Indian Institute of Technology Patna
Electrical & Electronics Engineering Department

M. Tech Program – Electrical and Electronics Engineering (Power and Control Systems)

Course Curriculum

Semester I

S. No		Course code	Course name	Credit Structure			
				L	T	P	C
1	Core	EE 571	Computer Aided Power System Analysis	3	0	0	3
2		EE 573	Basics of Power Electronics Converters	3	0	0	3
3	Elective	EE 5XX	Elective-I	3	0	0	3
4		EE 5XX	Elective-II	3	0	0	3
5		EE 5XX	Elective-III	3	0	0	3
6		EE 575	Power and Control Lab - I	0	0	3	1.5
7		HSS 513	Technical Communications	3	0	0	3
			Total	18	0	3	**19.5**

Semester 2

S. No		Course code	Course name	Credit Structure			
				L	T	P	C
1	Core	EE 549	Power System Dynamics and Control	3	0	0	3
2		EE 572	Control of Electric Drives	3	0	0	3
3	Elective	EE 5XX	Elective-IV	3	0	0	3
4		EE 5XX	Elective-V	3	0	0	3
5		EE 5XX	Elective-VI	3	0	0	3
6		EE 576	Power and Control Lab - II	0	0	3	1.5
7		EE5XX	Seminar	0	0	0	2
8		EExxx	Mini Project	0	0	0	2
			Total	15	0	3	**20.5**

Semester 3

S. No	Course code	Course name	Credit Structure			
			L	T	P	C
1	EE 591	Project Phase I	0	0	0	20
2	EE5XX	Grand Viva	0	0	0	4
		Total	0	0	0	**24**

Semester 4

S. No	Course code	Course name	Credit Structure			
			L	T	P	C
1	EE 592	Project Phase II	0	0	0	24
		Total	0	0	0	**24**

Total Credits = 19.5+20.5+24+24=88

First Semester Electives I-III:

Course code	Course name	Credit Structure			
		L	T	P	C
MH 503	Advanced Engineering Mathematics	3	0	0	3
EE 501	Control of Mechatronic Systems	3	0	0	3
EE 577	Digital Control	3	0	0	3
EE 589	Generalized Theory of Electrical Machines	3	0	0	3
EE 587	A First Course in Optimization	3	0	0	3
EE 591	Advanced Electric Drives	3	0	0	3
EE 593	Power System Deregulation	3	0	0	3
CS 561	Artificial Intelligence	3	0	0	3
EE 579	Advanced Control Theory	3	0	0	3
EE512	Embedded Systems	3	0	0	3
EE 585	Advanced Power System Protection	3	0	0	3

Second Semester Electives IV-VI:

Course code	Course name	Credit Structure			
		L	T	P	C
EE 504	Microprocessors and Embedded Systems	3	0	0	3
EE 555	Random Signal and Process	3	0	0	3
EE 580	Optimal Control Systems	3	0	0	3
EE 582	Control Techniques in Power Electronics	3	0	0	3
EE 584	Multivariable Control Theory	3	0	0	3
EE 586	HVDC Transmission and FACTS	3	0	0	3
EE 588	Nonlinear Dynamical Systems	3	0	0	3

Detailed Syllabus of Core Courses

EE 571 Computer Aided Power System Analysis 3-0-0-3

Loadflow for AC systems, fast decoupled load flow, optimal power flow.;Z - matrix for short circuit studies.;State estimation, LO algorithm, fast decoupled state estimation.;Security and contingency studies. Unit Commitment. Load frequency control.;Optimal hydro-thermal scheduling. AI applications

Texts/References

1. O.I.Elgerd, Electric Energy Systems Theory, McGraw Hill, 1971
2. G.W.Stagg and A.H.El-Abiad, Computer Methods in Power System Analysis, McGraw Hill 1968.
3. G.L.Kusic, Computer Aided Power Systems Analysis, Prentice Hall, 1986.
4. I.J.Nagrath and D.P.Kothari, Modern Power Systems Analysis, Tata McGraw Hill, 1980.
5. A.J.Wood and B.F.Wollenberg, Power Generation, Operation and Control, John Wiley, 1984

EE 573 Basics of Power Electronics Converters 3-0-0-3

Power semiconductor devices, BJT, MOSFET, IGBT, GTO and MCT: AC-DC Converters; Forced communication; synchronous link converters, DC-AC converters, buck, boost, buck-boost, cuk, flyback configuration, resonant converters, PWM inverters; active filters.

