RAJIV GANDHI UNIVERSITY OF KNOWLEDGE TECHNOLOGIES ANDHRA PRADESH

(NUZVID RKVALLEY SRIKAKULAM ONGOLE)

DEPARTMENT OF ELECTTICAL AND ELECTRONICS ENGINEERING

DRAFT COURSE STRUCTURE AND DETAILED SYLLABI FOR THE B.TECH PROGRAM IN ELECTRICAL AND ELECTRONICS ENGINEERING

(BOARD OF STUDIES PROPOSED COPY)

[AY 2022-23]

ENGINEERING FIRST YEAR : SEMESTER-1					
S. No	**Course Category**	**Course Code**	**Course Title**	**L-T-P**	**Credits**
1	BSC	MA1101	Engineering Mathematics-I	3-1-0	4
2	BSC	PY1104	Engineering Physics	3-1-0	4
3	BSC	PY1184	Engineering Physics Lab	0-0-3	1.5
4	ESC	EE1101	Fundamentals of Electrical Engineering	3-1-0	4
5	ESC	EE1102	Fundamentals of Electrical Engineering Lab	0-0-3	1.5
6	ESC	CS1109	Programming and Data Structures	3-1-0	4
7	ESC	CS1189	Programming and Data Structures Lab	0-0-3	1.5
8	HSS		Human Values	2-0-0	0
Total Credits				**14**	**20.5**
3 week Induction Programme (Non-Credit)- Before the Commencement of 1st Semester					

ENGINEERING FIRST YEAR : SEMESTER-2					
S. No	**Course Category**	**Course Code**	**Course Title**	**L-T-P**	**Credits**
1	BSC	EE1201	Electromagnetic Fields	3-0-0	3
2	BSC	MA1201	Engineering Mathematics-II	3-1-0	4
3	ESC	EC1201	Basic Electronics	3-1-0	4
4	ESC	EC1281	Basic Electronics Laboratory	0-0-3	1.5
5	PCC	EE1202	Electrical Macines-I	3-1-0	4
6	PCC	EE1203	Electrical Macines-I Laboratory	0-0-3	1.5
7	HSMC	EG1282	English Language Laboratory	1-0-3	2.5
8	ESC	CE1114	Engineering Graphics	1-0-2	2
9	MC	MC3101	Constitution of India	2-0-0	0
Total				**16**	**22.5**

ENGINEERING SECOND YEAR : SEMESTER-1					
S. No	**Course Category**	**Course Code**	**Course Title**	**L-T-P**	**Credits**
1	PCC	20EE2101	Network Analysis	3-1-0	4
2	PCC	20EE2102	Network Analysis Laboratory	0-0-3	1.5
3	PCC	20EC2101	Analog Electronic Circuits	3-1-0	4
4	PCC	20EC2181	Analog Electronic Circuits laboratory	0-0-3	1.5
5	BSC	20MA2101	Mathematics-III (Probability and Random processes)	3-1-0	4
6	PCC	20EE2103	Power Systems-I	3-1-0	4
7	ESC	20CS1209	Object Oriented Programming	3-1-0	4
8	MC		Professional Ethics	3-0-0	0
Total				29	23

ENGINEERING SECOND YEAR : SEMESTER-2					
S. No	**Course Category**	**Course Code**	**Course Title**	**L-T-P**	**Credits**
1	PCC	20EE2201	Electrical Machines-II	3-1-0	4
2	PCC	20EE2202	Electrical Machine-II Laboratory	0-0-3	1.5
3	PCC	20EE2203	Power Systems-II	3-1-0	4
4	PCC	20EC2203	Signals and Systems	3-1-0	4
5	PCC	20EC2205	Digital Logic Design	0-0-3	4
6	PCC	20EC2182	Digital Logic Design Lab	0-0-3	1.5
8	MC	BE4101	Environment Sciences	3-0-0	0
Total				28	19

