

B. Tech. [Electrical and Electronics Engineering (EEE)] - M. Tech. [Power and Control System]

<p>Program Learning Objectives:</p> <p>(i) Specialized training in the field of Power and Control system.</p> <p>(ii) Develop an orientation towards industrial training on specialized field.</p> <p>(iii) Imparting world class training to develop the foundation for making world class researcher in this field of research.</p> <p>(iv) Work collaboratively in multidisciplinary teams, demonstrating effective teamwork and communication to solve complex engineering problems.</p> <p>(v) Recognize the importance of ongoing professional development, engaging in activities such as certifications, workshops, and conferences to stay updated of industry trends.</p>	<p>Program Learning Outcomes:</p> <p>The graduates of this program will have</p> <ul style="list-style-type: none"> ● strong fundamentals in Power and Control system engineering. ● ability to analyze and synthesize engineering problems including design and conduct experiments, use standard test equipment and interpret experimental data. ● ability to design prototypes for real world problems. ● ability to work in a multidisciplinary team environment. ● ability to appreciate the complexities of professional environments, including taking responsibility for oneself, working effectively and professionally as a team member, and being mindful of ethical, economic, and contemporary concerns. ● ability to continue learning in Power and Control system field. ● ability to independently accomplish engineering tasks related to Power and Control research areas. ● ability to enter industry with the engineering techniques, skills, and tools required to be able to solve real-world problems in Power and Control system engineering.
<p>Program Goal 1: Academic excellence by providing a curriculum that aligns with industry standards and encourages critical thinking in Power and Control system engineering.</p>	<p>Program Learning Outcome 1a: Highly skilled market ready manpower to serve the emerging electrical and electronic sectors</p> <p>Program Learning Outcome 1b: Skilled Human resource to cater the needs of next generation power systems and EV technologies.</p>
<p>Program Goal 2: A culture of research and innovation by promoting faculty and student involvement in innovative projects in Power and Control system technologies.</p>	<p>Program Learning Outcome 2a: Trained researchers for implementing research projects in line with national priorities such as Energy, EVs, Smart Grids, Green Technologies.</p> <p>Program Learning Outcome 2b: Design and develop innovative smart technologies/products in energy and EVs as per the societal need</p>
<p>Program Goal 3: To design dynamic and flexible course structures for UG and PG programs as per the changing requirement of the industries</p>	<p>Program Learning Outcome 3a: Industry relevant UG, PG, and research programs</p> <p>Program Learning Outcome 3b: Trained manpower as per the industry requirement.</p>

Program Goal 4: To promote entrepreneurship among the students in the field of Power and Control system engineering	Program Learning Outcome 4a: Realization of working prototype towards product development Program Learning Outcome 4b: Promotion of in-house technology-based ventures catering societal needs.
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Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	EE41XX	B. Tech. Elective – I	3	0	0	3
2.	EE41XX	B. Tech. Elective – II	3	0	0	3
3.	HS41XX	HSS Elective - II	3	0	0	3
4.	XX41PQ	IDE - III	3	0	0	3
5.	EE4196	Summer Internship*	0	0	12	3
6.	EE4197	Project – I	0	0	12	6
7.	EE5101	Computer Aided Power System Analysis	3	0	2	4
TOTAL			15	0	26	25

***Note :**

For specific cases of internship after VIth Semester, the performance evaluation would be made on joining the VIIth Semester and graded accordingly in the VIIth Semester:

Note :

a) (i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening vacation between Semester VI and VII that may be done in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

a) (ii) Further, on return from internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

b) (i) In the VIIth semester, students can opt for a semester long internship on recommendation of the DAPC and approval of the Competent Authority.

b) (ii) On approval of semester long internship, at the maximum two courses (properly mapped/aligned syllabus) at par with institute electives may be opted from NPTEL and / or SWAYAM and the other two more should be done at the institute through course overloading in any other semester (either before or after the internship) and/or during following summer semester.

b) (iii) The candidates opting two courses from NPTEL and / or SWAYAM would be required to appear in the examination at the Institute as scheduled in the Academic Calendar.

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	EE5201	Power System Dynamics, Control and Protection	3	0	2	4
2.	EE5202	Nonlinear Dynamical Systems	3	0	2	4
3.	XX52PQ/ XX62PQ	M. Tech. Elective – I	3	0	0	3
4.	EE4297	Project – II	0	0	12	6
5.	RM6201	Research Methodology	3	1	0	4
TOTAL			12	1	16	21

Sl. No.	Subject Code	SEMESTER IX	L	T	P	C
1.	XX52PQ/ XX62PQ	M. Tech. Elective – II	3	0	0	3
2.	XX52PQ/ XX62PQ	M. Tech. Elective – III	3	0	0	3
3.	XX52PQ/ XX62PQ	M. Tech. Elective – IV	3	0	0	3
4.	EE5197	Project – III**	0	0	16	8
TOTAL			9	0	16	17

Sl. No.	Subject Code	SEMESTER X	L	T	P	C
1.	EE5297	Project IV**	0	0	36	18
TOTAL			0	0	36	18

****Note: M. Tech. Project outside the Institute**

In the IXth Semester, students can opt for a semester long M. Tech. project subject to confirmation from an Institution of repute for research project, on the assigned topic at any external Institution (Industry / R&D lab / Academic Institutions) based on recommendation of the DAPC provided:

(i.) The project topic is well defined in objective, methodology and expected outcome through an abstract and statement of the student pertaining to expertise with the proposed supervisor of the host institution and consent of the faculty member from the concerned department at IIT Patna as joint supervisor.

(ii.) The consent of both the supervisors (external and institutional) on project topic is obtained a priori and forwarded to the academic section through DAPC for approval by the competent authority for office record in the personal file of the candidate.

(iii.) Confidentiality and Non Disclosure Agreement (NDA) between the two organizations with clarity on intellectual property rights (IPR) must be executed prior to initiating the semester long project assignment and committing the same to external organization and vice versa.

(iv.) The evaluation in each semester at Institute would be mandatory and the report from Industry Supervisor will be given due weightage as defined in the Academic Regulation. Further, the final assessment of the project work on completion will be done with equal weightage for assessment of the host and Institute supervisors, project report after **plagiarism check**. The award of grade would comprise **combined assessment based on host supervisor evaluation, project report quality and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the components stated herein.

(v.) In case of poor progress of work and / or no contribution from external supervisor, the student need to revert back to the Institute essentially to fulfill the completion of M. Tech. project as envisaged at the time of project allotment. However, the recommendation of DAPC based on progress report and presentation would be mandatory for a final decision by the competent authority.

Grand TOTAL (Semester I to X) - 209

ELECTIVE GROUPS

B. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE4101	Electrical Traction and Propulsion	3	0	0	3
2.	EC4102	Deep Learning for Video Surveillance Systems	3	0	0	3
3.	EC4103	FPGA based System Design	3	0	0	3

B. Tech. Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC4101	Introduction to Quantum Computing	3	0	0	3
2.	EE4102	Power System Reliability	3	0	0	3
3.	EC4105	Digital Image Processing	3	0	0	3

M. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE6202	HVDC Transmission Systems	3	0	0	3
2.	EC6210	Advance FPGA Platform and System	3	0	0	3
3.	EE6212	Power System Optimization	3	0	0	3
4.	EE6213	Advance Electric Drives	3	0	0	3
5.	EE6214	Random Signals and Systems	3	0	0	3
6.	EE6215	Quantitative Feedback Theory	3	0	0	3
7.	EE6218	Optimal Control	3	0	0	3

M. Tech. Elective – II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5104	Renewable Energy Integration	3	0	0	3
2.	EE6101	Advanced Power System Reliability	3	0	0	3
3.	EE6102	Advanced State Estimation and Target Tracking	3	0	0	3
4.	EE6103	Multivariable Control System	3	0	0	3
5.	EC6105	CMOS Phase Locked Loops	3	0	0	3

