recovery. - Vector control of 3 phase squirrel cage motors - Principle of operation of vector control-

Synchronous Motor Drives - Introduction - Basic principles of synchronous motor operation methods of control - operation with field weakening - load commutated inverter drives. PMSM Drives, Switched reluctance Drive.

References:

1. Ned Mohan ,"Power Electronics", et. al ,Wiley 2006
2. R Krishnan," Electric Motor Drives, Modeling, Analysis, and Control", Pearson Education,2001
3. G.K.Dubey & C.R.Kasaravada ,"Power Electronics & Drives", Tata McGraw Hill,1993.
4. W.Shephered, L N Hulley Cambride ,Power Electronics & Control of Motor , University Press,2005.
5. Dubey ,Power Electronics Drives ,Wiley Eastern,1993.
6. Chilikin ,M ,Electric drives , Mir publications, 2nd edition,1976

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 104 POWER CONVERTERS- I

3 hours lecture per week

Objective: *To develop solid foundation in analyzing DC-DC and AC-DC converters*

Switching DC Power Supplies – Forward, flyback, pushpull, half bridge and full bridge converter circuit, operation, waveforms and design, small signal analysis of DC-DC converters and closed loop control – transfer function of dc-dc converters – stability analysis

Resonant DC-DC converters – load resonant converters – resonant switch converters – zero voltage switching, clamped voltage topologies – resonant dc link inverters with zero voltage switching – high frequency link integral half cycle converters

Current harmonics in rectifiers – harmonic standards – improved single phase and three phase rectifiers – Multi pulse and multi level rectifiers, Dual thyristor bridge and PWM rectifier.

Residential and industrial applications of power electronics – induction heating, welding, electronic ballast – utility applications - back to back HVDC transmission, UPS, static var compensators and active filters.

References:

1. Power Electronics Converters, Application And Design – Ned Mohan, T M Undeland, William P Robbins, John Wiley & Sons 2003
2. Power Electronics – M D Singh, Khanchandani, 2nd Edition, Tata Mcgraw Hill
3. Fundamentals Of Power Electronics, Second Edition, Robert W Erickson, Dragan Maksimovic, Kluwer Academic Publishers
4. Power Electronics Principles And Applications – Joseph Vithayathil – Tata Mcgraw Hill
5. Power Electronics – Cyril W Lander – Tata Mcgraw Hill.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 104*

PEL 105(A) DISTRIBUTION SYSTEMS MANAGEMENT AND AUTOMATION

3 hours lecture per week

Objective: *To develop deep understanding of various aspects of Power Distribution and Control related to it.*

Distribution Automation System : Necessity, System Control Hierarchy- Basic Architecture and implementation Strategies for DA- Basic Distribution Management System Functions- Outage management-

Integration of Distributed Generation and Custom Power components in distribution systems-Distribution system Performance and reliability calculations

Electrical System Design: Distribution System Design- Electrical Design Aspects of Industrial, Commercials Buildings- Electrical Safety and Earthing Practices at various voltage levels- IS Codes- Communication Systems for Control and Automation- Wireless and wired Communications- DA Communication Protocols, Architectures and user interface-Case Studies

Power Quality and Custom Power: Concept- Custom Power Devices - Operation and Applications

Deregulated Systems: Reconfiguring Power systems- Unbundling of Electric Utilities Competition and Direct access

References:

1. James, J.O Brien, “Construction Inspection Handbook - Quality Assurance and Quality Control ", Van Nostrand, New York, 1989
2. Kwaku A., Tenah and Jose M.Guevera, “Fundamental of Construction Management and Organization ",Prentice Hall of India, 1995.
3. Juran Frank, J.M. and Gryna, F.M. " Quality planning and Analysis ", Tata McGraw Hill, 1982.
4. Hutchins. G., “ISO 9000 ", Viva Books, NewDelhi, 1993.
5. Clarkson H. Oglesby, “Productivity Improvement in Construction ", McGraw Hill 1989.
6. John L.Ashford, " The Management of Quality in Construction ", E & F.N Spon, New York, 1989.
7. Steven McCabe, “Quality Improvement Techniques in Construction ", Addisson Wesley Longman Ltd.,England, 1998.
8. Jimmy W.Hinze, “Construction Safety ", Prentice Hall Inc., 1997.
9. Richard J. Coble, Jimmie Hinze and Theo C. Haupt, “Construction Safety and Health Management ",Prentice Hall Inc., 2001

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 105(B) SPECIAL MACHINES

3 Hours Lecture Per Week

Objective: *To develop understanding about special machines*

Stepper motor
Constructional features - Principle of operation-permanent magnet stepper motor – variable reluctance motor - hybrid motor-single and multi stack configurations - Torque equations - modes of excitations - drive circuits-microprocessor control of stepping motors – closed loop control – applications.

Servomotor
DC servomotors- construction - principle of operation-transfer function - armature control and field control - AC servomotor-construction - theory of operation - shaded pole ac servomotors applications.

Reluctance motors
Synchronous Reluctance motor - Constructional features - Types - Principle of operation - Axial and radial flux motors - operating principles - variable reluctance motor – hybrid motor - voltage and torque equations – characteristics – applications.
Switched reluctance motor - Constructional features - principle of operation – torque production - steady state performance prediction-Analytical method - Power converters and their controllers - Methods of rotor position sensing - Closed loop control of SRM – Characteristics – applications.

Permanent magnet motor
Permanent magnet brushless DC motors - Permanent magnetic materials – Magnetic characteristics - Principle of operation -Types-Magnetic circuit analysis - Torque equations - Power controllers - Motor characteristics and control, Permanent magnet synchronous motors-Principle of operation-- Torque equations-characteristics and control.

Linear Induction motor
Linear induction motor- Double sided linear induction motor from rotary type Induction motor – Scheme of LIM drive for electric traction – development of single sided LIM – Equivalent circuit-applications.

References:
1. M D Desai, Control system components, PHI
2. K Venkataratnam, Special Electrical Machines, Universities press(India) Pvt. Ltd. Hyderabad
3. R Krishnan, Electric Motor Drives, Modeling, Analysis, and control, PHI
4. Nasar S.A., Boldea I., Linear Motion Electric Machine, John Wiley & Sons
5. R.Krishnan, Switched Reluctance Motor Drives-Modelling, Simulation, Analysis, Design and application, CRC press New York,2001

Question Pattern:
There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 105(B)*

PEL 105 (C) ADVANCED DIGITAL SIGNAL PROCESSING

3 hours lecture per week

Objective: *To develop understanding of digital signal processing techniques*

MULTIRATE DIGITAL SIGNAL PROCESSING
Introduction to Multi-rate Digital Signal Processing – Sample rate reduction – decimation by integer factors- sampling rate increase – interpolation by integer factor – Design of practical sampling rate converters Filter Specification- filter requirement for individual stages – Applications.

STATISTICAL SIGNAL PROCESSING:
Random variables- random process- Ensemble averages, Stationary and ergodic processes, Autocorrelation and Autocovariance- properties of correlation matrix, White noise, Power Spectral Density, Spectral Factorization- Periodogram-Bias and variance. Stochastic models- AR, MA, ARMA processes- Yule Walker Equations- Linear Filters-Minimum mean square error-Weiner-Hopf equations-Linear Prediction-. Levinson-Durban Algorithms- Lattice Filter- Properties-Basic Concepts of Kalman Filters.

ADAPTIVE SIGNAL PROCESSING
Adaptive Signal Processing – Adaptive filters – Concepts- FIR Adaptive–The basic LMS adaptive algorithm – Practical limitations of the basic LMS algorithm – Recursive Least Square Algorithm – Limitations – Noise cancellation.

ADVANCED TRANSFORM TECHNIQUES
2-D Discrete Fourier transform and properties–2-D random process- properties-Classical spectral estimation- Applications. Wavelet Transforms: Fourier Transform- Basics of Wavelet Transform-Gabor transform classification of wavelets- Haar Wavelet –Applications.

References:
1. Proakis and Manolakis, Digital Signal Processing, Perason Education.
2. Simon Haykin, Adaptive Filter Theory, Pearson Education.
3. Hayes M. H, Statistical Digital Signal Processing and Modeling, John Wiley & Sons, NY
4. Steven M Kay, Modern Spectral estimation Theory and Application, PHI
5. Oppenheiem A. V and Schafer R. W, Discrete Time Signal Processing, PH
6. Papoulis a, Probability, random variables and Stochastic Processes, McGraw Hill NY
7. Chui C. K, An Introduction to Wavelets., Academic Press, NY
8. G. Bachman, L. Narici and E Beckenstein: Fourier and wavelet Analysis, Springer-Verlag, New York/Berlin/Heidelberg, 2000

Question Pattern:
There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 105(C)*

PEL 105 (D) CUSTOM POWER DEVICES

3 hours lecture per week

Objective: *To develop understanding of custom power devices*

Power quality –Power electronic application in Transmission systems and distribution systems-distributed generation- Power quality terms -transients, over voltage, under voltage, sag, swell, harmonics, flicker- PQ problems-poor power factor, unbalanced loads, disturbances in supply voltage

Custom power devices-Network configuring and compensating devices- SSCL, SSB, SSTS, custom power park- Structure and control of power converters-open loop voltage control and closed loop voltage control

DSTATCOM-compensator for single phase and three phase loads -generating reference current using PQ theory - three phase four wire systems- neutral current compensation, three phase four wire DSTATCOM.

DVR-Rectifier and capacitor supported-DVR structure-UPQC structure and control of left shunt and right shunt UPQC-Active filters-shunt, series, hybrid filters

References:

1. L Ghosh and G Ledwich,Power quality enhancement using custom power Devices,Kluwer Publications, London, 2003
2. K R Padiyar, FACTS controllers in Power Transmision and Distribution, New Age publications, New D elhi, 2007
3. R Sastry Vedam, power quality VAR compensation in power systems, CRC press,NewYork,2009
4. H Akagi, New Trends in active filters for power conditioning, IEEE TIA, vol.32,no.6,pp1312-1322,1996.
5. B Singh, P Jayaprakash, R Somayajulu, D P Kothari, ‘’ Reduced Rating VSC With a Zig-Zag Transformer for Current Compensation in a Three-Phase Four-Wire Distribution System”, IEEE Transactions on Power Delivery, VOL. 24, NO. 1, January 2009.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 105(D)*

PEL 105(E) POWER SEMICONDUCTOR DEVICES

3 hours lecture per week

Objective: *To develop understanding of the physics of power semiconductor devices*

Material properties – intrinsic carrier concentration – band gap narrowing – built in potential – zero bias depletion width – impact ionization coefficients – carrier mobility – resistivity – recombination lifetime

Avalanche breakdown – abrupt one-dimensional diode – ideal specific on-resistance – abrupt punch through diode – linearly graded junction diode – edge terminations – open base transistor breakdown – surface passivation

Schottky rectifier: structure – forward conduction – reverse blocking – device capacitance – tradeoff analysis. P – I – N rectifiers: structure – reverse blocking – switching performance – buffer layer – non punch through – tradeoff curves

Power MOSFET: Structure - Blocking voltage – forward conduction characteristics –on resistance – cell optimization – transfer characteristics – output characteristics – device capacitances – gate charge – high frequency operation – switching characteristics – safe operating area – integral body diode – high temperature characteristics

Bipolar junction transistor: structure – static blocking characteristics – current gain – emitter current crowding – output characteristics – on state characteristics – switching characteristics safe operating area – Darlington configuration

Thyristors: structure – blocking characteristics – on state characteristics – switching characteristics – light operated thyristors – self protected thyristors – gate turn off thyristor – triac

IGBT: structure – device operating and output characteristics – equivalent circuit – blocking characteristics – on state characteristics – current saturation model – switching characteristics – power loss optimization – safe operating area – blocking voltage scaling – high temperature operation

References:

1. P Jayant Baliga, Fundamentals of Power Semiconductor devices, Springer
2. M D Singh and Khanchandani, Power Electronics , 2nd Edition, Tata Mcgraw Hill
3. Joseph Vithayathil, Power Electronics Principles and Applications, Tata Mcgraw Hill

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 105(E)*

PEL 106 (A) DIGITAL SYSTEM DESIGN

3 hours lecture per week

Objective: *To develop understanding of digital system design using VHDL*

Review of logic design fundamentals – introduction to VHDL – designing with programmable logic devices – design of networks for arithmetic operations – digital design with SM charts – designing with programmable gate arrays and complex programmable logic devices – floating point arithmetic – transport and inertial delays – operator overloading – multivalued logic and signal resolution – IEEE 1164 standard logic – generate statements – synthesis of VHDL code – VHDL models for memories and buses – hardware testing and design for testability – design examples

References:

1. Charles H Roth, Jr, Digital Systems Design using VHDL, Thomson Brooks/Cole
2. John Wakerly, Digital Design: Principles and Practices, 4/e, Pearson Education.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 106(A)*

PEL 106 (B) ADVANCED MICROCONTROLLER BASED SYSTEMS

3 hours lecture per week

Objective: *To develop understanding of applications of microcontrollers in power electronics*

Evolution of micro-controllers – comparison between micro processor and micro controllers- Microprocessors- Architecture of 8086 - Architecture of 80386 series- Micro-controller development systems – simulators- -Architecture of 8096 and PIC series microcontrollers

8051 family – architecture of 8051 – 8051 programming model – 8051 pin diagram – internal RAM organization – ports – program status word – register – 8051 assembly language programming – register banks and stack – addressing modes – external data modes- Instruction set of 8051 – arithmetic operations – logical operations – data transfer operations – control transfer operations

Interfacing -programmable peripheral interface (8255) -programmable communication interface (8251) - programmable timer (8253)-Typical applications in the control of power electronic converters for power supplies and electric motor drives.