Text/References

1. Ned Mohan, Power Electronics: Converters, Applications, and Design, Wiley, 3rd Edition, 2002.

2. Robert W. Erickson, Dragan Maksimovic, “Fundamentals of Power Electronics” Springer Science & Business Media, 2007
3. Muhammad H. Rashid, Power Electronics Devices, Circuits, and Applications, Pearson, 4th Edition, 2014.

EE 549 Power System Dynamics and Control 3-0-0-3

Basic Concepts of dynamical systems and stability. Modelling of power system components for stability studies: generators, transmission lines, excitation and prime mover controllers, flexible AC transmission (FACTS) controllers.;Analysis of single machine and multi-machine systems. Small signal angle instability (low frequency oscillations): damping and synchronizing torque analysis, eigenvalue analysis.;Mitigation using power system stabilizers and supplementary modulation control of FACTS devices. Small signal angle instability (sub-synchronous frequency oscillations): analysis and counter-measures. Transient Instability: Analysis using digital simulation and energy function method. Transient stability controllers. Introduction to voltage Instability. Analysis of voltage Instability.

Texts/References:

1. P.Kundur, Power System Stability and Control, McGraw Hill Inc, New York, 1995.
2. P.Sauer & M.A.Pai, Power System Dynamics & Stability, Prentice Hall, 1997.

EE 572 Control of Electric Drives 3-0-0-3

Modelling of DC Machines, Phase Controlled DC Motor Drives, Chopper Controlled DC Motor Drives, Modeling of Polyphase Induction Machines, Phase Controlled Motor Drives, Frequency Controlled Induction Motor Drives, Vector Controlled Induction Motor Drives, Permanent Magnet Synchronous and Brushless DC Motor Drive Modeling and Control.

Texts / References:

1. R. Krishnan, *Electric Motor Drives: Modeling, Analysis and Control*, Prentice Hall, 2002.
2. Mohamed El-Sharkawi, *Fundamentals of Electric Drive*, CL- Engineering, 1st Edition, 2000

EE 575 Power and Control Lab-I 3-0-0-3

Study of 3-phase inverter, Study of 3-phase rectifier, Control of buck- boost converter, Position control of servo-motor, Speed control of 3- phase AC motor, Speed and position control of stepper motor, Load flow analysis with power flow control using series compensation, Control of power flow using back-to- back converter, Effect of SVC (Static Var Compensator) in controlling the bus voltage, Synchronization of alternators.

EE 576 Power and Control Lab-II 3-0-0-3

Overcurrent Protection, Differential Protection, Study of Circuit Breakers, DC Motor Speed Control, AC Motor Control, Process Measurement and Control

<u>Detailed Syllabus of Elective Courses</u>

Electives I-III

MH 503 Advanced Engineering Mathematics 3-0-0-3

Linear Algebra: Matrix algebra; basis, dimension and fundamental subspaces; solvability of Ax = b by direct Methods; orthogonality and QR transformation; eigenvalues and eigenvectors, similarity transformation, singular value decomposition, Fourier series, Fourier Transformation, FFT.

Vector Algebra & Calculus: Basic vector algebra; curves; grad, div, curl; line, surface and volume integral, Green's theorem, Stokes's theorem, Gauss-divergence theorem.
Differential Equations: ODE: homogeneous and non-homogeneous equations, Wronskian, Laplace transform, series solutions, Frobenius method, Sturm-Liouville problems, Bessel and Legendre equations, integral transformations; PDE: separation of variables and solution by Fourier Series and Transformations, PDE with variable coefficient.