M. Tech. Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5105	Power System Deregulation	3	0	0	3
2.	EE6104	Advanced Power System Protection	3	0	0	3
3.	EE6105	Switched Mode Power Converters	3	0	0	3
4.	EE6106	Advanced Digital Control System	3	0	0	3
5.	EC5111	VLSI Architecture Design and Implementation	3	0	0	3

M. Tech. Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5106	Energy Storage Systems	3	0	0	3
2.	EE6108	V2G and G2V Technology	3	0	0	3
3.	EC6108	Emerging Technologies for Beyond 5G	3	0	0	3

Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	EE41XX	B. Tech. Elective – I	3	0	0	3
2.	EE41XX	B. Tech. Elective – II	3	0	0	3
3.	HS41XX	HSS Elective - II	3	0	0	3
4.	XX41PQ	IDE - III	3	0	0	3
5.	EE4196	Summer Internship*	0	0	12	3
6.	EE4197	Project – I	0	0	12	6
7.	EE5101	Computer Aided Power System Analysis	3	0	2	4
TOTAL			15	0	26	25

B. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE4101	Electrical Traction and Propulsion	3	0	0	3
2.	EC4102	Deep Learning for Video Surveillance Systems	3	0	0	3
3.	EC4103	FPGA based System Design	3	0	0	3

Course Number	EE4101
Course Credit	3-0-0-3
Course Title	Electrical Traction and Propulsion
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2, 3 and 4
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving an introduction to electric traction, traction systems and drives, and propulsion mechanism
Course Outline	Electric Traction Introduction, Traction Systems and Latest Trends, Mechanics of Train Movement, Traction Motors and Their Control, Electric Locomotives and Auxiliary Equipment, Feeding and Distribution System. Direct Drive Linear Motors and applications. Fundamentals of electric propulsion system including land, water and space, including space flight dynamics, rocket propulsion systems overview, nozzle theory, combustion processes, and flight performance.
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	Texts/References: <ol style="list-style-type: none"> 1. Modern Electric Traction H. Partab Dhanpat Rai and Sons, New Delhi 2. Electric Traction J. Upadhyay S. N. Mahendra Allied Publishers Ltd., Dhanpat Rai and Sons, New Delhi 3. Electric Traction A.T. Dover Mac millan, Dhanpat Rai and Sons, New Delhi 4. Electric Traction Hand Book R. B. Brooks. Sir Isaac Pitman and sons ltd. London.

Course Number	EC4102
Course Credit	3-0-0-3
Course Title	Deep Learning for Video Surveillance Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with video surveillance tasks such as monitoring and processing of video footage, and understanding and analyzing of machine and deep learning models. The course also develop competence to take logical, scientific and correct decisions while predicting model outcomes. Aptitude and ability of performance measurement and management of video surveillance cameras is also covered.
Course Outline	<p>Introduction to Video Surveillance Systems: Introduction to image processing methods, Edge detection and linking, Image transforms, Introduction to video processing techniques, Video compression standards. Motion detection using optical flow method, motion modeling, Background modeling, Basic building blocks of video surveillance systems.</p> <p>Introduction to Deep Learning: Introduction to neural networks with linear algebra, Matrix mathematics and probability, Introduction to multilayer perceptron networks, forward and back propagation, Hyper-parameter tuning, Regularization and optimization in neural networks, Introduction to tensor-flow.</p> <p>Convolutional Neural Nets: Introduction to convolutional neural networks, Key concepts like convolution and pooling. Stacking convolutional layers for object detection.</p> <p>Recurrent Neural Nets: Introduction to recurrent neural networks (RNN, LSTM, GRU) for sequence level tasks (time series, video). Bidirectional and deep recurrent nets. Use them for activity recognition.</p> <p>Object Detection and Classification using Deep Learning: Haar like feature based object detection, Viola Jones object detection framework, Deep learning based object classification.</p> <p>Object Tracking using Deep Learning: Video monitoring for detection and tracking of single as well as multiple interacting objects, Region-based tracking, Contourbased tracking, Feature-based tracking, Model-based tracking, KLT tracker, Meanshift based tracking.</p> <p>Deep Learning based Human Activity Recognition: Template based activity recognition, CNN based activity recognition, RNN based activity recognition, abnormal behavior detection in crowded environments using deep learning</p> <p>Camera Networks for Surveillance: Types of CCTV (closed circuit television) camera- PTZ (pan-tilt zoom) camera, IR (Infrared) camera, IP (Internet protocol) camera, wireless security camera, multiple view geometry, camera network calibration, PTZ camera calibration, camera placement, smart imagers and smart cameras, Introducing graph signal processing, consensus networks.</p> <p>Emerging Techniques of Deep Learning in Visual Surveillance System: Augmented surveillance system, Operator attention based visual surveillance system, EEG and eye tracking based visual surveillance system, ONVIF standard for the interface of IP-based physical security products.</p>
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. M H Kolekar, "Intelligent Video Surveillance Systems: An Algorithmic Approach", CRC press Taylor and Francis Group, 2018 2. Q. Huihuan, X. Wu, Y. Xu, "Intelligent Surveillance Systems", Springer Publication, 2011. 3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", The MIT Press, 2017. <p>Reference Books:</p>

	<ol style="list-style-type: none">1. Murat A. Tekalp, "Digital Video Processing", Prentice Hall, 1995.2. Pradeep K Atrey, Mohan Kankanhalli, A Cavallaro, "Intelligent Multimedia Surveillance: Current Trends and Research" Springer Publication, 2013.3. Y. Ma and G. Qian (Ed.), "Intelligent Video Surveillance: Systems and Technology", CRC Press, 2009.4. H. Aghajan and A. Cavallaro (Ed.), Multi-Camera Network: Principles and Applications", Elsevier, 2009.
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Course Number	EC4103
Course Credit	3-0-0-3
Course Title	FPGA based System Design
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with design of complex digital systems & use the design flow for using FPGA. This also gives exposure to Softcore Processor IP, Memory and other IO IPs and digital IPs, understanding of IP integration for large scale FPGA based digital System. Also, it covers performance analysis and issues of large scale digital system on FPGA and completion of a significant project on the FPGA platform.
Course Outline	Introduction to reconfigurable and FPGA based system Design; Basic and Advanced FPGA Fabrics; Combinational, Sequential logic and FSM realization on FPGA; FPGA Architecting: Speed, Area and Power; Issues on FPGA based system Design: Area, Timing and Power; Design Methodologies: Behavioral /high level Design and Implementation methodologies: RTL, IP Core, System Generator; Processor and memory cores; Timing analysis; Clock distribution and management systems; IP Cores for FPGA: Block and Distributed memory, FIFO, CORDIC, Clock distribution and management systems; Large scale System Design: Platform FPGA, Multi-FPGA System; Busses and I/O communication system; System Design and Implementation using FPGA: DSP and Communication Blocks and Cryptography blocks Introduction to FPGA based Embedded system platform: Soft processor, AHB Bus and I/O interfacing – Case studies.
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	Text/Reference Books: <ol style="list-style-type: none"> 1. Wayne Wolf, “FPGA Based System Design”, Prentice Hall Modern Semiconductor Design Series, 2004. 2. Steve Kilts, “Advanced FPGA design – Architecture, Implementation and Optimization”, Wiley publications,2007. 3. Ron Sass and Andrew G. Schmidt, Morgan Kaufmann (MK), “Embedded System design with Platform FPGAs”, Elsevier,2010.