References:

1. Douglas V.Hall , ‘ Microprocessors and Interfacing - Programming and Hardware ‘, Tata McGraw-Hill , Eleventh edition , 2003.
2. Kenheth J. Hintz and Daniel Tabak, 'Microcontrollers - Architecture, Implementation and programming' McGraw Hill, USA, 1992.
3. John.B Peatman , ’Design with microcontrollers', McGraw Hill International Ltd, 1997.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 106 (C) POWER QUALITY ISSUES AND REMEDIAL MEASURES

3 hours lecture per week

Objective: *To develop understanding of power quality and measures to reduce its impact*

Introduction-power quality-voltage quality-overview of power quality phenomena-classification of power quality issues-power quality measures and standards-THD-TIF-DINC message weights-flicker factor-transient phenomena-occurrence of power quality problems power acceptability curves-IEEE guides, standards and recommended practices.

Harmonics- individual and total harmonic distortion- RMS value of a harmonic waveform triplen harmonics- important harmonic introducing devices- SMPS-Three phase power converters – arcing devices- saturable devices- fluorescent lamps- effect of power system harmonics on equipment and loads.

Modeling of networks and components under non-sinusoidal conditions-transmission and distribution systems-shunt capacitors-transformers-electric machines-ground systems-loads that cause power quality problems-power quality problems created by drives and its impact on drives

Power factor improvement- Passive Compensation. Passive Filtering, Harmonic Resonance, Impedance Scan Analysis- Active Power Factor Corrected Single Phase Front End, Control Methods for Single Phase APFC, Three Phase APFC and Control Techniques, PFC Based on Bilateral Single Phase and Three Phase Converter. Static VAR compensators- SVC and STATCOM

Active Harmonic Filtering-Shunt Injection Filter for single phase , three-phase three-wire and three-phase four-wire systems . d-q domain control of three phase shunt active filters uninterruptible power supplies-constant voltage transformers- series active power filtering techniques for harmonic cancellation and isolation . Dynamic Voltage Restorers for sag, swell and flicker problems.

References:

1. Heydt, Power Quality, Star in a circle publications
2. Dugan, Electric Power Systems Quality, Tata Mc Graw Hill
3. K R Padiyar, FACTS controllers in Power Transmission and Distribution, New Age publications, New Delhi, 2007
4. R Sastry Vedam, power quality VAR compensation in power systems, CRC press, NewYork,2009
5. H Akagi, New Trends in active filters for power conditioning, IEEE TIA, vol.32,no.6,pp1312-1322,1996.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 106(C)*

PEL 106 (D) HVDC TRANSMISSION SYSTEMS

3 hours lecture per week

Objective: *To develop understanding of HVDC Transmission systems*

Analysis of HVDC Converters: analysis of Graetz circuit – converter bridge characteristics – twelve pulse converters

HVDC system control: system control hierarchy – firing angle control – current and extinction angle control – starting and stopping of DC link – power control

Converter faults and protection: converter faults – protection against over currents and Over voltages – surge arresters - smoothing reactor - DC line protection

Reactive power requirements at steady state – sources of reactive power – static VAR systems - reactive power control during transients – generation of harmonics – design of AC and DC filters – multiterminal DC systems – types, control and protection

Converter model – modeling of DC network and AC network – modeling of DC links – DC load flow solution – per unit system for DC quantities – solution of AC – DC power flow Transient stability analysis – dynamic stability and power modulation

References:

1. K R Padiyar, HVDC Power Transmission Systems, New Age Intl'
2. Vijay K Sood, HVDC and FACTS Controllers, Kluwer Academic Publishers
3. J Arillaga, Y H Liu, N R Watson, Flexible Power Transmission – The HVDC Options – John Wiley and Sons

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 106(D)*

PEL 106 (E) DIGITAL SIGNAL PROCESSORS AND APPLICATIONS

3 hours lecture per week

Review of Discrete – Time Signal & System representation in Z – Transform domain – Inverse Z – Transform – Properties – System characterization in Z – domain -- Equivalence between Fourier Transform and the Z-Transform of a Discrete signal.

Sampling in Fourier domain - Discrete Fourier Transform and its properties – Linear filtering using DFT – Resolution of DFT - FFT Algorithm – Radix-2 FFT Algorithm – DIT & DIF Structures - Higher Radix schemes.

Classification of filter design - Design of IIR filters – Bilinear transformation technique– Impulse invariance method – Step invariance method.

FIR filter design – Fourier series method - Window function technique - Finite Word Length Effects.

Introduction to Multirate Signal Processing - Decimation - Interpolation - Case Studies On Speech Coding, Transform Coding – DSP based measurement system.

References:

1. Ludemann L. C., "Fundamentals of Digital Signal Processing", Harper and Row publications, 1986.
2. Antoniou A., "Digital Filters – Analysis and Design", Tata Mc-Graw Hill, 1980.
3. Oppenheim and Schaffer, 'Discrete time Signal processing', PHI, 1989.
4. P.P. Vaidhyanathan, Multirate systems and filter banks, PHI, 1993.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 106(E)*

PEL 107 (P) POWER ELECTRONICS LAB

2 hours practical per week

At least 12 experiments should be conducted in the lab

List of Experiments

1. Study the characteristics of a diode, SCR, Triac and MOSFET. Obtain I-V characteristics of a diode, SCR, Triac and MOSFET on CRO.
2. Realize DC-dc buck chopper using a MOSFET and control them in the open loop and record the DC supply voltage, supply current, load voltage and load current, device voltage and current in resistive and inductive loads.
3. Study characteristics of a 6-pulse uncontrolled three-phase bridge rectifier with filtered output.
Record the AC supply voltage and current waveform, harmonic spectrum, THD, crest , rms value, distortion factor, displacement factor and power factor, output DC voltage average value, peak-peak ripple and ripple factor in 6-pulse uncontrolled rectifiers with (i) resistive load (ii) dc series inductor filter, (iii) dc shunt capacitor filter, and (iv) dc series inductor and shunt capacitor (LC) . Simulate using a software the AC supply voltage and current waveform, Harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor and power factor, output DC voltage average value, peak-peak ripple and ripple factor in 6-pulse uncontrolled rectifiers with (i) resistive load (ii) dc series inductor filter, (iii) dc shunt capacitor filter, and (iv) dc series inductor and shunt capacitor (LC) filter.
4. Study the characteristics of 12-pulse and 24-pulse uncontrolled three-phase bridge rectifiers. AC supply voltage its current waveform, Harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor and power factor, output DC voltage average value, peak-peak ripple and ripple factor in 12-pulse and 24-pulse uncontrolled rectifiers with (i) resistive load (ii) dc shunt capacitor filter.
5. Study the performance of a single-phase AC-DC phase controlled converter.
Record AC supply voltage and current waveform, harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor and power factor, output DC voltage average value, peak-peak ripple and ripple factor in single-phase AC-DC bridge phase controlled converter at two firing angles with resistive (R) and inductive (R-L) loads. Simulate using a software the AC supply voltage and current waveform, Harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor and power factor, output DC voltage average value, peak-peak ripple and ripple factor
6. Study the performance of a DC-AC single-phase inverter with triangular carrier PWM control. AC voltage and current waveform, harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor and power factor, input DC current average value and waveform in DC-AC single-phase inverter.
7. Study the performance of single-phase AC voltage controllers with (i) resistive (R), (ii) resistive-inductive (R-L) and (iii) single-phase motor loads at two firing angles. AC supply voltage, load voltage and current waveform, harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor, active power, reactive power and apparent power and power factor for R and R-L loads.
8. Study the performance of a DC-AC three-phase inverter with PWM control.
AC supply voltage and current waveform, Harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor and power factor, input DC current average value and waveform.

9. Study the performance of 3-phase AC voltage controllers with (i) resistive (R), (ii) three-phase motor loads.
AC supply voltage, load voltage and current waveform, harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor, active power, reactive power and apparent power and power factor for R and motor loads.
10. Study the performance of a DC-DC boost chopper.
DC supply and output voltage and current waveforms, peak-to-peak ripple and ripple factor with R and R-L and R-L-E loads.
11. Study the power quality of lighting devices
Performance of commercially available T-5 fluorescent tubes with (i) magnetic ballast (ii) electronic ballast and (iii) 18W CFL, and (v) 100W incandescent bulb. Record lumens, AC supply voltage and current waveform, harmonic spectrum, THD, crest factor, rms value, distortion factor, displacement factor, active power, reactive power and apparent power and power factor at **three** voltage levels.
12. Study the performance of a DC-DC flyback power supply.
13. Study the performance of a DC-DC buck power supply.
14. Study the performance of a DC-DC boost power supply.
15. Study the performance of a DC-DC buckboost power supply.
16. Study the performance of a DC-DC half bridge power supply.

Sessional work assessment
Regularity – 5 marks
Class work, Lab Record, Mini project Report (if any), viva – 30 marks
Test– 15 marks
Total: Internal continuous assessment: 50 marks

University evaluation
Examination will be for 100 marks of which 70 marks are allotted for writing the procedure/formulae/sample calculation details, preparing the circuit diagram/algorithm/flow chart, conduct of experiment, tabulation, plotting of required graphs, results, inference etc., as per the requirement of the lab experiments, 20 marks for the viva-voce and 10 marks for the lab record.

Note: Duly certified lab record must be submitted at the time of examination

***** *Common to PED 107(P)*

PEL 108 (P) SEMINAR

2 hours practical per week

The student is expected to present a seminar in one of the current topics in the field of specialization and related areas. The student shall prepare a Paper and present a Seminar on any current topic related to the branch of specialization under the guidance of a staff member. The student will undertake a detailed study based on current published papers, journals, books on the chosen subject and submit seminar report at the end of the semester. The student shall submit typed copy of the paper to the Department. Grades will be awarded on the basis of contents of the paper and the presentation. A common format in (.pdf format) shall be given for reports of Seminar and Project. All reports of Seminar and Project submitted by students shall be in this given format.

Sessional work assessment

Presentation : 25

Report : 25

Total marks : 50

PEL 201 SWITCHED MODE POWER CONVERSION

3 hours lecture per week

Objective: *Understand the concepts, basic operation, steady-state operation of efficient switched mode power conversion techniques, including basic circuit operation and magnetics design.*

Design constraints of reactive elements in Power Electronic Systems: Design of inductor, transformer and capacitors for power electronic applications, Input filter requirement.

Basic concepts and steady-state analysis of second and higher order Switched Mode power converters: PWM DC - DC Converters (CCM and DCM) - operating principles, constituent elements, characteristics, comparisons and selection criteria.

Dynamic Modelling and control of second and higher order switched Mode power converters: analysis of converter transfer functions, Design of feedback compensators, current programmed, frequency programmed and critical conduction mode control.

Soft-switching DC - DC Converters: zero-voltage-switching converters, zero-current switching converters, Multi-resonant converters and Load resonant converters.

Pulse Width Modulated Rectifiers: Properties of ideal rectifier, realization of near ideal rectifier, control of the current waveform, single phase and three-phase converter systems incorporating ideal rectifiers and design examples.

Non-linear phenomena in switched mode power converters: Bifurcation and Chaos.