Numerical Technique: Numerical integration and differentiation; Methods for solution of Initial Value Problems, finite difference methods for ODE and PDE; iterative methods: Jacobi, Gauss-Siedel, and successive over-relaxation.

Complex Number Theory: Analytic function; Cauchy's integral theorem; residue integral method, conformal mapping. Statistical Methods: Descriptive statistics and data analysis, correlation and regression, probability distribution, analysis of variance, testing of hypothesis.

Text Books:

1. H. Kreyszig, "Advanced Engineering Mathematics", Wiley, (2006).
2. Gilbert Strang, "Linear Algebra and Its Applications", 4th edition, Thomson Brooks/Cole, India (2006).
3. J. W. Brown and R. V. Churchill, "Complex Variables and Applications", McGraw-Hill Companies, Inc., New York (2004).
4. J. W. Brown and R. V. Churchill, "Fourier Series and Boundary Value Problems", McGraw-Hill Companies, Inc., New York (2009).
5. G. F . Simmons, "Differential Equations with Applications and Historical Notes", Tata McGraw-Hill Edition, India (2003).
6. S. L. Ross, "Differential Equations" 3rd edition, John Wiley & Sons, Inc., India (2004).
7. K. S. Rao, "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd (2005).
8. R. Courant and F. John, "Introduction to Calculus and Analysis, Volume I and II", Springer-Verlag, New York, Inc. (1989).
9. K. Atkinson and W. Han, "Elementary Numerical Analysis" 3rd edition, John Wiley & Sons, Inc., India (2004).
10. R. A. Johnson and G. K. Bhattacharya, "Statistics, Principles and Methods", Wiley (2008)

EE501 **Control of Mechatronic Systems** **3-0-0-3**

Time response design: Routh-Hurwitz test, relative stability, Root locus design, construction of root loci, phase lead and phase-lag design, lag-lead design.

Frequency response design: Bode, polar, Nyquist, Nichols plot, lag, lead, lag-lead compensator, time delay, process plant response curve. PID controller design.

Modern control: Concept of states, state space model, different form, controllability, observability; pole placement by state feedback, observer design, Lunenburg observer, reduced order observer, observer based control.

Optimal control design: Solution-time criterion, control-area criterion, performance indices; zero steady state step error systems; modern control performance index: quadratic performance index, Ricatti equation.

Digital control:
Sampling process, sample and hold, analog to digital converter, use of z-transform for closed loop transient response, stability analysis using bilinear transform and Jury method, digital control design using state feedback

Non-Linear Control System:
Common physical non-linear system, phase plane method, system analysis by phase plane method, stability of non-linear system, stability analysis by describing function method, Liapunov's stability criterion, Popov's stability criterion.

Text Books:

1. K. Ogata, "Modern Control Engineering", Prentice Hall India (2002).
2. Gene F. Franklin, J. D. Powell, A E Naeini, "Feedback Control of Dynamic Systems", Pearson (2008).
3. John Van De Vegte, "Feedback Control Systems", Prentice Hall (1993).
4. Thomas Kailath, "Linear Systems", Prentice Hall (1980).
5. Alok Sinha, "Linear Systems: Optimal and Robust Control", Taylor & Francis (2007).
6. Brian D. O. Anderson and John B. Moore, "Optimal Control: Linear Quadratic Methods", Dover Publications (2007).
7. K. Ogata, "Discrete-Time Control Systems", PHI Learning (2009).
8. H.K. Khalil, "Nonlinear Systems", Prentice Hall (2001).

EE504 Microprocessor and Embedded Systems 3-0-0-3

Introduction to Embedded Systems and microcomputers: Introduction to Embedded Systems, Embedded System Applications, Block diagram of embedded systems, Trends in Embedded Industry, Basic Embedded system Models, Embedded System development cycle, Challenges for Embedded system Design, Evolution of computing systems and applications. Basic Computer architecture: Von-Neumann and Harvard Architecture.

Basics on Computer organizations. Computing performance, Throughput and Latency, Basic high performance CPU architectures, Microcomputer applications to Embedded systems and Mechatronics.