B. Tech. Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EC4101	Introduction to Quantum Computing	3	0	0	3
2.	EE4102	Power System Reliability	3	0	0	3
3.	EC4105	Digital Image Processing	3	0	0	3

Course Number	EC4101
Course Credit	3-0-0-3
Course Title	Introduction to Quantum Computing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the key components and architecture of quantum computing systems, including qubits, quantum gates, and quantum circuits. It also focuses on comprehending the principles of quantum information theory, including quantum entanglement, quantum entropy, and quantum teleportation. Implementation and analysis of quantum algorithms, such as Shor's algorithm for factoring and Grover's algorithm for search problems is also included.
Course Outline	Introduction: History, Motivation, Need of quantum bits, quantum states, quantum computations, quantum information, and quantum algorithms Overview of complex numbers and Linear Algebra, Introduction to quantum mechanics and its postulates, Bloch sphere Quantum gates: X, Z, Y, H, R, S, T, Square root of NOT Quantum Circuits: Single qubits and multiple qubits operations and quantum teleportation Quantum Algorithms: Deutsch's algorithm, Deutsch-Jozsa algorithm, Simon's algorithm Quantum Tools and Applications: Goal Challenges, Lights and Photon, Decoherence, Ion Trap, Quantum Simulation
Learning Outcomes	Complies with PLO 1b, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	Textbooks: <ol style="list-style-type: none"> Nielsen, M. A., and Chuang, I. L., Quantum computation and quantum information, 10th Anniversary Edition, 2010, Cambridge university press. Yanofsky, N. S., and Mannucci, M. A., Quantum computing for computer scientists, 1st Edition, 2008, Cambridge University Press. Reference Books: <ol style="list-style-type: none"> Johnston, E. R., Harrigan, N., and Gimeno-Segovia, M., Programming quantum computers: essential algorithms and code samples, 1st Edition, 2019, O'Reilly Media.

Course Number	EE4102
Course Credit	3-0-0-3
Course Title	Power System Reliability
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving reliability, application of probability distributions to evaluate the reliability of power systems.
Course Outline	Introduction to Reliability, Basic Probability Theory, Application of the binomial distribution, Network modelling and evaluation of simple systems, Network modelling and evaluation of complex systems, Probability distributions in reliability evaluation, System reliability evaluation using probability distributions, Distribution systems reliability-basic techniques and radial networks, Plant and Station availability.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	Texts/References: <ol style="list-style-type: none"> 1. R. Billinton, R.N.Allan, BS Publications, Reliability Evaluation of Power systems, 2007. 2. J. Endrenyi, John Wiley and Sons, Reliability Modeling in Electric Power Systems, 1978

Course Number	EC4105
Course Credit	3-0-0-3
Course Title	Digital Image Processing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the fundamental concepts of digital image processing, including filtering, transforms, morphology, colour and image analysis. It also covers the basic image processing algorithms in C or Matlab or Python and make ready the students for advanced version of the course.
Course Outline	Introduction to Digital Image Processing & Applications, Sampling, Quantization, Basic Relationship between Pixels, Imaging Geometry, Image Transforms, Image Enhancement, Image Restoration, Image Segmentation, Morphological Image Processing, Shape Representation and Description, Object Recognition and Image Understanding, Texture Image Analysis, Motion Picture Analysis, Image Data Compression.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson 2. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall <p>Reference Books:</p> <ol style="list-style-type: none"> 1. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis and Machine Vision, Springer

Course Number	EE5101
Course Credit	L-T-P-C: 3-0-2-4
Course Title	Computer Aided Power System Analysis
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on power system analysis of large power systems from programming perspectives.
Course Outline	Load flow for AC systems, fast decoupled load flow, optimal power flow. Fault Analysis, Symmetrical components, Z - matrix for short circuit studies. Introduction to state estimation, Weighted least squares method, LO algorithm, fast decoupled state estimation, DC state estimation, Network observability analysis. Security and contingency studies. Unit Commitment. Load frequency control. Optimal hydro-thermal scheduling. AI applications to Power Systems
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>Text/References</u> <ol style="list-style-type: none"> 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, D.P.Kothari, and R K Saket, Modern Power Systems Analysis, Tata McGraw Hill, 1980. 5. A.J.Wood and B.F.Wollenberg, Power Generation, Operation and Control, John Wiley, 1984

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	EE5201	Power System Dynamics, Control and Protection	3	0	2	4
2.	EE5202	Nonlinear Dynamical Systems	3	0	2	4
3.	XX52PQ/ XX62PQ	M. Tech. Elective – I	3	0	0	3
4.	EE4297	Project – II	0	0	12	6
5.	RM6201	Research Methodology	3	1	0	4
TOTAL			12	1	16	21

Course Number	EE5201
Course Credit	L-T-P-C: 3-0-2-4
Course Title	Power System Dynamics, Control and Protection
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goals 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on power system stability issues and control application for the same.
Course Outline	<p>Basic Concepts of dynamical systems and stability. Modeling of power system components for stability studies: generators, transmission lines, excitation and prime mover controllers, flexible AC transmission (FACTS) controllers.</p> <p>Analysis of single machine and multimachine systems. Small signal angle instability (low frequency oscillations): δ damping and synchronizing torque analysis, eigenvalue analysis.</p> <p>Mitigation using power system stabilizers and supplementary modulation control of FACTS devices. Small signal angle instability (subsynchronous frequency oscillations): analysis and counter-measures.</p> <p>Transient stability: Analysis using digital simulation and energy function method. Transient stability controllers.</p> <p>Introduction to voltage Instability. Analysis of voltage Instability.</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p>Text/References</p> <ol style="list-style-type: none"> 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. 3. K. R. Padiyar, "Power System Dynamics: Stability and Control" Anshan Ltd, 2004.

Course Number	EE5202
Course Credit	L-T-P-C: 3-0-2-4
Course Title	Nonlinear Dynamical Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge of nonlinear dynamical systems.
Course Outline	Introduction to nonlinear systems; analysis by phase plane and describing function methods, periodic solutions and limit cycles. Lyapunov stability theory. introduction to stability; equilibrium point; asymptotic stability; the Lure problem: Popov's method, circle criterion, direct and indirect methods of stability analysis, stability of non-autonomous systems. Hamiltonian Vector Fields: Symplectic Forms, relationship between Hamilton's equations and the symplectic form, transformation of Hamilton's equations under symplectic transformations, dynamics of completely integrable Hamiltonian systems in action-angle coordinates, stability of elliptic equilibria. Reversible dynamical systems: definition of reversible dynamical systems, examples of reversible dynamical systems, linearization of reversible dynamical systems, additional properties of reversible dynamical systems Introduction to hyperstability, Lagrangian and gradient systems: physical examples and analysis.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments, and Exams
Suggested Reading	<ol style="list-style-type: none"> 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

M. Tech. Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE6202	HVDC Transmission Systems	3	0	0	3
2.	EC6210	Advance FPGA Platform and System	3	0	0	3
3.	EE6212	Power System Optimization	3	0	0	3
4.	EE6213	Advance Electric Drives	3	0	0	3
5.	EE6214	Random Signals and Systems	3	0	0	3
6.	EE6215	Quantitative Feedback Theory	3	0	0	3
7.	EE6218	Optimal Control	3	0	0	3

Course Number	EE6202
Course Credit	L-T-P-C: 3-0-0-3
Course Title	HVDC Transmission Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on high voltage DC Transmission.
Course Outline	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. Multi Terminal DC Systems Filters for reducing harmonics and their design.
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>Text/References</u> 1. K.R. Padiyar, HVDC Power Transmission Systems, Wiley eastern Ltd. 1990. 2. E. W. Kimbark, “ <i>Direct Current Transmission</i> ”, Wiley-Interscience, New York.