References:

1. Robert W. Erickson and Dragan Maksimovic, 'Fundamentals of Power Electronics', Springer, 2nd Edition, 2001.
2. Marian K. Kazimierczuk, 'Pulse-width Modulated DC-DC Power Converters' John Wiley & Sons Ltd., 1st Edition, 2008.
3. Philip T Krein, 'Elements of Power Electronics', Oxford University Press, 2nd Edition, 2012.
4. Batarseh, 'Power Electronic Circuits', John Wiley, 2nd Edition, 2004.
5. H. W. Whittington, B. W. Flynn, D. E. Macpherson, 'Switched Mode Power Supplies', John Wiley & Sons Inc., 2nd Edition, 1997.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 202 POWER CONVERTERS- II

3 Hours Lecture Per Week

Objective: *To impart knowledge about AC – AC and DC – AC converters*

Single phase and three phase inverters: PWM switching scheme – unipolar and bipolar single phase inverter – three phase inverters – switch utilization – ripple in the inverter output – dc side current – conduction of switches – effect of blanking time – programmed harmonic elimination switching – current mode control

Three level inverter: basic topology and waveform, improvement in harmonics and high voltage application; resonant converters – load resonant converters – series loaded resonant converter - parallel loaded resonant converter – class E converters – resonant switch converter – ZCS and ZVS – resonant dc link inverter with zero voltage switching – high frequency link integral half cycle converter

Cycloconverters: Circuit, operating principle, control, harmonics, power factor and applications;

Industrial PWM driver chips for power supplies - UC 3843, 3825; Industrial gate driver chips for PWM voltage source inverters with isolation and protection circuits.

References:

1. Power electronics Converters, Application and design – Ned Mohan, T M Undeland, William P robbins, John Wiley & Sons 2003
2. Power Electronics – M D Singh, Khanchandani, 2nd Edition, Tata McGraw Hill
3. Fundamentals of Power Electronics, Second Edition, Robert W Erickson, Dragan Maksimovic, Kluwer Academic Publishers
4. Power electronics Principles and Applications – Joseph Vithayathil – Tata McGraw Hill
5. Power Electronics – Cyril W Lander – Tata McGraw Hill

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 202*

PEL 203 DYNAMICS OF ELECTRICAL MACHINES

3 hours lecture per week

Objective: *To understand the basic modelling and designing of machines.*

Unified approach to the analysis of electrical machine performance - per unit system - basic two pole model of rotating machines- Primitive machine -special properties assigned to rotor windings - transformer and rotational voltages in the armature voltage and torque equations resistance, inductance and torque matrix. Transformations - passive linear transformation in machines- invariance of power - transformation from three phase to two phase and from rotating axes to stationary axes-Park's transformation

DC Machines: Application of generalized theory to separately excited, shunt, series and compound machines. Steady state and transient analysis, transfer functions. Sudden short circuit of separately excited generator, sudden application of inertia load to separately excited dc motor.

Synchronous Machines: synchronous machine reactance and time constants-Primitive machine model of synchronous machine with damper windings on both axes. Balanced steady state analysis-power angle curves. Transient analysis- sudden three phase short circuit at generator terminals - armature currents and torque. Determination of reactance and time constants from short circuit oscillogram - Transient power angle curve-Hunting performance-equation of motion of rotor-linearised analysis for small oscillations.

Induction Machines: Primitive machine representation- Steady state operation-Equivalent circuit-Double cage rotor representation - Equivalent circuit -Induction machine dynamics during starting and braking.

References:

1. P.S.Bhimbra, 'Generalized theory of electrical machines’, Khanna Publishers, 2002
2. Charles V. Johnes, 'Unified theory of electrical machine'.
3. Adkins and Harley, 'General theory of ac machines'.
4. C. Concordia, 'Synchronous machines’
5. M. G. Say, ‘Introduction to unified theory of electrical machines'
6. E. W.Kimbark, 'Power System Stability Vol. IIP

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 204 (A) ELECTRO-MECHANICAL SYSTEMS

3 hours lecture per week

Objective: *To develop understanding about the analogy between electrical and mechanical systems.*

Introduction to Electro-Mechanical systems -sensors and transducers- signal conditioning-pneumatic and hydraulic systems- mechanical and electrical systems.

System modeling-mechanical, electrical, fluid and thermal system building blocks-system models- dynamic response of systems- first and second order systems-modeling dynamic systems-systems transfer functions-frequency response stability.

Controllers Closed loop controllers-continuous and discrete processes-proportional, derivative and integral controls-PID controller-digital controllers-controller tuning-adaptive control.

Digital circuits -Micro controllers and micro processors-digital logic circuits-micro controller architecture and programming-programmable logic controllers

References:

1. Dorf R.C. & Bishop R.H., *Modern Control Systems*, Addison Wesley
2. Krishna Kant, *Computer Based Industrial Control*, Prentice Hall of Indian Private Limited
3. HMT Limited, *Mechatronics*, Tata McGraw Hill Publishing Company Limited
4. Herbert Taub & Donald Schilling, *Digital Integrated Electronics*, McGraw Hill International Editions

Text Book

1. Bolton W., *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, Addison Wesley Longman Limited

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 204 (B) SMART GRID TECHNOLOGIES

3 hours lecture per week

Objective: *To develop understanding of power electronic applications in renewable energy*

Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, Concept of Resilient & Self Healing Grid, Present development & International policies in Smart Grid, Diverse perspectives from experts and global Smart Grid initiatives.

Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits,AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit(PMU), Intelligent Electronic Devices(IED) & their application for monitoring & protection.

Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

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

References:

1. Stuart Borlase ‘Smart Grid: Infrastructure, Technology and Solutions’, CRC Press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, ‘Smart Grid: Technology and Applications’, Wiley, 2012.
3. Vehbi C. Güngör, DilanSahin, TaskinKocak, Salih Ergüt, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke, ‘Smart Grid Technologies: Communication Technologies and Standards’ IEEE Transactions On Industrial Informatics, Vol. 7, No. 4, November 2011.
4. Xi Fang, Satyajayant Misra, Guoliang Xue, and Dejun Yang ‘Smart Grid – The New and Improved Power Grid: A Survey’ , IEEE Transaction on Smart Grids.

Question Pattern:

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PEL 204 (C) EMBEDDED SYSTEM DESIGN

3 hours lecture per week

Specifications: requirements – models of computation – state charts – general language characteristics – SDL – Petri nets – Message sequence charts – UML – Process networks – Java – VHDL – System C

Embedded System Hardware: Input – communication – processing units – memories – Output Embedded operating systems, middleware and scheduling: prediction of execution times – scheduling in real-time systems – embedded operating systems – middleware

Implementing embedded systems: task level concurrency management – high level optimizations – hardware/software partitioning – compilers for embedded systems – voltage scaling and power management – actual design flows and tools

Validation: simulation – rapid prototyping and emulation – test – fault simulation – fault injection – risk and dependability analysis – formal verification

References:

1. Peter Marwedel – Embedded system design – Springer – Kluwer Academic Publishers
2. Frank Vahid and Tony Givargis, Embedded System Design: A Unified Hardware/Software Introduction ,John Wiley & Sons.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 204(C)*

PEL 204 (D) PROCESS CONTROL AND AUTOMATION

3 hours lecture per week

Objective: *To understand about automation in industrial applications.*

Process Modeling- Introduction to Process control and process instrumentation-Hierarchies in process control systems-Theoretical models-Transfer function-State space models-Time series models-Development of empirical models from process data-chemical reactor modeling-. Analysis using softwares

Feedback & Feedforward Control- Feedback controllers-PID design, tuning, trouble shooting-Cascade control- Selective control loops-Ratio control-Control system design based on Frequency response Analysis-Direct digital design-Feedforward and ratio control-State feedback control- LQR problem- Pole placement -Simulation using softwares-Control system instrumentation-Control valves- Codes and standards- Preparation of P& I Diagrams.

Advanced process control-Multi-loop and multivariable control-Process Interactions-Singular value analysis-tuning of multi loop PID control systems-decoupling control-strategies for reducing control loop interactions-Real-time optimization-Simulation using softwares

Model predictive control-Batch Process control-Plant-wide control & monitoring- Plant wide control design- Instrumentation for process monitoring-Statistical process control-Introduction to Fuzzy Logic in Process Control-Introduction to OPC-Introduction to environmental issues and sustainable development relating to process industries. Comparison of performance different types of control with examples on softwares

References:

1. Seborg, D.E., T.F. Edgar, and D.A. Mellichamp, Process Dynamics and Control, John Wiley , 2004
2. Johnson D Curtis, Instrumentation Technology, (7th Edition) Prentice Hall India, 2002.
3. Bob Connel, Process Instrumentation Applications Manual, McGrawHill, 1996.
4. Edgar, T.F. & D.M. Himmelblau, Optimization of Chemical Processes, McGrawHill Book Co, 1988.
5. Macari Emir Joe and Michael F Saunders, Environmental Quality Innovative Technologies 7 Sustainable Development, American Society of Civil Engineers, 1997.
6. Nisenfeld(Ed) batch Control, Instrument Society of America, 1996.
7. Sherman, R.E. (Ed), Analytical instrumentation, Instrument Society of America, 1996.
8. Shinskey, F.G., Process Conrol Systems: Applications, Design and Tuning (3rd Edition) McGrawHill Book Co, 1988.
9. B. Wayne Bequette, Process control: modeling, design, and simulation Prentice Hall PTR, 2003
10. K. Krishnaswamy, Process Control, New Age International, 2007

Question Pattern:

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PEL 204 (E) FACTS CONTROLLERS

3 hours lecture per week

Objective: *To develop understanding of FACTS Controllers*

FACTS Concept and General System Considerations . Power Flow in AC System Definitions on FACTS . Basic Types of FACTS Controllers. Converters for Static Compensation. Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM).

GTO Inverters . Multi-Pulse Converters and Interface Magnetics. Transformer Connections for 12 , 24 and 48 pulse operation . Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies (includes SVM) Multi-level inverters of Cascade Type and their modulation. Current Control of Inverters.

Static Shunt Compensators . SVC and STATCOM . Operation and Control of TSC, TCR, STATCOM . Compensator Control. Comparison between SVC and STATCOM. STATCOM for transient and dynamic stability enhancement. Static Series Compensation . GCSC , TSSC , TCSC and SSSC . Operation and Control. External System Control for Series Compensators. SSR and its damping -Static Voltage and Phase Angle Regulators . TCVR and TCPAR . Operation and Control UPFC and IPFC .

The Unified Power Flow Controller . Operation ,Comparison with other FACTS devices, control of P and Q , Dynamic Performance , Special Purpose FACTS Controllers , Interline Power Flow Controller . Operation and Control.

References:

1. Hingorani, Understanding FACTS Controllers.
2. K R Padiyar, FACTS controllers in Power Transmision and Distribution, New Age publications, New Delhi, 2007.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 204(E)*

PEL 205 (A) STATIC VAR CONTROLLERS AND HARMONIC FILTERING

3 hours lecture per week

Fundamentals of Load Compensation , Steady-State Reactive Power Control in Electric Transmission Systems , Reactive Power Compensation and Dynamic Performance of Transmission Systems .

Power Qulity Issues. Sags, Sweels, Unbalance, Flicker, Distortion, Current Harmonics - Sources of Harmonics in Distribution Systems and Ill Effects. Static Reactive Power Compensators and their control. Shunt Compensators, SVCs of Thyristor Switched and Thyristor Controlled types and their control, STATCOMs and their control, Series Compensators of Thyristor Switched and Controlled Type and their Control, SSSC and its Control, Sub-Synchronous Resonance and damping, Use of STATCOMs and SSSCs for Transient and Dynamic Stability Improvement in Power Systems

Converters for Static Compensation. Single Phase and Three Phase Converters and Standard Modulation Strategies (Programmed Harmonic Elimination and SPWM). GTO Inverters. Multi-Pulse Converters and Interface Magnetics. Multi-Level Inverters of Diode Clamped Type and Flying Capacitor Type and suitable modulation strategies (includes SVM) . Multi-level inverters of Cascade Type and their modulation. Current Control of Inverters.

Passive Harmonic Filtering. Single Phase Shunt Current Injection Type Filter and its Control, Three Phase Three-wire Shunt Active Filtering and their control using p-q theory and d-q modelling. Three-phase four-wire shunt active filters. Hybrid Filtering using Shunt Active Filters. Series Active Filtering in Harmonic Cancellation Mode. Series Active Filtering in Harmonic Isolation Mode. Dynamic Voltage Restorer and its control. Power Quality Conditioner

References:

1. T.J.E Miller Reactive Power Control in Electric Systems John Wiley & Sons,1982.
2. N.G. Hingorani & L. Gyugyi Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. IEEE Press, 2000.
3. Ned Mohan et.al Power Electronics. John Wiley and Sons 2006

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 205 (B) INDUSTRIAL CONTROL ELECTRONICS

3 hours lecture per week

Review of switching regulators and switch mode power supplies-Uninterrupted power supplies-solid state circuit breakers – programmable logic controllers

Analog Controllers - Proportional controllers, Proportional – Integral controllers, PID controllers, Feed forward control

Signal conditioners-Instrumentation amplifiers – voltage to current, current to voltage, voltage to frequency, frequency to voltage converters ; Isolation circuits – cabling; magnetic and electro static shielding and grounding.