Microprocessor: 8086 Microprocessor and its Internal Architecture, Pin Configuration and their 12 functions, Mode of Operation, Introduction to I/O and Memory, Timing Diagrams, Introduction to Interrupts.

Microprocessor Programming: Introduction to assembly language, Instruction format, Assembly language programming format, Addressing mode, Instruction Sets, Programming 8086 microprocessor. Microprocessor Interfacing: Introduction to interfacing, Memory Interfacing, Programmable Peripheral Interfacing, Programmable I/O, Programmable Interrupt Controller, Programmable Timers, Programmable DMA Controller, Programmable Key board Controller, Data acquisition Interfacing: ADC, DAC, Serial and parallel data Communication interfacing. Microcontroller: Introduction to Microcontroller and its families, Criteria for Choosing Microcontroller. Microcontroller Architecture, Programming model, Addressing modes, Instruction sets, Assembly and C programming for Microcontroller, I/O programming using assembly and C language, Interrupt Controller, I/O interfacing, Timers, Real Time Clock, Serial and parallel Communication protocols, SPI Controllers. LCD Controller. Microcontroller Interfacing: Introduction to Microcontroller Interfacing and applications: case studies: Display Devices, controllers and Drivers for DC, Servo and Stepper Motor. Introduction to Advanced Embedded Processor and Software: ARM Processor, Unified Model Language (UML), Embedded OS, Real Time Operating System (RTOS), Embedded C.

Books:

1. Introduction to Embedded Systems: Shibu K V, McGRAW Hill Publications.
2. Embedded Systems: Raj Kamal, TATA McGRAW Hill Publications
3. Computer System Architecture: M. Morris Mano.
4. 8086 Microprocessors and Interfacings: D. Hall, TATA McGRAW Hill
5. The Intel Microprocessors: B. Brey, Prentice Hall Publications.
6. PIC Microcontrollers and Embedded Systems: M. A. Mazidi, R.D. Mckinlay and D. Casey, Pearson
Publications
7. Programming and Customizing the PIC Microcontroller: M. Predko, McGRAW Hill Publications.
8. Embedded C Programming and Microchip PIC: R. Barnett, L. O’Cull and S. Cox

EE 577 Digital Control 3-0-0-3

Discrete-time system representations: modeling discrete-time systems by linear difference equations and pulse transfer functions, time responses of discrete systems; discrete state-space models, stability of discrete-time systems. Finite settling-time control design: deadbeat systems, inter sample behavior, time-domain approach to ripple-free controllers, limitations and extensions of the deadbeat controller. State-feedback design techniques: linear system properties, state feedback using Ackermann's formula, tracking of known reference inputs. Output-feedback design techniques: observer design , observer-based output feedback design.

Texts / References:

1. B. C. Kuo, Digital Control Systems; Oxford University Press, 2/e, Indian Edition, 2007.
2. K. Ogata, Discrete Time Control Systems; Prentice Hall, 2/e, 1995.
3. M. Gopal, Digital Control and State Variable Methods; Tata Mcgraw Hill, 2/e, 2003.
4. G. F. Franklin, J. D. Powell and M. L. Workman; Digital Control of Dynamic Systems; Addison Wesley, 1998, Pearson Education, Asia, 3/e, 2000.
5. K. J. Astroms and B. Wittenmark, Computer Controlled Systems - Theory and Design; Prentice Hall, 3/e, 1997.

EE 589 Generalized Theory of Electrical Machines 3-0-0-3

Reference Frame: Commonly used reference frames, Transformation between reference frames; Transformations in Machines: Power invariance, 3-phase to 2-phase transformation, Park’s Transformation; DC Machines: Voltage and torque equations, transfer function of DC Machines, Steady State Analysis of DC Machines; Polyphase Induction Machines: D-Q model, axes transformation, Steady state analysis from different frames of references; Polyphase Synchronous Machines: Equivalent circuit, Park’s Model, Shot Circuit Analysis, Steady State Analysis; Permanent Magnet Machines: Basic operation principle, Park’s model, Steady State analysis for various PWM techniques.