Course Number	EC6210
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advance FPGA Platform and System
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	Advance FPGA platform and system focuses on the methods of design, development and implementation of complex digital systems using advanced Field-Programmable Gate Arrays (FPGAs) fabrics platform. The course covers topics such as advance FPGA architecture, design methodologies, IP core integration, and implementation of Digital signal processing, control and communication Systems. It also highlights the methods and tools for implementation of Machine learning algorithms.
Course Outline	Introduction to reconfigurable and FPGA based system Design; Basic and Advanced FPGA Fabrics; Combinational and Sequential logic realization on FPGA; Issues on FPGA based system Design: Area, Timing and Power; Design; Behavioral /high level Design and implementation methodologies: HDL, IP Core, System Generator; Processor and memory cores; Timing analysis; Clock distribution and management systems; Large scale System Design: Platform FPGA, Multi-FPGA System; Busses and I/O communication system; DSP system Design and Implementation using FPGA; FPGA based Embedded system platform: Design and implementation methods. Introduction to Implementation methods and tools for machine learning algorithms. Advance FPGA for real time application: A Case Studies on signal processing, Communication and control systems.
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p><u>Text/References</u></p> <ol style="list-style-type: none"> 1. Steve Kilts, "Advanced FPGA design – Architecture, Implementation and Optimization", Wiley publications,2007.7. Samir Palnitkar, "Verilog HDL: A Guide to Digital Design and Synthesis", Second Edition, Prentice Hall PTR, 2003. 2. Wayne Wolf, "FPGA-Based System Design", Prentice Hall Modern Semiconductor Design Series, 2004. 3. Ron Sass and Andrew G. Schmidt, Morgan Kaufmann (MK), "Embedded System design with Platform FPGAs", Elsevier,2010.

Course Number	EE6212
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Power System Optimization
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1 and 2
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on optimization and its application to power systems.
Course Outline	Introduction to optimization, optimality conditions for unconstrained optimization, KKT conditions, convex and non-convex optimization, Linear and Non-linear programming, Quadratic programming, Least Squares Overview of power systems and power system optimization. Economic Dispatch and its solution using Gradient Methods, Newton's Method Unit Commitment and its solution using Dynamic Programming Optimal Power flow and its solution using Gradient Methods, Newton Method Introduction to optimization tools – MatLab Optimization Toolbox, GAMS, GUROBI, CPLEX
Learning Outcomes	Complies with PLO 1a, 2a, and 3a
Assessment Method	Quizzes, Assignments, Exams
Suggested Readings	<ol style="list-style-type: none"> 1. Stephen P. Boyd, Lieven Vandenberghe, Convex Optimization, Cambridge University Press, 2004. 2. A. Ravindran, K. M. Ragsdell and G. V. Reklaitis, Engineering Optimization Methods and Applications, John Wiley & Sons, New York, 2006. 3. Allen J. Wood and Bruce F. Wollenberg, Power Generation Operation and Control, John Wiley and Sons, New York, 1984. 4. James Momoh, "Electric Power Systems Applications of Optimization", CRC press, 2015.

Course Number	EE6213
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advance Electric Drives
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1 and 2
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech to get advance knowledge of modelling and control of DC and AC machines.
Course Outline	<p>Generalized theory and Kron's primitive machine model, Modelling of dc machines Modeling of induction machine, Modeling of synchronous machine Reference frame theory and per unit system</p> <p>Control of Induction Motor Drive Scalar control of induction motor Principle of vector control and field orientation Sensorless control and flux observers' Direct torque and flux control of induction motor Multilevel converter-fed induction motor drive Utility friendly induction motor drive</p> <p>Control of Synchronous Motor Self-controlled synchronous motor Vector control of synchronous motor, Cycloconverter-fed synchronous motor drive Control of synchronous reluctance motor</p> <p>Control of Special Electric Machines Permanent magnet synchronous motor Brushless dc motor Switched reluctance motor Stepper motors and control</p>
Learning Outcomes	Complies with PLOs 1a, 2a, 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Reading	<p><u>Text/References</u></p> <ol style="list-style-type: none"> 1. P.C. Krause, O. Wasynczuk, and S. D. Sudhoff, "Analysis of Electric Machinery", McGraw-Hill Book Company. 2. R. Krishnan, "Electric Motor Drives: Modeling, Analysis and Control", Prentice Hall. 3. P. S. Bhimbra, "Generalized Theory of Electric Machines", Khanna Publication. 4. B. K. Bose, "Modern Power Electronics and AC Drives", Pearson Education.

Course Number	EE6214
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Random Signals and Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on random processes and its effects on linear systems.
Course Outline	<p>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.</p> <p>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.</p> <p>Random process in frequency domain: Peridogram and power spectral density, Weiner-Khintchine-Einstein Theorem, concept of bandwidth, spectral estimation.</p> <p>Linear system: Discrete time and continuous time LTI system, concept of convolution, system described in frequency domain, state space description of the system.</p> <p>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.</p> <p>Processing of random signals: Noise in systems, noise bandwidth, SNR, bandlimited random process, noise reduction, matched filter, Wiener filter.</p> <p>The Kalman filter: Mean square estimation, discrete Kalman filter, innovation, Kalman filter vs Wiener filter, properties of Kalman filter, Kalman Bucy filter, engineering examples.</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p>Text</p> <ol style="list-style-type: none"> 4. Miller, Scott, and Donald Childers, "probability and random processes: with applications to signal processing and communications", Academic Press, 2012. 5. Wim C. van Etten, "Introduction to random signals and Noise", Chichester, England: Wiley, 2005. 6. Peyton Z. Peebles, "Probability, random variables, and random signal principles". McGraw Hill Book Company, 1987. <p>References</p> <ol style="list-style-type: none"> 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 Pares 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

Course Number	EE6215
Course Credit	L-T-P-C: 3-0-0-3
Course Title	QUANTITATIVE FEEDBACK THEORY
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	This course will help the students in learning the systematic loop shaping procedures for uncertain, unstable, non-minimum phase systems to satisfy the designer specifications such as tracking specifications, input/output disturbance rejection specifications and robust stability specifications.
Course Outline	<p>Fundamentals Principle and purpose of feedback- Stability of linear time invariant (LTI) Feedback systems: Asymptotic stability and internal stability- Single input single output (SISO) Degrees of freedom (DOF) feedback structures: one and two DOF – Review of classical control concepts: Nyquist stability criterion- Nichols Chart- Uncertain systems- Description of Uncertainties: Parametric and Non-parametric uncertainty- Need for Robust control- Overview of robust control design methods.</p> <p>Quantitative feedback theory (QFT) Preliminaries System(Plant) modelling- Types of robust control problem- Robust performance: disturbance rejection and tracking problem– Robust Stability- Guidelines to select the specifications- Zero Exclusion principle- Loop transmission function and its importance- Concept of loop shaping Sensitivity function and Complementary sensitivity function- Water Bed effect- Benefits and Cost of feedback</p> <p>QFT Synthesis of SISO LTI Uncertain Feedback Systems QFT Design Procedure for SISO LTI system: QFT Templates/ Value set generation- QFT Bound generation methods: Template manipulation and Quadratic Inequality (QI) approach Derivation of QIs for different design specifications- QFT Controller design using Loop shaping approach- Optimal shaping of nominal loop transfer function- Shaping of QFT Prefilter- Design Examples.</p> <p>QFT Synthesis of SISO Unstable and Non-Minimum Phase system Fundamental limitations on Loop transmission function: Unstable pole and right half plane (RHP) zero- Nyquist Stability criterion in the Nichols Chart- Guidelines to Design Controllers QFT Synthesis of Unstable Systems – Synthesis of NMP System: QFT Bound adjustment step All pass system- Robust Design of Smith Predictor- Design Examples.</p> <p>QFT Synthesis for special control structures Cascade Control of SISO Uncertain System: Inner- Outer loop design, Outer-Inner loop design – QFT based Feedforward Controller design - Digital QFT Control design- QFT design for Model matching problem- Introduction to Multi-input Multi output (MIMO) QFT design: Sequential and Non Sequential approaches – Design Examples.</p>
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<ol style="list-style-type: none"> 1. Quantitative Feedback Theory: Fundamentals and Applications, C. H. Houpis, S.J. Rasmussen, Mario Garcia-Sanz, 2nd Edition, CRC Press, 2018. 2. Robust Control Engineering: Practical QFT Solution, Mario Garcia-Sanz, 1st Edition, CRC Press, 2017. 3. Quantitative feedback design of Linear and Nonlinear Control Systems, Oded Yaniv, 1st Edition, Springer, 1999. 4. Design of Robust Control Systems: From Classical to Modern Practical Approaches, Marcel J. Sidi, 1st Edition, Krieger Publishing Company, 2001. 5. Quantitative Feedback Design Theory (QFT), Horowitz, 1st Edition, QFT Publishers, Denver, CO. 1993. 6. Synthesis of feedback systems, Horowitz, 1st Edition, Academic Press, 1963. 7. Robust control: Theory and Applications, K-Z. Liu, Y. Yao, 1st Edition, 2016.