Opto-Electronic devices and control , Applications of opto isolation, interrupter modules and photo sensors – Fibre optics – Bar code equipment, application of barcode in industry.

Stepper motors and servo motors- control and applications. Servo motors – servo motor controllers – servo amplifiers – selection of servo motor – applications of servo motors.

References:

1. Michael Jacob, 'Industrial Control Electronics – Applications and Design', Prentice Hall, 1988.
2. Thomas, E. Kissel, ' Industrial Electronics'PHI, 2003
3. James Maas, 'Industrial Electronics', Prentice Hall, 1995.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 205(C) POWER ELECTRONIC APPLICATIONS IN RENEWABLE ENERGY SYSTEMS

3 hours lecture per week

Objective: *To develop understanding of power electronic applications in renewable energy*

General aspects of renewable energy technology- wind, solar, small/micro hydro, fuel cell, geothermal, OTEC, wave, nuclear fusion.

General Power electronics- dc to dc converters, ac-dc conversion, dc to ac conversion, ac to ac conversion-matrix converters

Wind Energy: Grid connected-Fixed speed and variable speed wind turbines, Type A, type B, type C, type D-induction generators-SCIG, WRIG, DFIG,WRSG and PMSG- soft starter-frequency converters-wind farms. Stand alone wind energy conversion systems-voltage and frequency controllers—Induction generator-PMSG.

Photovoltaic: Residential PV systems- battery-inverter -grid connected systems.
Small/micro hydro: grid and standalone systems
Fuel cells: Low power and high power fuel cells.

Energy Storage systems for advanced power application: superconducting magnetic energy storage (SMES), battery energy storage systems (BESS), Ultra capacitors, Flywheel energy storage (FES) and their applications.
Hybrid Generation systems: hybrid systems-micro grid-control
Future of power electronics technology: device-packaging-circuit and control.

References:

1. D P Kothari and Nagrath, "Modern Power System Analysis", Mcgraw Hill, , Chapter 1, 2011.
2. Thomas Ackerman, "Wind power in power systems", John Wiley& Sons, Chapter 4, London, 2005..
3. M G Simoes and F A Farret, "Alternate energy systems,"CRC Press, ,Chapter 7, London,2008.
4. J P Lyons and V Vlatkovic, "power electronics and alternative energy generation", in proc IEEE power electronics specialist conference, vol.1, no 1, pp.16-21, Aachen 2004.
5. P F Rebeiro, B K Jhonson, M L Crow, A Arsoy and Y Liu, "Energy Storage systems for advanced power application", in proc IEEE conf. vol.89, no 12, Dec. 2001.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 205(C)*

PEL 205 (D) ENERGY CONSERVATION

3 hours lecture per week

Objective: *To understand electric the need of energy conservation and the road to achieve it*

Potential for Industrial energy conservation- Economic analysis of investments- simple payback period- NPV- IRR.

Motors: Operational-retrofit-energy efficient motors-pf correction and variable speed drives

Lighting, Electric load management, power quality, Energy management information systems

Boilers, Compressors, Steam distribution, Refrigeration:

Pumps, Fans and blowers, Cooling tower, Industrial furnaces, Diesel generator Water audit and conservation Solar energy options for industries Energy, climate change and clean development mechanism Future cleaner energy options

References:

Handbook on energy audit and environment management, Y P Abbi, Shashank jain, TERI press, New delhi-2006.

Further reading:

1. Energy management policy: guidelines for energy intensive industry, ministry of power, GOI, 2003.(available at www.bee-india.nic.in)
2. Compressed air systems, TERI, 1999.
3. Renewable energy resources, TERI, 2004
4. Power generation and diesel gen-sets, PCRA, New Delhi
5. Energy conservation using electric drives, B K Bose

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature

***** *Common to PED 205(D)*

PEL 205 (E) COMPUTER CONTROLLED SYSTEMS

3 hours lecture per week

Objective: *To develop understanding of the principles of computer control in physical systems*

Sampling of continuous time signals, discrete time systems model, process oriented models, analysis of discrete time systems, disturbance models
Design approaches, translation of analog design, state space design methods, pole placement design based on input-output models
Optimal design methods: state space approach, input-output approach, identification, adaptive control, implementation of digital controllers.

References:

1 Karl J Astrom, Bjorn Wittenmark, Computer Controlled Systems, 2nd Edition – Prentice Hall International

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 205(E)*

PEL 206 (A) ARTIFICIAL NEURAL NETWORKS AND FUZZY SYSTEMS

3 hours lecture per week

Objective: *To develop understanding of applications of artificial neural networks and fuzzy systems*

Biological foundations, ANN models, Types of activation function, Introduction to Network architectures: Multi Layer Feed Forward Network (MLFFN), Radial Basis Function Network (RBFN), Recurring Neural Network (RNN)

Learning process. Supervised and unsupervised learning. Error-correction learning, Hebbian learning, Boltzmen learning, Single layer and multilayer percepturs, Least mean square algorithm, Back propagation algorithm, Applications in forecasting and pattern recognition and other engineering problems.

Fuzzy sets. Fuzzy set operations. Properties, Membership functions, Fuzzy to crisp conversion. fuzzification and defuzzification methods, applications in engineering problems.

Fuzzy control systems . Introduction, simple fuzzy logic controllers with examples, special forms of fuzzy logic models, classical fuzzy control problems. inverter pendulum, image processing . home heating system. Adaptive fuzzy systems, hybrid systems.

References:

1. J.M. Zurada, .Introduction to artificial neural systems, Jaico Publishers, 1992.
2. Simon Haykins, .Neural Networks . A comprehensive foundation, Macmillan College, Proc, Con, Inc, New York, 1994.
3. D. Driankov, H. Hellendorn, M. Reinfrank, .Fuzzy Control . An Introduction. , Narora Publishing House, New Delhi, 1993.
4. H.J. Zimmermann, .Fuzzy set theory and its applications, III Edition, Kluwer Academic Publishers, London. 2001
5. G.J. Klir, Boyuan, .Fuzzy sets and fuzzy logic, Prentice Hall of India (P) Ltd., 1997.
6. Stamatios V Kartalopoulos, .Understanding neural networks and fuzzy logic .basic concepts and applications., Prentice Hall of India (P) Ltd., New Delhi, 2000.
7. Timothy J. Ross, .Fuzzy logic with engineering applications, McGraw Hill, New York.
8. Suran Goonatilake, Sukhdev Khebbal (Eds), .Intelligent hybrid systems., John Wiley & Sons, New York, 1995.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 206(A)*

PEL 206 (B) ROBOTICS AND AUTOMATION

3 hours lecture per week

Geometric configuration of robots – Manipulators – Drive systems – Internal and external sensors-– End effectors – Control systems – Robot programming languages and applications – Introduction to robotic vision

Direct and inverse kinematics – Rotation matrices – Composite rotation matrices – Euler angle-representation – Homogenous transformation – Denavit Hattenberg representation and various arm configurations.

Lagrange – Euler formulation, joint velocities – Kinetic energy – Potential energy and motion-equations – Generalized D'Alembert equations of motion.

General consideration on trajectory planning joint interpolation & Cartesian path trajectories.- Control of Robot Manipulators-PID control computed, torque technique – Near minimum time control – Variable structure control – Non-linear decoupled feedback control – Resolved motion control and adaptive control.

References:

1. Fu K S, Gonazlez R C and Lee C S G, Robotics (Control, Sensing, Vision and Intelligence), McGraw-Hill, 1987.
2. Wesley, E Sryda, Industrial Robots: Computer Interfacing and Control. PHI, 1985.
3. Asada and Slotine, Robot Analysis and Control, John Wiley and Sons, 1986.
4. Philippe Coiffet, Robot Technology, Vol. II (Modeling and Control), Prentice Hall INC, 1981.
5. Saeed B Niku, Introduction to Robotics, Analysis, Systems and Applications, Pearson Education, 2002.

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

PEL 206 (C) ENERGY MANAGEMENT

3 hours lecture per week

Objective: *To develop understanding of management techniques to efficiently utilize energy*

Importance of energy management. Energy auditing: methodology System approach and End use approach to efficient use of Electricity; Electricity tariff types; Types and objectives-audit instruments- ECO assessment and Economic methods-specific energy analysis-Minimum energy paths-consumption models-Case study. Demand side management.

Electric motors- Energy efficient controls and starting -Motor Efficiency and Load Analysis- Energy efficient motors-Case study; Load Matching and selection of motors.

Variable speed drives; Pumps and Fans-Efficient Control strategies- Optimal selection and sizing -Case study

Reactive Power management-Capacitor Sizing-Degree of Compensation-Capacitor losses- Location-Placement-Maintenance, case study. Peak Demand controls- Methodologies- Types of Industrial loads-Optimal Load scheduling-case study.

Lighting- Energy efficient light sources-Energy conservation in Lighting Schemes- Electronic ballast-Power quality issues-Luminaries, case study.

Energy conservation in Pumps, Fans (flow control), Compressed Air Systems, Refrigeration & air conditioning systems. Boiler -efficiency testing, excess air control, Steam distribution & use- steam traps, condensate recovery, flash steam utilization

Cogeneration-Types and Schemes-Optimal operation of cogeneration plants-case study; electric loads of Air conditioning & Refrigeration-Energy conservation measures- Cool storage. Types- Optimal operation-case study; Electric water heating-Gysers-Solar Water- Heaters- Power Consumption in Compressors, Energy conservation measures

References:

1. Handbook on Energy Audit and Environment Management , Y P Abbi and Shashank Jain, TERI, 2006
2. Utilization, Generation & Conservation of Electrical Energy, Sunil S.Rao, Khanna publishers, 2007.
3. Anthony J. Pansini, Kenneth D. Smalling, .Guide to Electric Load Management., Pennwell Pub; (1998)
4. Partab H., 'Art and Science of Utilisation of Electrical Energy', Dhanpat Rai and Sons, 1975
5. Tripathy S.C.,'Electric Energy Utilization And Conservation', Tata McGraw Hill, 1991
6. L.C.Witte, P.S.Schmidt, D.R.Brown , Industrial Energy Management and Utilisation, Hemisphere Publ, Washington,1988.
7. Industrial Energy Conservation Manuals, MIT Press, Mass, 1982.
8. Guide Book for National Certification Examination for Energy Managers & Energy Auditors – Bureau of Energy Efficiency, Ministry of Power, Govt of India. (Author), William J. Kennedy, Fairmont Press; 6 edition (April 23, 2008)

Question Pattern:

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***** *Common to PED 206(C)*

PEL 206 (D) DATA ACQUISITION AND SIGNAL CONTROL

3 hours lecture per week

Transducers & Signal Conditioning

Data Acquisition Systems(DAS)- Introduction . Objectives of DAS . Block Diagram Description of DAS- General configurations - Single and multichannel DAS-Transducers for the measurement of motion, force, pressure, flow, level, dc and ac voltages and currents (CTs, PTs for supply frequency as well as high frequency, Hall Effect Current Sensors, High Voltage Sensors , Optosensors, Rogowski Coil, Ampflex Sensors etc.) - Signal Conditioning: Requirements - Instrumentation amplifiers: Basic characteristics . Chopped and Modulated DC Amplifiers-Isolation amplifiers - Opto couplers - Buffer amplifiers .Noise Reduction Techniques in Signal Conditioning- Transmitters .Optical Fiber Based Signal Transmission-Piezoelectric Couplers- Intelligent transmitters.

Filtering and Sampling

Review of Nyquist.s Sampling Theorem-Aliasing . Need for Prefiltering-First and second order filters - classification and types of filters - Low -pass, High-pass, Band-pass and Band-rejection and All Pass: Butterworth, Bessel, Chebyshev and Elliptic filters . Opamp RC Circuits for Second Order Sections-Design of Higher Order Filters using second order sections using Butterworth Approximation-Narrow Bandpass and Notch Filters and their application in DAS. Sample and Hold Amplifiers

Signal Conversion and Transmission

Analog-to-Digital Converters(ADC)-Multiplexers and demultiplexers - Digital multiplexer . A/D Conversion . Conversion Processes , Speed, Quantization Errors . Successive Approximation ADC . Dual Slope ADC . Flash ADC . Digital-to-Analog Conversion(DAC) . Techniques, Speed, Conversion Errors, Post Filtering- Weighted Resistor, R-2R, Weighted Current type of DACs- Multiplying Type DAC-Bipolar DACs- Data transmission systems-Schmitt Trigger-Pulse code formats- Modulation techniques and systems-Telemetry systems.