Texts:

1. A. K. Mukhopadhyay, Matrix Analysis of Electrical Machines, New Age, 1996.
2. P. Vas, *Electrical Machines and Drives: A Space-Vector Theory Approach* (Monographs in Electrical and Electronic Engineering), Oxford University Press, 1993.
3. W. Leonhard, *Control of Electrical Drives*. Springer, Berlin, 1985.

References:

1. D. O'Kelly and S. Simmons, *Introduction to Generalized Electrical Machine Theory*, McGraw- Hill Education, 1968.

EE 587 A first course in Optimization 3-0-0-3

Motivation. mathematical review , matrix factorizations, sets and sequences, convex sets and functions, linear programming and simplex method, Weierstrass' theorem, Karush Kuhn Tucker optimality conditions, algorithms, convergence, unconstrained optimization, Line search methods, method of multidimensional search, steepest descent methods, Newton's method, modifications to Newton's method , trust region methods, conjugate gradient methods, quasi-Newton's methods. constrained optimization, penalty and barrier function methods, augmented Lagrangian methods, polynomial time algorithm for linear programming, successive linear programming, successive quadratic programming.

Text/References

1. R. Fletcher Practical Optimization (2nd Edition) John Wiley & Sons, New York, 1987.
2. M.S.Bazaraa , H.D.Sherali and C.Shetty , Nonlinear Programming, Theory and Algorithms, John Wiley and Sons, New York, 1993.

EE 593 Power System Deregulation 3-0-0-3

Fundamentals of deregulation: Privatization and deregulation, Motivations for Restructuring the Power industry; Restructuring models and Trading Arrangements: Components of restructured systems, Independent System Operator (ISO): Functions and responsibilities, Trading arrangements (Pool, bilateral & multilateral), Open Access Transmission Systems; Different models of deregulation: U K Model, California model, Australian and New Zealand models, Deregulation in Asia including India, Bidding strategies, Forward and Future market; Operation and control: Old vs New, Available Transfer Capability, Congestion management, Ancillary services; Wheeling charges and pricing: Wheeling methodologies, pricing strategies

Text/Reference

1. Operation of restructured power systems. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Boolen, Kluwer Academic Pub., 2001.
2. Restructured electrical power systems: operation, trading and volatility Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker Pub., 2001

EE 591 Advanced Electric Drives 3-0-0-3

Motors with continuous rotation, Electromagnetic Stepping Drives, Drives with limited motion, Piezoelectric drives, Open loop and closed loop control of fractional horse power motors, Magnetic bearings and their control, Integration and Control of Mechanical transfer units such as gears, pulleys, flexible drives etc., Project design of drive systems, Application of Artificial Intelligence in Electric Drives, AI based steady state and transient analysis of Induction Machines, AI based Switch Reluctance Machine performance estimation and Control.

Texts/References:

1. B. Wu, *High-Power Converters and AC Drives.* Wiley-IEEE Press, New Jersey, 2006
2. W. Leonhard, *Control of Electrical Drives*. Springer, Berlin, 1985.
3. N. Mohan, *Advanced Electric Drives: Analysis, Control and Modeling using Simulink*. MNPERE, 2001.

4. Hans Dieter Stoelting, *Handbook of fractional Horsepower Drives*, Springer, 1st edition, 2009
5. Ion Boldea, Syed A. Nasar, *Electric Drives*, CRC Press, 2nd Edition, 2005
6. Peter Vas, *Artificial Intelligence Based Electrical Machines and Drives: Application of Fuzzy, Neural and Genetic Algorithm Based Techniques*, Oxford University Press, 1999.

CS561: Artificial Intelligence 3-0-0-3

Prerequisite NIL

Introduction, Problem Solving: Uninformed search, Informed search, local Search, Online search; Knowledge and Reasoning: Building a Knowledge Base, Semantic Nets, Frames, First order logic, Inference in First Order Logic; Probabilistic Reasoning Systems: Bayes' Nets; Learning: Learning from examples and analogy, Naive Bayes, Computational Learning Theory, Explanation Based Learning, Neural Networks; Evolutionary Optimization: Genetic algorithms, Multi objective optimization, Differential Evolution, Particle Swarm Optimization; Introduction to NLP; Introduction to Fuzzy sets.