Course Number	EE6218
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Optimal Control
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1, 2, and 3
Course Description	This course will help the students in learning the various fundamentals and formulations of various Optimal Control Settings, Continuous and Discrete Linear-Quadratic Regulators (LQR) and Linear-Quadratic Tracking (LQT) concepts, Constrained Optimal Control, Dynamic Programming, Riccati equations
Course Outline	<p>Non-Linear Optimization: Unconstrained, Constrained, Lagrange Multipliers, Quadratic Programming.</p> <p>Examples of Optimal Control Problems, Formulation of Continuous-Time Optimal Control Problems, Formulation of Discrete-Time Optimal Control Problems, Extrema of functional.</p> <p>Calculus of Variation approach to optimal control problems: Necessary and Sufficient conditions, Optimal control problems with different boundary conditions – final time (fixed, free) and final state (fixed, free), Linear-Quadratic Regulation (LQR) Problems, Frequency Domain Interpretation of LQR - Linear Time Invariant System, LQR with specified degree of stability, Linear-Quadratic Tracking (LQT) Problems,</p> <p>Constrained Optimal Control: Pontryagins Minimum Principle, Min Time, Min Energy, Min Fuel Problems.</p> <p>Dynamic Programming: Principle of Optimality, Computation of Optimal Control using Dynamic Programming, Hamilton-Jacobi-Bellman Equation.</p> <p>Discrete-Time Optimal Control Problems via variational approach, Discrete LQR, Discrete LQT.</p>
Learning Outcomes	Complies with PLO 1a, 21, 3a
Assessment Method	Quizzes, Assignments, Exams
Suggested Readings	<ol style="list-style-type: none"> 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. 5. Naidu Desineni Subbaram, Optimal Control Systems, CRC Press, Boca Raton London New York, Washington, D.C, 2002

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	<p>Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan.</p> <p>Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods.</p> <p>Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation.</p> <p>Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test,</p>

	ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.). Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and sharing research, Plagiarism and its fallout (case studies), Internet research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.
Learning Outcome	On successful completion of the course, students should be able to: 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

1. C. R. Kothari, Research methodology: Methods and Techniques, 3rd Edn., New age International 2014.
2. Mark N K. Saunders, Adrian Thornhill, Phkip Lewis, “Research Methods for Studies, 3/c Pearson Education, 2010.
3. K.N. Krishnaswamy, apa iyer, siva kumar, m. Mathirajan, “Management Research Methodology”, Pearson Education, 2010.
4. Ranjit Kumar; “Research Methodology: A Step by Step Guide for Beginners; 2/e; Pearson Education, 2010.
5. Suresh C. Sinha, Anil K. Dhiman, ess ess, 2006 “Research Methodology” Panner Selvam.R. “Research Methodology”, Prentice Hall of India, New Delhi, 2004.
6. C.G. Thomas, Research methodology and scientific writing, Ane books, Delhi, 2015.
7. H. J. Ader and G. J. Mellenbergh, Research Methodology in the Social, Behavioural and Life Sciences Designs, Models and Methods, 3rd Edn., Sage Publications, London, 2000.

Sl. No.	Subject Code	SEMESTER IX	L	T	P	C
1.	XX52PQ/ XX62PQ	M. Tech. Elective – II	3	0	0	3
2.	XX52PQ/ XX62PQ	M. Tech. Elective – III	3	0	0	3
3.	XX52PQ/ XX62PQ	M. Tech. Elective – IV	3	0	0	3
4.	EE5197	Project – III**	0	0	16	8
TOTAL			9	0	16	17

M. Tech. Elective – II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5104	Renewable Energy Integration	3	0	0	3
2.	EE6101	Advanced Power System Reliability	3	0	0	3
3.	EE6102	Advanced State Estimation and Target Tracking	3	0	0	3
4.	EE6103	Multivariable Control System	3	0	0	3
5.	EC6105	CMOS Phase Locked Loops	3	0	0	3

Course Number	EE5104
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Renewable Energy Integration
Learning Mode	Lecture
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of M. Tech. The course aims at giving a broad overview of renewable energy grid integration with emphasis on the power electronics, policy, regulation and control.
Course Outline	<p>Policy and Regulation, Modeling of Variable energy resources, Variable energy resources in power system, forecasting renewable energy</p> <p>Connecting renewable energy to power grids, System flexibility, demand response and distributed energy resources</p> <p>Variable energy resources in island power system, Solar, Wind, Tidal and Wave energy integration</p> <p>Power Electronics for grid integration: DC-DC converter, DC-AC converter, Filter Design, Parallel Inverter etc.</p> <p>Enabling and disruptive technologies for grid integration</p> <p>DC distribution system and microgrids: Concept of DC distribution, Power electronic, DC distribution standard, grid integration etc.</p>
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. Robert Ericson, Fundamentals of Power Electronics, Chapman & Hall, 2004. 1. Lawrence E Jones, Renewable Energy Integration, Science Direct, 2014. 2. Moreno-Munoz, Antonio. Large scale grid integration of renewable energy sources. No. 137837. IET, 2017. 3. Fox, Brendan. Wind power integration: connection and system operational aspects. Vol. 50. Iet, 2007. 4. Dragicevic, Tomislav, Patrick Wheeler, and Frede Blaabjerg. DC distribution systems and microgrids. Institution of Engineering and Technology, 2018. 5. Jamil, Majid, M. Rizwan, and D. P. Kothari. Grid Integration of Solar Photovoltaic Systems. CRC Press, 2017.

Course Number	EE6101
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advanced Power System Reliability
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech. The course aims at giving a broad overview of power system reliability at an advanced level.
Course Outline	<p>Basic Probability Theory: Probability concepts, rules for combining probability, probability distributions, random variables, density and distribution functions, mathematical expectations, variance and standard deviation.</p> <p>Basic Reliability Evaluation: General reliability functions, probability distributions in reliability evaluation, network modeling and evaluation of series, parallel, series –parallel, network modeling and evaluation of complex systems, cut-set method, tie-set method, discrete Markov chains, continuous Markov process, frequency and duration technique concepts, application to multi-state problems, approximate system reliability evaluation.</p> <p>Generation System Reliability: Generation system models, capacity outage table, recursive algorithm, loss of load indices, inclusion of scheduled outages, load forecast uncertainty, loss of energy indices, expected energy generation, energy limited systems, Gram-Charlier series and its application to generation system reliability evaluation, generating capacity –frequency and duration method.</p> <p>Interconnected System: Probability array method in two interconnected systems, effect of tie capacity, tie reliability and number of tie lines, equivalent assistance unit method for reliability evaluation of interconnected system, elementary concepts for reliability evaluation of multi-connected systems.</p> <p>Composite Generation and Transmission System Reliability: Radial configurations, conditional probability approach, network configuration, state selection, system and load point indices.</p> <p>Distribution System Reliability: Basic technique and application to radial systems, customer–oriented indices, load and energy indices, effect of lateral distributor protection, effect of disconnects, effect of protection failures, effect of load transfer, meshed and parallel networks, approximate methods, failure modes and effects analysis, inclusion of scheduled maintenance, temporary and transient failures, inclusion of weather effects.</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p>Texts/References:</p> <ol style="list-style-type: none"> 1. Reliability Evaluation of Power systems by R. Billinton, R.N.Allan, BS Publications, 2007. 2. Reliability Evaluation of Engineering Systems Concepts and Techniques by R. Billinton, R.N.Allan, Kluwer Academic, 1992 3. Reliability Modeling in Electric Power Systems by J. Endrenyi, John Wiley and Sons, 1978