Digital Signal Transmission And Interfacing

DAS Boards-Introduction . Study of a representative DAS Board-Interfacing Issues with DAS Boards, I/O vs Memory Addressing, Software Drivers, Virtual Instruments, Modular Programming Techniques for Robust Systems, Bus standard for communication between instruments - GPIB (IEEE-488bus) - RS-232C- USB-4-to-20mA current loop serial communication systems.Communication via parallel port . Interrupt-based Data Acquisition.Software Design Strategies-Hardware Vs Software Interrupts-Foreground/ background Programming Techniques- Limitations of Polling . Circular Queues

References:

1. Ernest O Doeblin., Measurement Systems: Application and Design, McGraw Hill (Int. edition) 1990
2. George C.Barney, Intelligent Instrumentation, Prentice Hall of India Pvt Ltd., New Delhi, 1988.
3. Ibrahim, K.E., Instruments and Automatic Test Equipment, Longman Scientific & Technical Group Ltd., UK, 1988.
4. John Uffrenbeck, The 80x86 Family ,Design, Programming, And Interfacing, Pearson Education , Asia, 2002
5. Bates Paul, Practical digital and Data Communications with LSI, Prentice Hall of India, 1987.
6. G.B. Clayton, .Operational Amplifiers, Butterworth &Co, 1992
7. A.K Ray, Advanced Microprocessors and Peripherals, Tata McGrawHill, 1991

8. Oliver Cage, .Electronic Measurements and Instrumentation., McGraw-Hill, (Int. edition) 1975

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PEL 206 (E) ELECTRIC VEHICLES

3 hours lecture per week

Objective: *To understand electric vehicles and to develop design skills for electric vehicles*

Fundamentals of Vehicle Propulsion and Brake: - Vehicle Resistance - Dynamic Equation -Tire–Ground Adhesion and Maximum Tractive Effort - Power Train Tractive Effort and Vehicle Speed - Vehicle Power Plant and Transmission Characteristics – Vehicle Performance

Internal Combustion Engines – 4 stroke spark ignited and compression ignited engines – 2 stroke engines – Wankel rotary engines – strirling engines – gas turbine engines – quasi isothermal brayton cycle engines

Electric vehicles: configuration – performance – tractive effort in normal driving – energy consumption

Hybrid electric vehicles: series and parallel electric drive trains
Electric propulsion systems: DC motor drives – Induction motor drives – permanent magnet BLDC motor drives – SRM drives – SRM design
Parallel (Mechanically Coupled) Hybrid Electric Drive Train Design - Design and Control Methodology of Series–Parallel (Torque and Speed Coupling) Hybrid Drive Train -

Statistics of Daily Driving Distance - Energy Management Strategy - Energy Consumed in Braking and Transmission - Regenerative Breaking - Control Strategy for Optimal Energy Recovery

Fuel Cells - Fuel Cell Hybrid Electric Drive Train Design - Power and Energy Design of Energy Storage

References:

1. Modern Electric Vehicles, Hybrid Electric and Fuel Cell Vehicles – 2nd Edition – Meherdad Ehsani, Yimin Gao, Ali Emadi – CRC Press
2. Electric Vehicle Technology Explained – James Larminie, John Lowry – John Wiley & Sons

Question Pattern:

There would be 7 questions out of which 5 should be answered. Each question would carry 20 marks each. Each question shall carry a maximum of four sub sections which can have uneven distribution of marks. The questions would touch upon all the sections of the syllabus as far as possible and would preferably be analytic in nature.

***** *Common to PED 206(E)*

PEL 207 (P) POWER ELECTRONICS AND CONTROL LAB

2 hours practical per week

Objective: *To enable the students gain sufficient knowledge on the programming, simulation and control of Electrical circuits, Power Electronics Systems and Electric Drives.*

List of Experiments:

1. Transient response of RLC circuits
a. Response to Pulse input
b. Response to step input
2. Study of single phase full converter using RL&E loads and single phase AC voltage controller using RL&E loads.
3. DC motor characteristics.
4. Plotting of bode plots, root locus and Nyquist plots for the transfer functions of systems up to 5th order.
6. Rectifier fed DC Motor drive.
7. Three phase AC voltage control with PWM control.
8. Transfer function analysis of a given circuit.
9. Resonant pulse commutation circuit and buck chopper.
10.Single phase inverter with PWM control.
11. Multi-Pulse converter.
12. Dual Converters.
13. Three phase Cycloconverter.
14. Chopper controlled DC Motor.
15. Speed control of BLDC motor by using MATLAB/SIMULINK.
16. Improvement of power quality in transmission lines by using STATCOM using MATLAB/SIMULINK.
17. Simulative analysis of the following using ORCAD/MULTISIM/PROTEUS software.
    a) Single-Phase Diode-Bridge Rectifiers
    b) Three-Phase Diode-Bridge Rectifiers
    c) Step-Down (Buck) DC-DC Converters
    d) Step-Up (Boost) DC-DC Converter
    e) Step-Down/Up (Buck-Boost) DC-DC Converter in CCM

Sessional work assessment
Regularity – 5 marks
Class work, Lab Record, Mini project Report (if any), viva – 30 marks
Test – 15 marks
Total: Internal continuous assessment: 50 marks
University evaluation
Examination will be for 100 marks of which 70 marks are allotted for writing the procedure / formulae / sample calculation details, preparing the circuit diagram / algorithm / flow chart, conduct of experiment, tabulation, plotting of required graphs, results, inference etc., as per the requirement of the lab experiments, 20 marks for the viva-voce and 10 marks for the lab record.

Note: Duly certified lab record must be submitted at the time of examination

PEL 208 (P) TERM PAPER

2 hours practical per week

The student is expected to present a report on the literature survey conducted as a prior requirement for the project to be taken up in the third and fourth semesters. Head of department can combine TP hours of many weeks and allot a maximum of 4 weeks exclusively for it. Students should execute the project work using the facilities of the institute. However, external projects can be taken up, if that work solves a technical problem of the external firm. Prior sanction should be obtained from the head of department before taking up external project work. Project evaluation committee should study the feasibility of each project work before giving consent. An overview on the project work should be introduced before the closure of first semester. A paper should be prepared based on the project results and is to be published in refereed Conferences/ Journals.

Sessional work assessment

Presentation : 25

Report : 25

Total marks : 50

PEL 301 (P) THESIS PRELIMINARY

This shall comprise of two seminars and submission of an interim thesis report. This report shall be evaluated by the evaluation committee. The fourth semester Thesis-Final shall be an extension of this work in the same area. The first seminar would highlight the topic, objectives, methodology and expected results. The first seminar shall be conducted in the first half of this semester. The second seminar is presentation of the interim thesis report of the work completed and scope of the work which is to be accomplished in the fourth semester.

Weightages for the 8 credits allotted for the Thesis-Preliminary

Evaluation of the Thesis-Preliminary work: by the guide - 50% (200 Marks)

Evaluation of the Thesis–Preliminary work: by the Evaluation Committee-50% (200 Marks)

PEL 401(P) THESIS

Towards the end of the semester there shall be a pre submission seminar to assess the quality and quantum of the work by the evaluation committee. This shall consists of a brief presentation of Third semester interim thesis report and the work done during the fourth semester. At least one technical paper is to be prepared for possible publication in journals / conferences. The final evaluation of the thesis shall be an external evaluation. The 12 credits allotted for the Thesis-Final may be proportionally distributed between external and internal evaluation as follows.

Weightages for the 12 credits allotted for the Thesis

Internal Evaluation of the Thesis work: by the guide - (200 Marks)

Internal Evaluation of the Thesis work: by the Evaluation Committee - (200 Marks)

Final Evaluation of the Thesis work by the Internal and External Examiners:-

(Evaluation of Thesis + Viva Voce) - (100+100 Marks)

Reg.No............

Name..............

I Semester M.Tech Degree(Reg./Sup.) Examination

POWER ELECTRONICS

PE1101 Mathematical Methods For Power Engineering

Time : 3 Hours Max.Marks : 100

1. Solve the following LPP

$$Maximize\ \ Z = 2x_1 + x_2 + 3x_3$$
$$subject\ to\ \ x_1 + x_2 + 2x_3 \leq 5$$
$$2x_1 + 3x_2 + 4x_3 = 12$$
$$x_1,\ x_2,\ x_3 \geq 0$$

20 *marks*

2. Define subspace. A non-empty subset U of a vector space V over a field F is a subspace of V if and only if

   (a) for every $x, y \in U$, $x + y \in U$ and

   (b) for every $x \in V$ and $a \in F$, $ax \in U$.

20 *marks*

3. Define basis, dimension and kernel. Let $F : R^4 \longrightarrow R^3$ be a linear map defined by $F(x, y, s, t) = (x-y+s+t, x+2s-t, x+y+3s-3t)$. Find the basis and dimension of the

   (a) image U of F

   (b) kernel W of F

20 *marks*

4. The joint pdf of a two dimensional discrete random variable (X, Y) is given below,

	X					
Y	0	1	2	3	4	5
0	0	0.01	0.03	0.05	0.07	0.09
1	0.01	0.02	0.04	0.05	0.06	0.08
2	0.01	0.03	0.05	0.05	0.05	0.06
3	0.01	0.02	0.04	0.06	0.06	0.05

   (a) Find $P(X, Y)$ and $P(max(X, Y) = 3)$

(b) Find the probability distribution of the random variable $Z = min(X, Y)$

20 *marks*

5. (a) If the joint pdf of a two dimensional random variable (X, Y) is given by

$$f(x) = \begin{cases} k(6 - x - y), & o < x < 2, \quad 2 < y < 4 \\ 0, & elsewhere \end{cases}$$ Find

i. value of k

ii. $P(X < 1, Y < 3)$

iii. $P(X + Y < 3)$

iv. $P(X < 1/Y < 3)$

10 *marks*

(b) The joint probability mass function of (X, Y) is given by $p(x, y) = k(2x + 3y)$, $x = 0, 1, 2;$ $y = 1, 2, 3.$ Find all the marginal distributions and also the probability distribution of $(X + Y)$

	y		
X	1	2	3
0	3k	6k	9k
1	5k	8k	11k
2	7k	10k	13k

10 *marks*

6. A firm produces products A and B and sells them at a profit of Rs.2 and Rs.3 each respectively. Each product is processed on machines G and H. Product A requires 1 minute on G and 2 minute of H whereas product B requires 1 minute on each of the machines. Machine G is not available for more than 6 hour.40 minute per day whereas the time constraint for machine H is 10 hours. Solve the problem.

20 *marks*

7. (a) State and prove Cayley-Hamilton theorem.

10 *marks*

(b) Show that the feasible solution $x_1 = 0 \quad x_2 = 0, \quad x_3 = 1 \quad and \quad Z = 6$

to the system of equations

$x_1 + x_2 + x_3 = 2$

$x_1 - x_2 + x_3 = 2$

with *Maximize* $Z = 2x_1 + 3x_2 + 4x_3$ is not basic.

10 *marks*

Reg.No............

Name...............

I Semester M.Tech Degree(Reg./Sup.) Examination

POWER ELECTRONICS

PE1101 Mathematical Methods For Power Engineering

Time : 3 Hours Max.Marks : 100

1. (a) Define vector space and give one example.

5 marks

(b) Show that the feasible solution
$x_1 = 0 \quad x_2 = 0, \quad x_3 = 1 \quad and \quad Z = 6$
to the system of equations
$x_1 + x_2 + x_3 = 2$
$x_1 - x_2 + x_3 = 2$
with $Maximize \quad Z = 2x_1 + 3x_2 + 4x_3$ is not basic.

15 marks

2. (a) Define subspace. A non-empty subset U of a vector space V over a field F is a subspace of V if and only if

   i. for every $x, y \in U$, $x + y \in U$ and

   ii. for every $x \in V$ and $a \in F$, $ax \in U$.

8 marks

(b) A firm produces two types of produces A and B through two machines P and Q and A needs 2 hours of P and 2 hours of Q and B needs 3 hours of P and 1 hour of Q. Machine P can run at least for 24 hours per day. Machine Q can run atleast for 16 hours per day. If profit from A and M are Rs. 4 and Rs. 5 per unit respectively. Use simplex method and solve for maximum profit.