References:

S. Russel and P. Norvig. Artificial Intelligence: A Modern Approach (Second edition), Pearson
E. Charniak, Introduction to Artificial Intelligence, Addison Wesley, 1985.
P. H. Winston, Artificial Intelligence, Addison Wesley, 1993.
E. Rich and K. Knight, Artificial Intelligence, Addison Wesley, 1990.
R.Honavar and E. Uhr, Artificial Intelligence and Neural Networks, Academic Press, 1992.
F. Hayes Roth, Building Expert Systems, Addison Wesley, 1983.
P. R. Cohen, The Handbook of Artificial Intelligence, Vol.1,2 and 3, Kaufman Inc.,1982.
B. K. P. Horn, Robot Vision, MIT Press, 1985. J. Carbonell, Machine Learning paradigms and Methods,
MIT Press, 1990.
Journals:- Artificial Intelligence, AI Magazine, IEEE Expert, Machine Learning, Computer Vision Image Processing and Graphics, IEEE Transactions on Neural Networks.

EE579 Advanced Control Theory 3-0-0-3

Frequency response design: Design of lag, lead, lag-lead and PID controllers, the Nyquist criterion, analysis and design, relative stability and the Bode diagram, closed-loop response, sensitivity, time delays; Root locus design: construction of root loci, phase-lead and phase-lag design, PID controller design; Modern design: controllability and observability, state feedback with integral control, reduced order observer; Optimal control design: Solution-time criterion, Control-area criterion, Performance indices, Zero steady state step error systems; Modern control performance index: Quadratic performance index, Ricatti equation; Digital controllers: Use of z-transform for closed loop transient response, stability analysis using bilinear transform and Jury method, deadbeat control, Digital control design using state feedback; On-line identification and control: On-line estimation of model and controller parameters.

Texts/References

1. G. F. Franklin, J. D. Powel and A. E. Emami-Naeini: Feedback Control of Dynamic Systems, Prentice Hall Inc. 2002.
2. M. Gopal: Control Systems, 3/e, Tata McGraw Hill, 2008.
3. M. Gopal: Digital Control and State Variable Methods, Tata McGraw Hill, 2003.
4. K. J. Astrom and T. Hagglund: Advanced PID Control, ISA, Research Triangle Park, NC 27709, 2005

EE512 Embedded Systems 3-0-0-3

Introduction to the Embedded systems, Embedded System models and Development Cycle, Modeling of continuous, discrete and hybrid systems, Embedded system design and examples, Hierarchical state machine, Design space exploration, Sensors, Actuators, Embedded processor and memory architecture,

Introduction to Embedded OS and RTOS, Scheduling, Multi-tasking, Temporal logic, Embedded System I/Os, Interfacing techniques, Communication Protocols and device driver, Embedded system analysis and verification.

Text/Reference Books:

1. Shibu K V, ―Introduction to Embedded Systems‖, Tata McGraw Hill Education Private Limited, 2009.
2. E. A. Lee and S. A. Seshia, ―Introduction to Embedded Systems‖, Second Edition, MIT Press, 2017.
3. Embedded Systems: Architecture, Programming and design, Raj Kamal, Second Edition, Tata McGraw Hill publisher, 2010,
4. Steve Furber, ― ARM System-On-Chip Architecture‖, Second Edition, Pearson Publisher, 2015.
5. N. Sloss, D. Symes, and C. Wright, "ARM system developer's guide: Designing and optimizing and system software", Elsevier, 2008