Course Number	EE6102
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advanced State Estimation and Target Tracking
Learning Mode	Lectures
Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	This course will help students learn the theoretical aspects of discrete-time stochastic estimators and filters with target-tracking applications. The interest of the course will cover tracking of a single target as well as multiple targets.
Course Outline	<p>Basic Concept of Estimation: Introduction, maximum likelihood and maximum a posteriori estimation, least square and minimum mean square error estimation, Fisher information matrix, Cramer-Rao lower bounds.</p> <p>State Estimation Methods: Principle of Bayesian estimation, recursive state estimation and filtering, filtering with linear Gaussian systems (the Kalman filter), extended Kalman filter, unscented / sigma point Kalman filtering, cubature Kalman filter, sequential importance sampling, resampling strategy, sampling importance resampling (SIR) filter, particle filtering, Rao–Blackwellization.</p> <p>Tracking a Single Target: Maneuvering models, multiple model filtering techniques, tracking a single target in clutter, probabilistic data association (PDA).</p> <p>Tracking Multiple Targets: Multiple targets in clutter, joint probabilistic data association (JPDA), multiple hypothesis tracking (MHT), track-to-track fusion with and without memory, track-to-track association, covariance intersection.</p> <p>Tracking with Multiple Sensors: multi-sensor tracking of a maneuvering target in clutter, multi-sensor tracking configuration, multi-sensor multi-target data association.</p> <p>A case study: Multi-sensor air traffic surveillance.</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p><u>Text/References</u></p> <ol style="list-style-type: none"> 1. B. Ristic, S. Arulampalam, N. Gordon, Beyond the Kalman Filter: Particle Filters for Tracking Applications, Artech House Radar Library, 2004. 2. Y. B. Shalom, and X. R. Li. Multitarget-multisensor tracking: principles and techniques. Vol. 19, 1995. 3. Bar-Shalom, Yaakov, X. Rong Li, and Thiagalingam Kirubarajan. Estimation with applications to tracking and navigation: theory algorithms and software. John Wiley & Sons, 2004. 4. Shovan Bhaumik and Paresh Date, Nonlinear Estimation: Methods and Applications with Deterministic Sample Points, CRC Press, 2019 5. Jia, Bin, and Ming Xin. Grid-based nonlinear estimation and its applications. CRC Press, 2019.

Course Number	EE6103
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Multivariable Control System
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1 and 2
Course Description	This course will help students learn the theoretical aspects of dynamical systems in State-Space framework and properties of systems such as Controllability and Observability. Further, State-feedback control, Output feedback control and LQR, Robust Stability will be covered.
Course Outline	<p>State-space dynamic systems (continuous-time): Introduction to LTI state-space models, Four canonical forms for LTI state-space models, One more canonical form, transformations, Time (dynamic) response, Balanced Realization, Diagonalizing the A matrix, The Jordan canonical form; MIMO canonical forms, Zeros of a state-space system, Linear time-varying systems, What about nonlinear systems? The z transform, Working with the z transform, Discrete-time state-space form, More on discrete-time state-space models, Linear time-varying and nonlinear discrete-time systems.</p> <p>Stability: Vector norms and quadratic forms, Matrix gain, Lyapunov stability, Proof of the Lyapunov stability theorem, Discrete-time Lyapunov stability, Stability of locally linearized systems, Input-output stability, LTV case, Input-output stability, LTI case</p> <p>Observability and controllability: Continuous-time observability: Where am I?, Continuous-time controllability: Can I get there from here?, Discrete-time controllability and observability, Cayley-Hamilton theorem, Continuous-time Gramians, Discrete-time Gramians, Computing transformation matrices, Canonical (Kalman) decompositions, PBH controllability/observability tests, Minimal realizations: Why not controllable/observable ?</p> <p>State-feedback control: Bass-Gura pole placement, Ackermann's formula, Reference input, Pole placement, Integral control for continuous-time systems, State feedback for discrete-time systems, MIMO control design</p> <p>Output-feedback control: Open-loop and closed-loop estimators, The observer gain design problem, Discrete-time prediction estimator, Compensation design: Separation principle, The compensator, continuous- and discrete-time, Current estimator/compensator, Compensator design using current estimator, Discrete-time reduced-order estimator, Discrete-time reduced-order prediction compensator, Continuous-time reduced-order estimator, Estimator pole placement</p> <p>Linear quadratic regulator: Introduction to optimal control, Dynamic programming: Bellman's principle of optimality, The discrete-time LQR problem, Infinite-horizon discrete-time LQR, The continuous-time LQR problem, Solving the differential Riccati equation via simulation, Continuous-time systems and Chang-Letov Method.</p> <p>Robust stability and performance analysis for MIMO systems: General control configuration with uncertainty, Representing uncertainty, Obtaining P, N and M, Robust stability of the M -structure, Robust stability for complex unstructured uncertainty, Robust stability with structured uncertainty, Robust Performance</p>
Learning Outcomes	Complies with PLO 1a, 2a, 3a
Assessment Method	Quizzes, Assignments, Exams
Suggested Readings	<ol style="list-style-type: none"> 1. S. Skogestad and I. Postlethwaite, Multivariable Feedback Control: Analysis and Design, John Wiley & Sons, 2nd Edition, 2005 2. J.M. Maciejowski, Multivariable Feedback Design, Addison-Wesley, 1st Edition, 1989 3. J.P. Hespanha, Linear Systems Theory, Princeton University Press, 2nd Edition, 2018 4. L. A. Zadeh and C. A. Desoer, Linear System Theory: The State Space Approach, Springer-Verlag, 2008. 5. W. Rugh, Linear System Theory, Prentice Hall, 2nd Edition, 1995.

Course Number	EC6105
Course Credit	L-T-P-C: 3-0-0-3
Course Title	CMOS Phase-Locked Loops
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	CMOS Phase-Locked Loops (PLLs) involve the design and implementation of frequency synthesis circuits using Complementary Metal-Oxide-Semiconductor (CMOS) technology. The course covers topics such as PLL architecture, phase detection and comparison, loop filter design, voltage-controlled oscillator (VCO) characteristics, and applications in clock generation, frequency synthesis, and communication systems.
Course Outline	Introduction to PLL, Various types of PLL PLL building blocks: Phase detectors, Phase/Frequency detectors, Ring and LC Voltage-controlled Oscillators (VCO), Frequency Dividers Analysis of PLL: Type-I and Type-II 2nd order PLL; Higher-order loop filters and PLL; PLL Stability Designing PLL: a 2nd order PLL Jitter and Phase noise in Oscillators and PLLs, PLL-based frequency synthesizer: Integer-N and Fractional-N synthesizers, $\Delta\Sigma$ Fractional-N synthesizers All-Digital PLL: Time-to-Digital Conversion, Digital Filters, Digitally Controlled Oscillators, Delay-locked Loops Low jitter frequency synthesizer: Subsampling PLL Architecture and its components
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<u>Text/References</u> 1. B. Razavi, "Design of CMOS Phase-Locked Loops" Cambridge Univ Press, 2020. 2. William F Egan, "Phase-lock Basics," IEEE-Wiley 3. Floyd M. Gardner, "Phase Lock Techniques" 3rd Edition, Wiley-inter-science 4. Ronald E Best, "Phase-locked Loop, Design, Simulation and Applications", 6th edition, McGrawHill 5. Venceslav F Kroupa, "Phase Lock Loops and Frequency Synthesis," Wiley 6. Shanthi Pavan, Richard Schreier, "Understanding Delta-Sigma Data Converters" IEEE-Wiley

M. Tech. Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5105	Power System Deregulation	3	0	0	3
2.	EE6104	Advanced Power System Protection	3	0	0	3
3.	EE6105	Switched Mode Power Converters	3	0	0	3
4.	EE6106	Advanced Digital Control System	3	0	0	3
5.	EC5111	VLSI Architecture Design and Implementation	3	0	0	3

Course Number	EE5105
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Power System Deregulation
Learning Mode	Lectures
Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on Power system restructuring and various business models at different sectors.
Course Outline	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.
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments: 20 %, Mid Sem: 30 % and End Sem: 50 %
Suggested Readings	<u>Text/References</u> 1. Operation of restructured power systems. Kankar Bhattacharya, Jaap E. Daadler, Math H.J. Bollen, Kluwer Academic Pub., 2001. 2. Restructured electrical power systems: operation, trading and volatility Mohammad Shahidehpour, Muwaffaq Alomoush, Marcel Dekker Pub., 2001.