12 marks

3. The joint pdf of a two dimensional discrete random variable (X, Y) is given below,

	X					
Y	0	1	2	3	4	5
0	0	0.01	0.03	0.05	0.07	0.09
1	0.01	0.02	0.04	0.05	0.06	0.08
2	0.01	0.03	0.05	0.05	0.05	0.06
3	0.01	0.02	0.04	0.06	0.06	0.05

(a) Find $P(X,Y)$ and $P(max(X,Y)=3)$

(b) Find the probability distribution of the random variable $Z = min(X,Y)$

20 marks

4. Solve the following LPP using the method of penalties

$$\begin{aligned} &Minimize\ \ Z = 4x_1 + 3x_2 + x_3 \\ &subject\ to\ \ x_1 + 2x_2 + 4x_3 \geq 12 \\ &\qquad 3x_1 + 2x_2 + x_3 \geq 8 \\ &\qquad x_1,\ x_2,\ x_3 \geq 0 \end{aligned}$$

20 marks

5. (a) Define the following with examples

   i. Random variable in discrete case
   ii. Random variable in continuous case
   iii. Probability mass function
   iv. Probability density of a continuous random variable
   v. Cumulative distribution function

10 marks

(b) Verify whether $f(x) = \begin{cases} |x|, & -1 \leq x \leq 1 \\ 0, & elsewhere \end{cases}$ can be a pdf of a random variable.

10 marks

6. The input to a binary communication system, denoted by a random variable X, takes one of two values 0 and 1 with probability 3/4 and 1/4 respectively. Because of the errors caused by noise in the system the output Y differs from the input occasionally. The behavior of the communication system is modeled by the conditional probabilities given below,
$P(Y = 1/X = 1) = 3/4$ and $P(Y = 0/X = 0) = 7/8$
Find

   (a) $P(Y = 1)$
   (b) $P(Y = 0)$
   (c) $P(X = 1/Y = 1)$

20 marks

7. State and prove rank nullity theorem.

20 marks

Reg.No...........

Name...............

I Semester M.Tech Degree(Reg./Sup.) Examination

POWER ELECTRONICS

PEL101 Mathematical Methods For Power Engineering

Time : 3 Hours Max.Marks : 100

1. State and prove rank-nullity theorem

20 *marks*

2. (a) Let T be the linear operator on R^3 defined by $T(x,y,z) = (2y+z, x-4y, 3x)$. Find the matrix of T in the basis $\{f_1 = (1,1,1), f_2 = (1,1,0), f_3 = (1,0,0)\}$.

10 *marks*

(b) Let F be a field and S, be any non-empty set. Then the set V of all functions from S into F be defined by, $(f+g)(x) = f(x) + g(x)$ and $(af)(x) = af(x)$, $f, g \in V$ and $a \in F$. Prove that V is a vector space.

10 *marks*

3. Define basis, dimension and kernel. Let $F : R^4 \longrightarrow R^3$ be a linear map defined by $F(x,y,s,t) = (x-y+s+t, x+2s-t, x+y+3s-3t)$. Find the basis and dimension of the

(a) image U of F

(b) kernel W of F

20 *marks*

4. State and prove Cayley-Hamilton theorem.

20 *marks*

5. A firm can produce three types A,B and C of cloths using three kinds, red, green and blue wool. One unit length of type A cloth need 2 meters of red wool and 3 meters of blue wool. One unit length of type B cloth need 3 meters of red wool, 2 meters of

green wool and 2 meters of blue wool. One unit of type C cloth need 5 meters of green wool and 3 meters of blue wool. The firm has only a stock of 8 meters of red wool, 10 meters of green wool and 15 meters of blue wool. It is assumed that the income obtained from unit length of type A cloth is Rs.3, of type B cloth is Rs.5 and of type C cloth Rs.4. Formulate the problem and solve for the maximum income from the cloth produced.

20 *marks*

6. The joint probability mass function of (X, Y) is given by $p(x, y) = k(2x + 3y)$, $x = 0, 1, 2$; $y = 1, 2, 3$. Find all the marginal distributions and also the probability distribution of $(X + Y)$

	y		
X	1	2	3
0	3k	6k	9k
1	5k	8k	11k
2	7k	10k	13k

20 *marks*

7. Solve the following

$$\begin{aligned} &Maximize \quad Z = 4x_1 + 3x_2 + 4x_3 + 6x_4 \\ &subject\ to \quad x_1 + 2x_2 + 2x_3 + 4x_4 \leq 80 \\ &\qquad 2x_1 + 2x_3 + x_4 \leq 60 \\ &\qquad 3x_1 + 3x_2 + x_3 + x_4 \leq 80 \\ &\qquad x_1,\ x_2,\ x_3,\ x_4 \geq 0 \end{aligned}$$

20 *marks*

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I Semester M.Tech. Degree (Reg./Sup.) Examination

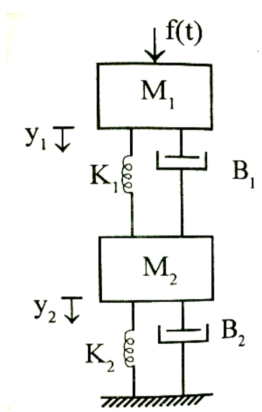
POWER ELECTRONICS

PEL102: SYSTEM THEORY

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	Construct two different state models for the system with transfer function **Y(S)/U(S) =S^3+8S^2+17S+8 / (S+1) (S+2)(S+3)**	20
2	a) Define state variable, state vector ,state space	5
	b) Derive the state model of the system	15



3 Check the stability of the systems described by

a) $\dot{X}1 = X_2$ 10

$\dot{X}2 = -X_1 - X_1^2 X_2$

b) $\dot{X}1 = -X_1 - X_2 - X_2^3$ 10

$\dot{X}2 = -3X_1 + X_2$

4 a) Explain the different types of equilibrium points of a non – linear systems 10

b) A linear autonomous system is described by the state equation 10

$\dot{X} = AX$ where $A = \begin{bmatrix} -2k & 4k \\ 4k & -6k \end{bmatrix}$

Find the restrictions on the parameter K to guarantee stability of the system

5 a) A two input linear system has the following system matrices 15

$A = \begin{bmatrix} 0 & 1 \\ 7 & -4 \end{bmatrix}$ $B = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ $C = [1\ 0]$

Find state feedback gain matrices such that the poles of the closed loop systems are at S=- 1 and S= -2

b) State Controllability and Observability of the system. 5

6 Explain the following optimal control problems 20

(1).Minimum time problem

(2). Minimum energy problem

(3).Minimum fuel problem

(4). Tracking problem

7 Consider the system described by $dy/dt = -y+u$ with performance index $J = \int_0^\infty (y^2+u^2)dt$. Use reduced matrix Riccattic equation for designing the optimal regulator 20

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL102: SYSTEM THEORY

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	Obtain the state model of the given system **$(2Z^3+Z^2+Z+2)/(Z^3+4Z^2+5Z+2)$**	
	I)Phase variable form	10
	2)Canonical form	10
2	Consider the system described by $\dot{Y}=(-y+u)$ having performance index $J=\int_0^\infty (y^2+u^2)dt$ use Riccatti Equation and design the optimal regulator	20
3	Explain the following optimal control problems (1).Minimum time problem (2). Minimum energy problem (3).Minimum fuel problem (4). Tracking problem	20
4	a) Check the stability of the non linear systems described by	

$\dot{X}1 = -6X_1 + 2X_2$ 15

$\dot{X}2 = -2X_1 - 6X_2 - 2X_2^2$

Find the stability of the system by the use of Krasovski's method

b) Explain asymptotic stability and instability in terms of Lyapunov 5

5 a) Explain the different types of equilibrium points of a non – linear systems 10

b) Explain the condition for complete state controllability and Observability 10

6 Determine the optimal control law for the system 20

$\dot{X} = \begin{bmatrix} 0 & 1 \\ 0 & -1 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$ with the performance measure to be minimized as $J = \int_0^{\infty} (x^2 + u^2)\, dt$ use Lyapunov's method

7 Check the stability of the systems described by

a) $\dot{X}1 = X_2$ 10

$\dot{X}2 = -X_1 - X_1^2 X_2$

b) $\dot{X}1 = -X_1 - X_2 - X_2^3$ 10

$\dot{X}2 = -3X_1 + X_2$

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL102: SYSTEM THEORY

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	Obtain the state model of the given system **$(2s^3+s^2+s+2)/(s^3+4s^2+5s+2)$**	
	I)Phase variable form	10
	2)Canonical form	10
2	a) Consider the discrete system given by Y(K+2)+5Y(K)+6Y(K)=U(K) obtain the state model of the system.	15
	b) Explain about Robust Control System.	5
3		
	a) A regulator system has a plant Y(s)/U(s)=10/ (s+1)(s+2)(S+3), by use of state feedback control u=-k x. It is desired to place the closed loop poles at s=-2+j2 , s=-2-j2 , s=-10.Determine the necessary state feedback gain matrix	15
	b) Explain Reduced Matrix Riccattic equation.	5
4	Consider the non linear systems described by a) $\dot{X}1$ = - $2X_1$	20

$\dot{X}_2 = -2X_2 + 2X_1X_2^2$

Find the stability of the system by the use of Krasovski's method

5 Explain the different types of equilibrium points of a non –linear systems 10

Explain the following 1.Robust control system 2. Tracking problem 10

6 A two input linear system has the following system matrices 20

$$A=\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix} \quad B=\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \quad C=[0 \ \ 0 \ \ 1]$$

Check the controllability and Observability of the system

7 Consider the control system defined by

$$\dot{X} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$ using the control law $u=-k_1x_1 - k_2x_2$.

Determine the constants k_1, k_2 so that the following performance index is minimised as $J=\int_0^\infty (x^T x)\,dt$. 20

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL103: Power Electronic Drives

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer **any five full** questions*

Question No		*Marks*
1	a) What is mean by load equalization?	5
	b) Find the value of moment of inertia of flywheel required for load equalization	15
2	a) Write note on steady state stability of electric drive	12
	b) Obtain the equilibrium points and determine their steady state stability when motor and load torque are $T=(1+2\omega)$ and $T_l = 3\sqrt{\omega}$	8
3	With derivations and block diagram explain the following controllers for dc motor. i) speed controller ii) current controller	20
4	a) A 440 V,50Hz, 4 pole, 1415 rpm, delta connected squirrel cage induction motor has the following parameter: Rs=0.6 Ω, Rr'=0.8 Ω, Xr'=0.6 Ω, Xm=15Ω Motor is fed from a current source inverter at a constant flux. Determine i) Motor torque , speed and current when operating at 40Hz and rated slip speed. ii) Inverter frequency and stator current for the rated motor torque and a motor speed of 1000 rpm.	12
	b) Why stator voltage control is an inefficient method of induction motor speed control.	8

5	a) Explain the causes of harmonics in induction motor drives	5
	b) Explain time harmonics and space harmonics in Induction motor.	10
6	a) Explain VSI fed induction motor drive.	10
	b) Explain CSI fed induction motor drive.	10
7	Describe self control and separately controlled synchronous motor fed from VSI.	20

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL103: Power Electronic Drives

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	a) With block diagram explain different parts of electric drive	12
	b) What are the different advantages of electric drive?	8
2	a) Explain different breaking mechanisms in DC motor	5
	b) Explain chopper control of DC motor drive	15
3	a) A 220V ,1500 rpm, 10A, separately excited DC motor is fed from a single phase fully controlled rectifier with an ac source voltage of 230V, 50Hz,Ra= 2Ω.Conduction can be assumed to be continuous. Calculate the firing angle for (i) Half the rated motor torque and 500rpm. (ii) Rated motor torque and (-1000 rpm)	10
	b) Find the equivalent values of drive parameters for rotational and translational loads ? .	10
4	a) What are the different speed control methods used for induction motor	5
	b) Explain Vector control of Induction motor.	15
5	a) Explain the operation of induction with soft starter	15
	b) What are the different advantages of using soft starter in induction motor.	5

6 a) Explain the working and torque equation of switched reluctance motor. 10

b) A 500 kW, three phase, 50Hz, 0.8 power factor lagging, 4 pole star connected synchronous motor has the following parameter: Xs= 15 ohm, Rs= 0 . Rated field current is 10A. Calculate 10

(i) Armature current and power factor at rated torque and rated field current.

(ii) Field current to get unity power factor at the rated torque.