EE 585 Advanced Power System Protection 3-0-0-3

Protective Devices: Philosophy of protection, Methods of earthing and their effect on fault conditions. Different types of relays: attracted armature type, balanced beam type, induction type. Static relays: Generalised theory of phase and magnitude, comparator, realization of different relay characteristics of static devices. Evolution of Power System Protection and the Emergence of Digital Relaying, Digital Signal Processing Basics and Architecture of Numerical Relay: Introduction to Digital Signal Processing, The DSP Signal Processing Chain, Analog to Digital Converters, Anti-aliasing Filter, Algorithms Based on Undistorted Single Frequency Sine Wave, Algorithms Based on Solution of Differential Equation, Algorithms Based on Least Squared Error, Discrete Fourier Transform, FFT and Goertzel Algorithm, Introduction to Digital Filtering, Synchrophasors, Introduction to computer relaying, Relaying applications of traveling waves, Wide area measurement applications

References:

1) Arun G. Phadke and James S. Thorp, “Computer Relaying for Power Systems,” 2nd Edition, Wiley, 2009.
2) S. R. Bhide, “Digital Power System Protection,” PHI Learning Private Limited, 2014.

Elective Courses IV-VI

EE555 Random signals and systems 3-0-0-3

Probability and statistics of multivariable (a quick revision): Bayes theorem, multiple random variable, discrete random variable, probability mass function and probability density function, a few well known distributions, moments.

Random process: Concept of random process, ensemble, mathematical tools for studying random process, correlation function, stationarity, ergodicity, a few known stochastic processes: random walk, Poisson process, Gaussian random process, Markov chains, Brownian motion etc., pseudorandom process, nonlinear transformation of random process.

Random process in frequency domain: Peridogram and power sprectral density, Weiner-Khintchine-Einstein Theorem, concept of bandwidth, spectral estimation.

Linear system: Discrete time and continuous time LTI system, concept of convolution, system described in frequency domain, state space description of the system.

Linear systems with random inputs: Linear system fundamentals, response of a linear system, convolution, mean, autocorrelation and cross correlation function in LTI system, power spectral density in LTI, cross power spectral density in LTI.

Processing of random signals: Noise in systems, noise bandwidth, SNR, bandlimited random process, noise reduction, matched filter, Wiener filter.

The Kalman filter: Mean square estimation, discrete Kalman filter, innovation, Kalman filter vs Wiener filter,properties of Kalman filter, Kalman Bucy filter, engineering examples.

Text book:

1. Miller, Scott, and Donald Childers, “probability and random processes: with applications to signal processing and communications”, Academic Press, 2012.
2. Wim C. van Etten, “Introduction to random signals and Noise”, Chichester, England: Wiley, 2005.
3. Peyton Z. Peebles, “Probability, random variables, and random signal principles”. McGraw Hill Book Company, 1987.

Reference:

1. Geoffrey R. Grimmett, and David Stirzaker, “Probability and random processes”, Oxford university press, 2001.
2. Alberto Leon-Garcia, “Probability, statistics, and random processes for Electrical engineering”, Upper Saddle River, NJ: Pearson/Prentice Hall, 2008.
3. Grewal, Mohinder, and Angus P. Andrews, “Kalman filtering: theory and practice with MATLAB”, John Wiley & Sons, 2014.
4. Alberto Leon-Garcia, “Probability, statistics, and random processes for Electrical engineering”, Upper Saddle River, NJ: Pearson/Prentice Hall, 2008.
5. Kay, Steven M, “Fundamentals of statistical signal processing”, Prentice Hall PTR, 1993.
6. H.L. Van Trees, “Detection, estimation, and modulation theory, part I”, New York, NY: John Wiley & Sons, Inc., 1971.
7. Brown, Robert Grover, and Patrick YC Hwang., “Introduction to random signals and applied Kalman filtering”, New York: Wiley, 1992.

8. Shovan Bhaumik, and Paresh Date, “Nonlinear estimation: methods and applications with deterministic Sample Points”, CRC Press, 2019.
9. Steven Key, “Intuitive probability and random processes using MATLAB®”, Springer Science & Business Media, 2006.
10. D. J. Gordana, “Random signals and processes primer with MATLAB”, Springer Science & Business Media, 2012

EE 580 Optimal Control Systems 3-0-0-3

Introduction. static and dynamic optimization. Parameter optimization.;Caculus of Variations : problems of Lagrange,. Mayer and Bolza. Euler-Language equation and transversality conditions, Lagrange multipiliers.;Pontryagin’s maximum principle; theory; application to minimum time, energy and control effort problems, and terminal control problem. Dynamic programming : Belaman’s principle of optimality, multistage decision processes. application to optimal control.;Linear regulator problem : matrix Riccati equation and its solution, tracking problem.;Computational methods in optimal control. application of mathematical programming. singular perturbations, practical examples.