Course Number	EE6104
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advanced Power System Protection
Learning Mode	Lectures
Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on Digital power system relaying and its applications.
Course Outline	<p>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: Generalized 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</p> <p>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.</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p><u>Text/References</u></p> <ol style="list-style-type: none"> 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.

Course Number	EE6105
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Switched Mode Power Converters
Learning Mode	Lectures
Learning Objectives	Complies with Program Objectives 1 and 2.
Course Description	The course is designed to meet the requirements of Ph.D. and M. Tech students to get sufficient knowledge on switched mode power converters. Also, it may be useful for B. Tech final year students.
Course Outline	<p>Power Semiconductor Devices and Passive Elements: Power Diode, Power BJT, Power MOSFET and Power IGBT. Discussion on Capacitor and Inductor. Design of Magnetics.</p> <p>Gate Driver and Snubber Circuits: Discussion on gate driver and snubber circuit requirements.</p> <p>Switched Mode DC-DC Converters: Non-isolated Converters (Buck, Boost, Buck-boost, Full-bridge, Cuk, Sepic and Zeta). Design and control of Buck converter. Isolated DC-DC Converters (Half-bridge, Full-bridge, Forward, Flyback and Push-pull). Design and control of Flyback converter.</p> <p>Switched Mode DC-AC Converters: Single-phase and three-phase PWM VSIs. Discussion on AC filters</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Reading	<p><u>Textbooks:</u></p> <ol style="list-style-type: none"> 1. Ned Mohan, Tore M, Undelnad, William P, Robbins (3 Edition), Power Electronics: Converters, Applications and Design; Wiley, 2002 2. Robert Ericson, Fundamentals of Power Electronics, Chapman & Hall, 2004. <p><u>References:</u></p> <ol style="list-style-type: none"> 1. Ramanarayanan V., Switched Mode Power Conversion, 2007. 2. Umanand L., Power Electronics: Essentials and Applications, Wiley, 2009. 3. Jayant Baliga B., Power Semiconductor Devices, PWS, 1996.

Course Number	EE6106
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Advanced Digital Control System
Learning Mode	Lectures and Tutorials
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	This course will help the students in learning the fundamentals and various components of Digital Control, Digital PID design, discrete state space models, Analyse SISO and MIMO systems and various stability techniques, Deadbeat response and various stability techniques.
Course Outline	<p>Introduction to digital control Introduction -Discrete time system representation –Sample & Hold-Mathematical modeling of sampling process –Data Reconstruction-Design of the hardware and software architecture – Software requirements- Selection of ADC and DAC- Choice of the sampling period –Prefilter/Antialiasing filters - Effects of quantization errors - Phase delay introduced by the ZOH-Sampling period switching- Dual rate control. Modeling discrete-time systems by pulse transfer function -Revisiting Z-transform -Mapping of s-plane to z-plane - Pulse transfer function - Pulse transfer function of closed loop system - Sampled signal flow graph -Stability analysis of discrete time systems -Jury stability test - Stability analysis using bi-linear transformation</p> <p>Design of sampled data control systems Design of PID controller-Filtering the derivative action- Integrator windup- Bumpless transfer between manual and automatic mode - Incremental form-Root locus method - Controller design using root locus - Root locus based controller design using MATLAB - Nyquist stability criteria - Bode plot – Lead compensator design using Bode plot - Lag compensator design using Bode plot - Lag-lead compensator design in frequency domain-Deadbeat response design -Design of digital control systems with deadbeat response - Practical issues with deadbeat response design - Sampled data control systems with deadbeat response</p> <p>Discrete state space model and state feedback design Introduction to state variable model for SISO systems- Various canonical forms – Characteristic equation, state transition matrix - Solution to discrete state equation-Controllability, observability and stability of discrete state space models -Controllability and observability – Stability Pole placement by state feedback - Set point tracking controller - Full order observer - Reduced order observer-Servo Design- State feedback with Integral Control-Deadbeat Control by state feedback and deadbeat observers -Output feedback design - Output feedback design: Theory - Output feedback design: Examples. Introduction to Multivariable & Multi-input Multi-output (MIMO) Digital Control Systems</p> <p>Nonlinear Digital control systems Discretization of nonlinear systems - Extended linearization by input redefinition - - input and state redefinition - output differentiation - Extended linearization using matching conditions – Nonlinear difference equations - Logarithmic transformation- Equilibrium of nonlinear discrete-time systems - Lyapunov stability theory- Lyapunov functions - Stability theorems -Rate of convergence – Lyapunov stability of linear systems - Lyapunov’s linearization method- Instability theorems - Estimation of the domain of attraction - Stability of analog systems with digital control Hybrid Systems - State plane analysis - Discrete-time nonlinear controller design- Controller design using extended linearization- Controller design based on Lyapunov stability theory - Input-output stability and the small gain theorem, Absolute stability</p>
Learning Outcomes	Complies with PLO 1a, 2a, 3a
Assessment Method	Quizzes, Assignments, Exams
Suggested Readings	<ol style="list-style-type: none"> 1. B.C Kuo, ‘Digital Control Systems’, Oxford University Press, Inc., New York, 2nd Ed, 1995 2. G.F. Franklin, J.D. Powell, and M.L. Workman, ‘Digital control of Dynamic Systems’, Addison-Wesley Longman, Inc., Menlo Park, CA, 1998. 3. M. Gopal, ‘Digital Control and State Variable Methods’, 4th Ed, Tata McGraw Hill Publishing Company, 2017.

	<ol style="list-style-type: none">4. John F. Walkerly, 'Microcomputer architecture and Programs', Tata McGraw Hill Publishing Company, John Wiley and Sons Inc., New York, 1981.5. K. Ogata, 'Discrete Time Control Systems' , 2nd Ed, Prentice Hall India Learning Private Limited, 2005.6. C. H. Houpis and G.B. Lamont, 'Digital Control Systems', McGraw Hill Book Company, 2nd Ed, 1992.7. C.L. Philips and H.T Nagle, Jr., 'Digital Control System Analysis and Design', Prentice Hall, Inc., Englewood Cliffs, N. J., 19958. M. Sami Fadali Antonio Visioli, 'Digital Control Engineering Analysis and Design', 3rd Ed, Academic Press, 2019
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Course Number	EC5111
Course Credit	L-T-P-C: 3-0-0-3
Course Title	VLSI Architectural Design and Implementation
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	VLSI Architectural Design and Implementation covers the principles of designing and implementing efficient VLSI architectures. The course includes topics such as pipeline design, data path optimization, and hardware description languages.
Course Outline	<p>Introduction to VLSI System Design and Implementation; Architectural mapping with case studies: Data path, Control path Synthesis; Control Strategies: Hardware implementation of various control structures; Micro-program control techniques; Design issues: Timing, Area, power analysis; FSM Architecture and Synthesis, HDL design and implementation of VLSI architecture;</p> <p>Semiconductor Memory and Peripheral Architectures; Computer arithmetic architecture design and analysis: Introduction to integer and floating-point arithmetic, Adders, Subtractors, Sequential and Array multipliers & dividers, square root, Absolute Difference Value, CORDIC.</p> <p>Hardware architecture design and performance analysis: Sequential/Folding architectures; bit and word serial architecture; High performance architectures: pipelined, parallel and Systolic Array with examples; Architectural performance Analysis: Throughput and Latency; Low Power VLSI Architectures; Basic Hardware Architectures for Digital Signal processing and machine learning algorithms.</p> <p>Introduction to VLSI Chip testing methods and Architectures: Introduction to Chip Fault Model, DFT Architecture, BIST Architecture.</p>
Learning Outcomes	Complies with PLOs 1a, 1b, 2 and 3a
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Readings	<p><u>Text/References</u></p> <ol style="list-style-type: none"> 1. Peter Pirsch, "Architectures for Digital Signal Processing", John Willy & sons, 2nd Edition, 2014. 2. K. K. Parhi, " VLSI Digital Signal Processing Systems: Design and Implementation", A Wiley-Interscience publications, 2011. 3. Behrooz Parhami, " Computer Arithmetic: Algorithm and Hardware Design", Behrooz Parhami, Oxford University Press, 2nd Edition, 2009. 4. A. Bellaouar, M. I. Elmarsny, "Low Power Digital VLSI Design", A. Bellaouar, M. I. Elmarsny, Kluwe academic Publication, 1995. 5. DSP Integrated Circuit, L. Wamhammer, Academic Press, 1999.