(iii) Torque for unity power factor operation at field current of 12.5 A.

7 With neat diagram explain the adjustable frequency operation of synchronous motor 20

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL103: Power Electronic Drives

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	(a) What are the speed torque conventions? Explain multi- quadrant operation?	12
	(b) A motor equipped with a flywheel has to supply a load torque of 600 N-m for 10 seconds followed by a no load period long enough for the flywheel to regain its full speed. it is desired to limit the motor torque to 450 N-m. What should be the moment of inertia of the flywheel.? The no load speed of the motor is 600 rpm and it has a slip of 8 % at torque of 400 N-m. Assume the motor speed- torque characteristics to be a straight line in the range of operation. Motor has an inertia of 10 kg-m^2.	8
2	Explain VSI and CSI fed induction motor drive system.	20
3	a) Write a note on synchronous motor .	12
	b) Explain the operation of reluctance motor.	8
4	a) Explain the operation of a separately excited dc motor with single phase fully controlled rectifier control in discontinuous mode.	12
	(b) Obtain the operating characteristics of a dc series motor	8
5	Explain time harmonics and space harmonics in Induction motor.	20

6	Explain in detail about Regenerative Braking and Plugging.	20
7	(a) State and explain different methods of speed sensing?	12
	(b) Explain current limit control with a block diagram?	8

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL104: Power Converters – I

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	a) Perform the state space modeling of a boost converter.	12
	b) Obtain the steady state transfer function of the boost converter.	8
2	a) Explain the difference between an SMPS and LPS.	5
	b) A Flyback converter is operating in a complete demagnetizing mode. Derive the voltage transfer ratio in terms of load resistance R, switching frequency f, transformer inductance L and duty ration D.	15
3	a) A resonant full bridge circuit is having a series connection of L= 100µ H, c=0.1µF and R =20Ω Determine i) The undamped resonant frequency ii) The actual oscillatory frequency iii) The maximum switching frequency possible for the discontinuous mode of operation.	8
	b) Perform a comparison based on switching losses in a Parallel Loaded Resonant Converter for different cases of switching frequencies.	12
4	a) Draw the following waveforms for a push –pull converter 1. Voltage across diode $V_{D.}$ 2. Voltage drop across the inductor $V_{L.}$ 3. Voltage drop across the switches.	8

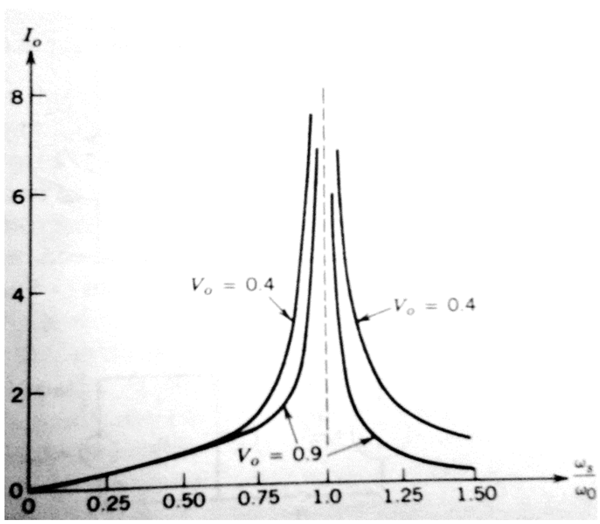
b) Briefly explain the forward converter topology. Explain the significance of tertiary winding in forward converters. 12

5 a) Briefly explain a topology that can be used to reduce switching losses in inverter. 10

b) Explain the operation of a dual converter in all the quadrants of operation while connected to a dc motor as the load. 10

6 a) Justify the need of Resonant converters. 10

b) Design an SLR dc-dc converterwith an isolation transformer (between LC network and rectifier connected to the load) of turns ratio n:1, Vd=155 V, and the operating frequency, f_s=100 kHz. The output is at 5 V and 20 A. If the converter is in discontinuous mode with ω_s<0.5 ω_o. the normalized V_o is 0.9 and normalized frequency is 0.45. Using the curve given obtain n,L_r,C_r. 10



7 Write short notes on

a) Electronic welding power supplies 6

b) Principal of operation of high frequency lamp ballast 8

c) Power electronic based induction heating. 6

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**** Common to PED 104***

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL104: Power Converters – I

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No			*Marks*
1	a)	Briefly explain the working of a Forward Converter.	5
	b)	Obtain the transfer function $v_o(s)/d(s)$ in a forward converter operating in a continuous- conduction mode. Assume N1/N2 =1.	15
2	a)	Explain Series load resonant converters with suitable waveforms and explain the significance of resonant frequency in the switching of SLR.	12
	b)	Differentiate between Series load resonant and Parallel load resonant converters	8
3	a)	Explain in detail about Resonant switch converters.	12
	b)	Compare between resonant load converters and resonant switch converters based on switching losses.	8
4	a)	Explain the importance of ZVS-CV topology.	5
	b)	With neat and detailed waveforms and circuit diagram explain the working of ZVS-CV topology.	15
5	a)	Explain the harmonic content analysis of a single phase rectifier with and without source inductance.	10

b) With a neat circuit diagram and brief explanation draw the output waveform a 6-pulse converter. 10

6 Figure 1 shows a multilevel rectifier. Two fully controlled converters are stacked at the output side to obtain a higher output voltage. The input sources for the individual converters are derived from a 230 V, 50 Hz ac source through a transformer with turns ratio 2:1. The dc load current is constant and ripple free. The top converter (converter 1) is fired at an angle α1 = 30° and the bottom converter (converter 2) is fired at an angle α2 = 60°

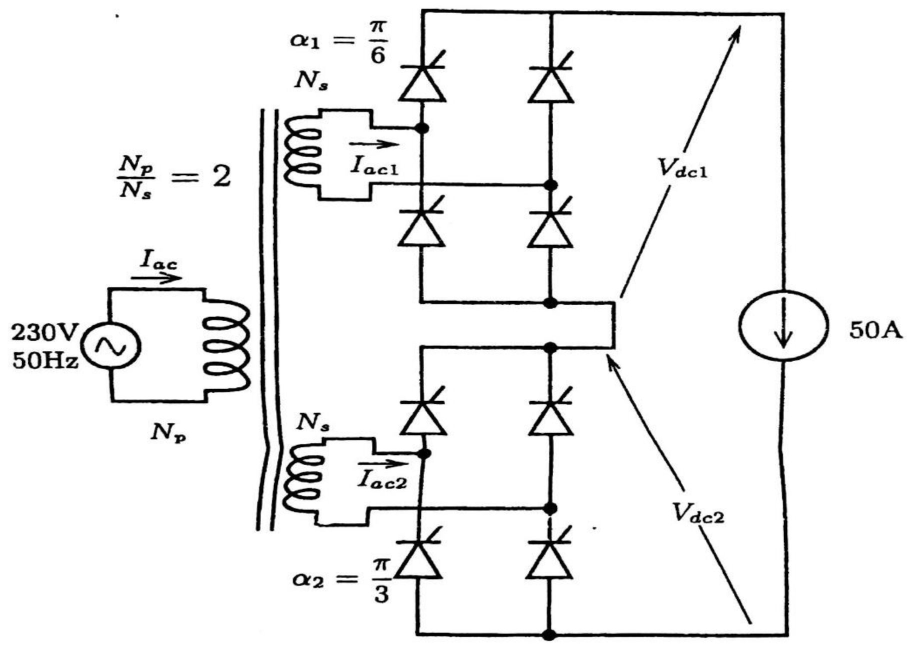

Figure 1

a) Sketch the waveforms $V_{dc1}(t)$, $V_{dc2}(t)$ and $V_{dc}(t)$ for one full cycle. 6

b) Sketch the waveforms $i_{ac1}(t)$, $i_{ac2}(t)$ and $i_{ac}(t)$ for one full cycle. 6

c) Evaluate the average dc output voltage, the output average power and the input power factor. 8

7

a) Perform the state space modelling of a buck converter. 12

b) Obtain the steady state transfer function. 8

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**** Common to PED 104***

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL104: Power Converters – I

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	Briefly Explain about the applications of power electronics in the following	
	a) induction heating	6
	b) welding	8
	c) electronic ballast	6
2	a) Explain in detail the steps involved in linearization of the power stage using state space averaging method.	8
	b) Perform the state space modelling of a Buck converter.	12
3	a) Briefly explain a topology that can be used to reduce switching losses in inverter.	10
	b) Explain the operation of a dual converter in all the quadrants of operation while connected to a dc motor as the load.	10
4	Explain the effect of the following	
	a) TCR	10
	b) TSC	10
	on the power quality improvement of a power electronic circuit.	

5 a) Explain the priniciple of operation of a three phase single switch boost power factor correction circuit. 10

b) Explain the principal of operation of static VAr compensators using thyristors as switching devices. 10

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6 a) Explain the importance of ZVS-CV topology. 8

b) With neat and detailed waveforms and circuit diagram explain the working of ZVS-CV topology. 12

7 a) Draw the following waveforms for a push –pull converter 10

1. Voltage across diode $V_{D.}$
2. Voltage drop across the inductor $V_{L.}$
3. Voltage drop across the switches.

b) Write short notes on

a) Multi pulse rectifier 5

b) Multi phase rectifier 5

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**** Common to PED 104***

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL105 (B): Special Machines

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	a) Explain the theory of operation of stepper motor and draw the static and dynamic characteristics of the machine.	12
	b) Describe the different modes of excitation of stepper motor	8
2	a) Explain the principle of operation of an ac servomotor and draw the torque-speed and torque-control voltage characteristics of the machine	15
	b) Explain armature controlled DC servo motor	5
3	a) Explain the constructional details of a reluctance motor highlighting the specialties in rotor construction.	12
	b) Explain the factors affecting the pulling into step process of a reluctance motor.	8
4	a)Explain the distinctive difference between switched reluctance motor and conventional reluctance motors.	8
	b) Explain the working of switched reluctance motor with neat diagrams and also explain the inductance profile of SRM.	12

5	a)	Why is rotor position sensing required in switched reluctance motor?	8
	b)	Explain the rotor position sensing using logic controller for a switched reluctance motor.	12
6	a)	Compare Brushless DC motor and conventional DC motor and also explain the applications of BLDC motor.	10
	b)	Explain the constructional details and principle of operation of Permanent Magnet Synchronous Motor	10
7	a)	Describe the working principle of a Linear Induction Motor?	10
	b)	Obtain the equivalent circuit of the machine	10

**** Common to PED 105(B)***

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL105 (B): Special Machines

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer **any five full** questions*

Question No		Marks
1	a) Describe the constructional features of variable reluctance type and permanent magnet type stepper motor?	12
	b)What are monofilar and bifilar windings?	8
2	a) With neat diagram, explain the different types of DC servomotor.	10
	b) Derive the transfer function of armature controlled dc servomotor	10
3	a) Explain the principle of operation and pulling in process of a synchronous reluctance motor.	12
	b) What are the various factors affecting on pulling in process of a reluctance motor and discuss how they affect the process.	8
4	a)Draw and explain the inductance-rotor displacement profile for a switched reluctance motor and derive the expression for torque developed in a switched reluctance motor	12
	b)Explain the terms energy and co-energy related to a switched reluctance motor	8

5	a) Draw and explain the power converter diagram for an 8/6 SRM and obtain the current and torque waveforms. Explain the control of SRM in motoring and braking modes.	12
	b) Explain the principle of operation of a switched reluctance motor.	8
6	a) Compare Brushless DC motor and conventional DC motor.	10
	b) Explain the power circuit and controller operation of Brushless DC motor drive.	10
7	a) Describe the construction and principle of operation of Linear Induction Motor .	12
	b) Explain the end effect and edge effect of a Linear Induction Motor	8

**** Common to PED 105(B)***

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL105 (B): Special Machines

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer **any five full** questions*

Question No		*Marks*
1	a) Explain the drive system and control circuitry for stepper motor	15
	b) Explain the modes of excitation of stepper motor	5
2	a) Explain the constructional details and principle of operation of an ac servomotor	12
	b)Draw the torque-speed characteristics and torque-control voltage characteristics of an ac servomotor and derive the transfer function of the machine.	8
3	a)Explain the constructional details of reluctance motors highlighting the specialties in rotor construction.	8
	b) Draw the phasor diagram of synchronous reluctance motor and derive the expression for electromagnetic torque developed.	12
4	a) Explain the closed loop speed control of switched reluctance motor.	10
	b) Why rotor position sensors are essential for the working of an SRM? Explain the indirect method for rotor position sensing?	10