Text/References

1. D.E.Kirk, Optimal Control Theory, Prentice-Hall. 1970.
2. A.P.Sage and C.C.White II, Optimum Systems Control, 2nd ED., Prentice-Hall, 1977.
3. D.Tabak and B.C.Kuo, Optimal Control by Mathematical Programming, Prentice-Hall, 1971.
4. B.D.O. Anderson and J.B.Moore, Linear Optimal Control, Prentice-Hall, 1971.

EE 586 HVDC Transmission and FACTS 3-0-0-3

General aspects of DC transmission, converter circuits and their analysis, DC link controls, faults and abnormal operation and protection; Mechanism of active and reactive power flow control; Basic FACTS controllers: SVC, STATCOM, TCSC, TCPAR, UPFC; Modeling of FACTS Controllers; System static performance improvement with FACTS controllers; System dynamic performance improvement with FACTS controllers

1. K.R. Padiyar, HVDC Power Transmission Systems, Wiley eastern Ltd. 1990.
2. Hingorani N. G. “Understanding FACTS Concepts & Technology of FACTS Systems,” IEEE PRESS, 2000.
3. R. M. Mathur and R. K. Varma, Thyristor Based FACTS Controllers for Electric Power Transmission Systems, IEEE Press and Wiley Interscience, New York, 2002

EE 584 Multivariable Control Theory 3-0-0-3

Mathematical Fundamentals: Invariant subspaces, Similarity transformations, Quotienting and equivalence classes; Canonical Representations and Feedback Laws:, Multivariable Observer and controller canonical representations, multivariable pole placement problem, multivariable observer design problem; System decomposition: Controllability indices and system invariants, Controllability subspaces and Observability subspaces, stabilizability and detectability, Disturbance decoupling and Output stabilization problems; Binary Systems:Introduction to linear modular systems.

Texts/ References:

1. C. T. Chen, Linear System Theory and Design , 3 rd Edn., Oxford 1999.
2. O. Gasparyan, Linear and Nonlinear Multivariable Feedback Control: A Classical Approach , John Wiley and Sons, 2007.
3. W. M. Wonham, Linear Multivariable Control: A Geometric Approach , Springer, 1985.

EE 582 Control Techniques in Power Electronics 3-0-0-3

State space modeling and simulation of linear systems, Discrete time models, conventional controllers using small signal models, Hysteresis controllers, Output and state feedback switching controllers. Averaged - switch modeling, modeling of dynamics of converters operating in discontinuous conduction mode, input filter design.

Text/References:

1. Muhammad Rashid, Power Electronics Handbook, Academic Press-Elsevier, 2001.
2. B. Wu, *High-Power Converters and AC Drives.* Wiley-IEEE Press, New Jersey, 2006.
3. Erickson and Maksimovic, Fundamentals of Power Electronics, 2nd ed., Springer Science+Business (2000),

EE 588 Nonlinear Dynamical Systems 3-0-0-3

Introduction to nonlinear systems; analysis by phase plane and describing function methods. Lyapunov stability theory. The Lure problem: Popov's method, circle criterion. Hyperstability.

Hamiltonian, Lagrangian and gradient systems: physical examples and analysis. Stability of Hamiltonian systems. Periodic systems: Floquet-Lyapunov theory, Krein's stability theorem.

Text/References

1. V. M. Popov : Hyperstability of control systems. Springer Grundleheren series, 1970.
2. M. Vidyasagar, Nonlinear systems analysis. 2nd Edition. Prentice Hall, 1993.
3. Y. A. Yakubovitch and V. M. Starzhinskii, Linear differential equations with periodic coefficients. Wiley, 1975