M. Tech. Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	EE5106	Energy Storage Systems	3	0	0	3
2.	EE6108	V2G and G2V Technology	3	0	0	3
3.	EC6108	Emerging Technologies for Beyond 5G	3	0	0	3

Course Number	EE5106
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Energy Storage Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	<p>The emerging energy generation sources such as solar and wind generates energy in variable patterns. Hence, energy storage is becoming of major importance to store and supply energy without any interruption. The energy storage can be in mechanical, electrochemical, or chemical forms.</p> <p>So, the course is designed to meet the requirements of M. Tech students to get sufficient knowledge on energy storage techniques. Also, it may be useful for PhD students to explore their research areas in the energy storage systems.</p>
Course Outline	<p>Energy storage systems overview - Scope of energy storage, needs and opportunities in energy storage, Technology overview and key disciplines, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors. Importance of energy storage systems in electric vehicles, Current electric vehicle market.</p> <p>Thermal storage system-heat pumps, hot water storage tank, solar thermal collector, application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation of thermal energy storage systems.</p> <p>Chemical storage system- hydrogen, methane etc., concept of chemical storage of solar energy, application of chemical energy storage system, advantages and limitations of chemical energy storage, challenges, and future prospects of chemical storage systems.</p> <p>Electromagnetic storage systems - double layer capacitors with electrostatically charge storage, superconducting magnetic energy storage (SMES), concepts, advantages and limitations of electromagnetic energy storage systems, and future prospects of electromagnetic storage systems.</p> <p>Electrochemical storage system</p> <p>(a) Batteries-Working principle of battery, primary and secondary (flow) batteries, battery performance evaluation methods, major battery chemistries and their voltages- Li-ion battery & Metal hydride battery vs lead-acid battery</p> <p>(b) Supercapacitors- Working principle of supercapacitor, types of supercapacitors, cycling and performance characteristics, difference between battery and supercapacitors, Introduction to Hybrid electrochemical supercapacitors.</p> <p>(c) Fuel cell: Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor systems.</p> <p>Battery design for transportation, Mechanical Design and Packaging of Battery Packs for Electric Vehicles, Advanced Battery-Assisted Quick Charger for Electric Vehicles, Charging Optimization Methods for Lithium-Ion Batteries, Thermal run-away for battery systems, Thermal management of battery systems, State of Charge and State of Health Estimation Over the Battery Lifespan, Recycling of Batteries from Electric Vehicles</p>
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested Reading	<p>Textbooks:</p> <ol style="list-style-type: none"> 1. Frank S. Barnes and Jonah G. Levine, Large Energy Storage Systems Handbook (Mechanical and Aerospace Engineering Series), CRC press, 2011. 2. Ralph Zito, Energy storage: A new approach, Wiley, 2010. 3. Pistoia, Gianfranco, and Boryann Liaw, Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost. Springer International Publishing AG, 2018. 4. Robert A. Huggins, Energy storage, Springer Science & Business Media, 2010. <p>References:</p>

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| | <ol style="list-style-type: none">1. Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, The Role of Energy Storage with Renewable Electricity Generation, National Renewable Energy Laboratory (NREL) -a National Laboratory of the U.S. Department of Energy. |
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Course Number	EE6108
Course Credit	L-T-P-C: 3-0-0-3
Course Title	V2G and G2V Technology
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	The course is designed to meet the requirements of M. Tech. And Ph.D. The course aims at giving a broad overview of charging concept, energy management in V2G to G2V concept and Fast charging.
Course Outline	Introduction to advanced concepts: DC fast charging, charging infrastructure, Energy Management Strategies, EV charging infrastructure and technology, Bidirectional power converters Energy Flow management through power converters, Grid integration, Load management, Renewable Energy Integration, Grid Ancillary Services and technology, electrification challenges, Smart Charging and Communication
Learning Outcomes	Complies with PLOs 1a, 2a, and 3a.
Assessment Method	Quizzes/Assignments, Mid Sem, and End Sem
Suggested reading	Text/References: <ol style="list-style-type: none"> 1. Emadi, A. (Ed.), Miller, J., Ehsani, M., "Vehicular Electric Power Systems" Boca Raton, CRC Press, 2003. 2. Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 2013. 3. Larminie, James, and John Lowry, "Electric Vehicle Technology Explained" John Wiley and Sons, 2011

Course Number	EC6108
Course Credit	3-0-0-3
Course Title	Emerging Technologies for Beyond 5G
Learning Mode	Lectures
Learning Objectives	After learning this course, the students should be able to: <ol style="list-style-type: none"> 1. understand the evolution of different generation of telecom technology 2. understand about next generation communication system 3. know about the role of frequency in communication system 4. know about the vehicle-to-everything communications 5. know about the basics of molecular, quantum, and aerial communication
Course Description	This course deals with the Statistical Signal Processing.
Course Outline	Introduction to telecom standards and evolution of different generation of communication system, services, key performance index, protocols. Next generation communication system and network architecture. Hybrid RF and optical system working at different frequencies, such mmWave and THz. Vehicle-to-everything (V2X) communications: introduction, architecture, QoS requirement, and resource allocation. Molecular communications: introduction of molecular communications, propagation and channel models, capacity analysis, modulation techniques, applications of molecular technology. Quantum communications: introduction and applications of quantum communications, photon polarization. Introduction to drone and its applications, international rules, regulations, standards & practices, civil aviation requirements, classification & categorization of drones. Aerial communication and networking: air-to-ground channel models, data collection using drone, computation in sky, fronthaul and backhaul links for aerial communications, deployment of swarm of drones. Tactile Internet (TI): introduction to TI and its application, haptic communication, humanmachine interaction, quality of service requirements for TI and resource allocations for haptic data transmission.
Learning Outcome	Complies with PLO 1b, 2a, 3a, 6a, 7, and 8
Assessment Method	Quiz, Assignments, and Exams
Suggested Readings	<p><u>Text Books:</u></p> <ol style="list-style-type: none"> 1. Huang, Kao-Cheng, and Zhaocheng Wang. Millimeter wave communication systems, John Wiley & Sons, 2011. 2. Kürner, Thomas, Daniel M. Mittleman, and Tadao Nagatsuma, eds. THz Communications: Paving the Way Towards Wireless Tbps. Cham, Switzerland: Springer, 2022. <p><u>Reference Books:</u></p> <ol style="list-style-type: none"> 1. Chen, Shanzhi, et al. Cellular Vehicle-to-Everything (C-V2X). Springer Nature, 2023. 2. Nakano, Tadashi. Molecular communication. Cambridge University Press, 2013. 3. Protecting Information: From Classical Error Correction to Quantum Cryptography, S. Loepp & W. K. Wothers, Cambridge Press, 2006 4. Quantum Computation and Quantum Information, M. Nielsen and I. L. Chuang, Cambridge Press, 2006.