5	a) Explain the working principle of a brushless dc motor and explain the production of unidirectional torque in the machine	12
	b) Discuss the advantages and disadvantages of Brushless DC motor.	8
6	a) Derive an expression for torque of a Brushless DC motor.	14
	b) Explain self control of permanent magnet synchronous motor?	7
7	a) Compare a linear induction motor with its rotating counterpart.	10
	b) Explain longitudinal end effect and transverse edge effect in linear induction motor	10

**** Common to PED 105(B)***

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL106(B): Advanced Microcontroller Based Systems

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	Explain Architecture of 80386	20
2	Briefly Explain Assembly language programing and Simulators	20
3	Draw and explain architecture of 8051	20
4	a) Write a ASM program in 8051 to sort 10 numbers in ascending order b) Write a ASM program in 8051 to do basic calculator functions	20
5	Explain the architecture of a Programmable Peripheral Interface (8255) and method of interfacing a Stepper motor with 8051.	20
6	Explain architecture and program options of programmable timer (8253)	20
7	Briefly Explain any one application of 8051 in Power Electronics based control.	20

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL106(B) : Advanced Microcontroller Based Systems

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	Explain Architecture of 8051	20
2	Explain interfacing of programmable communication interface (8251) with Command words	20
3	Draw and explain Architecture of PIC Microcontroller	20
4	Describe the Instruction set of 8051	20
5	Draw and explain Architecture of 8086 and 8096	20
6	Explain comparison between Microprocessors and micro controllers. Briefly explain about Microcontroller development systems and ASM programing	20
7	Explain the process of interfacing a Stepper motor with an 8051 and a program to drive the motor.	20

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I Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL106(B): Advanced Microcontroller Based Systems

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	Explain Architecture of 8086	20
2	Briefly Explain functional elements of Microcontroller development systems	20
3	Draw and explain Architecture of PIC Microcontroller	20
4	Describe the Memory organization in 80386	20
5	Explain Timers used in 8051 with Command word and Status words	20
6	Explain the architecture of 8051 Microcontroller	20
7	Briefly Explain any one application of Microcontroller based systems in Power Electronics	20

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II Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL201: Switched Mode Power Conversion

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	a) Design of a input filter with a detailed analysis	12
	b)Explain detail with linear voltage regulators	8
2	A boost converter has the following parameters: $V_1 = 8to18V$, $V_0 = 24V$, $P_{O\min} = 0$, $r_L = 0.05\Omega$, $r_C = 0.01\Omega$, $r_{DS} = 0.055\Omega$, $C_0 = 100pF$, $R_F = 0.025\Omega$, $V_F = 0.3V$, $f_s = 100kHz$ and $V_r / V_0 \leq 1\%$ .Find the component values, component stresses and the efficiency at a full power	20
3	a) Explain the dc analysis of a buck converter with CCM	12
	b) Derive the DC voltage transfer functions of a buck converter in DCM	8
4	a) Explain the power losses and efficiency of a boost converter in CCM with an equivalent circuit	12
	b) Derive the DC transfer function in DCM for a buck-boost converter	8
5	Explain the DC analysis of Flyback PWM DC-DC converters	20
6	a) Design of a current programmed control technique	12

b) Explain the sinusoidal analysis of a resonant converters 8

7 a) Explain the realization of a non-ideal rectifier 6

b) Modelling the losses and efficiency in CCM High quality rectifiers . 14

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II Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL202: Power Converters – II

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	a) Explain briefly the difference between Resonant Load Converters and Resonant Switch Converters based upon the switching losses.	12
	b) Perform a comparison between ZCS and ZVS topology.	8
2	Write short notes on :	
	a) Switch Utilization factor	8
	b) Amplitude modulation index	8
	c) Effect of Blanking time	6
3	a) With neat switching sequence diagrams and waveforms explain the operation of a three phase inverter in 180^{o} Conduction mode.	15
	b) Why is Resonant mode converters preferred over Switched mode converters?	5
4	a) With neat waveforms explain unipolar and bipolar switching schemes for a single phase inverter.	12
	b) Explain the effect of modulation index on harmonics.	8
5		8

a) Briefly explain the working of a three phase to sinlge phase cycloconverter. 12

b) Using a three phase three pulse cycloconverter depict the waveform created when the frequency is stepped down to $1/5^{th}$ of input frequency. Show the points of thyristor triggering in the waveform.

6 a) Explain the importance of ZVS-CV topology. 8

b) With neat and detailed waveforms and circuit diagram explain the working of ZVS-CV topology. 12

7 12

a) Explain in detail the Architecture of UC 3843. 8

b) Why are isolation provided for the gate driver chips?

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II Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL203: Dynamics of Electrical Machines

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	a) A coil moves in a time varying magnetic field whose spatial distribution along the airgap periphery is sinusoidal. Find an expression for voltage induced in the coil.	10
	b) Obtain an expression for the electrical torque of the Kron's primitive machine. Show that no torque is produced by interaction between the flux and current on the same axis	10
2	a) Derive the transformation for currents between a rotating balanced 2 phase (α,β) winding and a pseudo-stationary two phase (d,q) winding.	10
	b)For steady state balanced operation with $i\alpha=I_m \cos(wt+\Phi)$ and $i\beta=I_m\sin(wt+\Phi)$. Determine the primitive coil current i_d and i_q and show that these are steady dc values.	10
3	a) Enumerate the assumptions pertaining to the use of generalized mathematical model of dc machines.	5
	b) The following constants pertain to a 250V d.c. separately excited generator. Field- 60Ω,30H; Armature - 0.03Ω, 0.02H; Load- 1.37Ω, 1.78H; Slope of airgap line- 36V/field ampere at rated speed. The generator is initially unexcited but running at rated	15

speed and connected to the load. A 240V d.c. supply is suddenly switched on to the field coils. Neglecting magnetic non-linearity and any speed changes, find out the variation of armature current as a function of time.

4 a) A separately excited dc generator gave no load output voltage of 240V at a speed ωr and for a field current 3A. Find $M_d\omega r$. 5

b) The other constants of the generator are $r_f = 60\Omega$, $L_f = 60H$, $r_a = 0.02\Omega$, $La = 0.01H$, $R_L = 0.38\Omega$, $L_L = 0$. Find the voltage v_L as a function of time after 240V is suddenly applied to the field winding with the armature running at constant speed ωr. 15

5 a) Starting from the impedance matrix of a 3-phase salient pole synchronous machine, without amortisseurs, derive the phasor voltage equation under balanced steady state operation. Hence draw the phasor diagram for motor. 10

10

b) From the torque matrix of a 3-phase salient pole alternator and its phasor diagram, obtain an expression for synchronous power in terms of the load angle.

6 a) A symmetrical sudden 3-phase short circuit is applied to the terminals of an excited salient pole synchronous generator (without damper bars) running at rated speed. Develop an expression for the armature current at any instant of time following the short circuit, in case armature transformer voltages and armature resistances are neglected. 10

b) Explain how X_d, X_d', X_d'' can be determined from the armature current oscillograms obtained after a sudden symmetrical 3-phase short circuit at the alternator terminals. 10

7 a) Write down the voltage equations for the mathematical model of a poly phase induction machine and hence obtain an expression for the steady state torque. 10

b) When running on full load at 400V, a 3 phase delta connected induction 10 motor takes an input of 60A at 0.85 pf when running light at 400V, the motor input current and power are 16A and 2200 watts respectively. Its friction and windage losses are 800 watts. If the stator resistance per phase is 0.6Ω, calculate the shaft power and its efficiency at a full load slip of 0.04.

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II Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

PEL204(A) : Electro- Mechanical Systems

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer **any five full** questions*

Question No		*Marks*
1	a) Explain Architecture of Electro-Mechanical systems.	15
	b) Give any real-time example of first order systems Electro Mechanical systems.	5
2	a) Explain functional block diagram of a Digital Logic Controller	15
	b) Explain advantages of PLC over DLC.	5
3	a) Briefly Explain about any four feedback sensors used in motors	15
	b) Explain application of Position encoder in a closed loop system for Servomotors.	5
4	a) Briefly Explain factors affecting dynamic modeling of a system .	12
	b) Explain fluid and thermal system building blocks	8
5	Explain Closed loop controllers and Controller tuning with an example	20
6	a) Explain PID Controllers	12
	b) Explain frequency response stability	8

7	Explain in detail about Adaptive controllers. Briefly explain about the types of Adaptive filters	20

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POWER ELECTRONICS

PEL205(C): Power Electronic Applications in Renewable Energy Systems

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	a) Explain briefly about fixed speed and variable speed wind turbines	12
	b) Explain in detail the different control mechanisms used in wind turbines.	8
2	a) Explain how electrical energy can be produced from a fuel cell	8
	b) Explain about solar energy systems	12
3	Explain briefly about the following	
	a) Type A	5
	b) Type B	5
	c) Type C	5
	d) Type D wind turbine configurations	5
4	a) Explain briefly about geothermal energy system	8
	b) Explain briefly about ocean thermal energy conversion system	12
5	Explain about	

	a)	AC voltage controller	8
	b)	Voltage control in PWM inverters.	12
6	a)	Draw the block diagram of solar Photo Voltaic system and explain the principle of operation in detail.	10
	b)	Explain the block diagram of SCIG based wind energy conversion system	10
7	a)	Explain about Battery Energy Storage Systems (BESS)	8
	b)	Explain briefly about Flywheel energy storage(FES) system	12

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Common to PED 205(C)

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II Semester M.Tech. Degree (Reg./Sup.) Examination

POWER ELECTRONICS

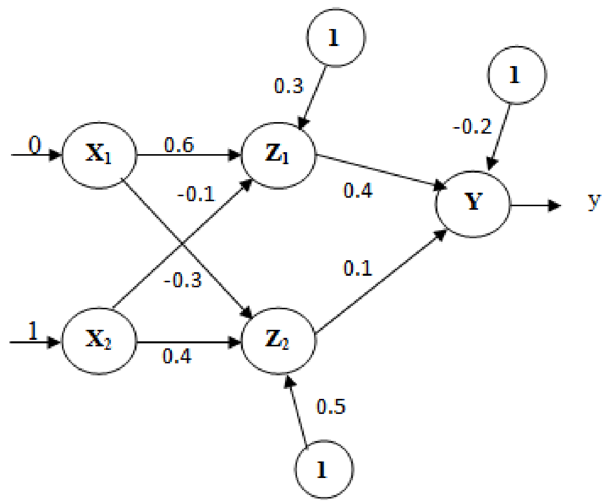
PEL206(A): Artificial Neural Networks and Fuzzy Systems

Time : 3 Hours **Max. Marks :100**

Instruction : *Answer* ***any five full*** *questions*

Question No		*Marks*
1	(a)Explain briefly the difference between Artificial Neural Network and Biological Neural Network.	10
	(b) Explain the Basic models of Artificial Neural Network in detail.	10
2	Design and Implement AND Function with Bipolar inputs and targets using Least mean square Algorithm. Find the Total mean square error till Epoch 1. (Assume initial weights=0.1, $\alpha = 1$).	20
3	Write a note on:	
	(a) Fuzzification	6
	(b) Defuzzification	6
	(c) Inference Systems	8
4	Using BPN, find the new weights for the net shown in figure. It is presented with a input pattern [0 1] and the target output is 1. Use a	20

learning rate α = 0.25 and binary sigmoidal function.



5 Find the composition of the following through min-max operations. 20

$$h = \begin{bmatrix} 0.5 & 0.1 & 0.5 \\ 0.2 & 0.9 & 0.2 \\ 0.8 & 0.6 & 0.1 \end{bmatrix} \qquad \tilde{s} = \begin{bmatrix} 0.6 & 0.4 & 0.7 \\ 0.5 & 0.8 & 0.9 \\ 0.1 & 0.2 & 0.3 \end{bmatrix}$$

6 Two fuzzy sets $\tilde{i}$ ={(A,0.4), (B,0.3), (C,0.1), (D,0.1), (E,0.9), (F,0.8)}, 20
$\tilde{b}$ ={(A,0.99),(B,0.8), (C,0.1),(D,0.2),(E,0.5), (F,0.5)}
Find the following:

(a) $\tilde{b} \cup \tilde{b}^{C}$
(b) $\tilde{i} \cup \tilde{b}$
(c) $\tilde{i} - \tilde{b}$
(d) Verify Demorgan's Law

7 (a) Explain Fuzzy Logic control systems with necessary diagrams. 10

(b) Explain in detail the various classical Fuzzy control problems. 10

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**** Common to PED 206(A)***