ENGINEERING THIRD YEAR: SEMESTER-1

S. No	Course Category	Course Code	Course Title	L-T-P	Credits
1	PCC	20EC2103	Digital Signal Processing	4-0-0	4
2	PCC	20EC2203	Linear Integrated Circuits	3-1-0	4
3	PCC	20EC2283	Linear Integrated Circuits Lab	0-0-3	1.5
4	PCC	20EE3105	Internet of things Lab	0-0-3	1.5
5	PCC	20EE3101	Power Electronics	3-1-0	4
6	PCC	20EE3102	Power Electronics Lab	0-0-3	1.5
7	PCC	20EE3103	Control systems	3-1-0	4
8	PCC	20EE3104	Control systems Lab	0-0-3	1.5
9	PROJ	20EE3191	Mini-Project-I (Socially Relevant Project)	0-0-2	1.5
10	ESC	20HS3101	Aptitude and Reasoning	3-0-0	0
11	MC	HS31XX	Placement Skills	2-0-0	0
Total Credits					23.5

ENGINEERING THIRD YEAR: SEMESTER-2

S. No	Course Category	Course Code	Course Title	L-T-P	Credits
1	PCC	20EE3206	Power System Operation and Control(PSOC)	4-1-0	4
2	HSC	BMXY01	Product Design & Innovation	1-0-0	1
3	PEC	EE32XX	Elective-1	3-0-0	3
4	PEC	EE32XX	Elective-2	3-0-0	3
5	OEC	XX32XX	Open Elective-1	3-0-0	3
6	OEC	XX32XX	Open Elective-2	3-0-0	3
7	PROJ	20EE3292	Mini Project-II	0-0-3	1.5
8	PROJ	20EE3210	Summer Internship (After VI semester)		3
Total Credits					**21.5**
MC		20MC3201	Career Development Course	2-0-0	0

Total contact hours : 18 hours
*Mini Project-2 work load not included in above calculation

ENGINEERING FOURTH YEAR: SEMESTER-1					
S. No	**Course Category**	**Course Code**	**Course Title**	**L-T-P**	**Credits**
1	PEC	20EC41XX	Elective-3	3-0-0	3
2	PEC	20EC41XX	Elective-4	3-0-0	3
3	OEC	20XX41XX	Open Elective-3	3-0-0	3
4	PROJ	20EC4192	Summer Internship Project	0-0-6	3
5	PROJ	20EC4193	Project I	0-0-8	4
Total Credits					**16**

Total contact hours: 11 hours

*Project-1 work load not included in above calculation

*Summer Internship Project will be after completion of Engineering Third Year Semester-2

ENGINEERING FOURTH YEAR: SEMESTER -2					
S. No	**Course Category**	**Course Code**	**Course Title**	**L-T-P**	**Credits**
1	HSC	20HS4299	Community Service	0-0-4	2
3	PEC	20EC42XX	Elective-5	3-0-0	3
5	OEC	20XX42XX	Open Elective-4	3-0-0	3
6	PROJ	20EC4294	Project-II & Dissertation	0-0-12	6
Total Credits					**14**

Total contact hours: 6 hours

*Project-2 and Community Service work load not included in above calculation

	TOTAL	E1-S1	E1-S2	E2-S1	E2-S2	E3-S1	E3-S2	E4-S1	E4-S2
BSC	**20.5**	9.5	7	4	0	0	0	0	0
ESC	**22.5**	11	7.5	4	0	0	0	0	0
HSC	**5.5**	0	2.5	0	0	0	1	0	2
PCC	**66**	0	5.5	15	19	22	4	0	0
PEC	**15**	0	0	0	0	0	6	6	3
OEC	**12**	0	0	0	0	0	6	3	3
PROJECTS/ MINI PROJ	**13**	0	0	0	0	1.5	1.5	4	6
SUM INTERN	**6**	0	0	0	0	0	3	3	0
	160	**20.5**	**22.5**	**23**	**19**	**23.5**	**21.5**	**16**	**14**

20EC2103	Digital Signal Processing	PCC	4L: 0T: 0P	4 credits

Course Objective

1. To understand the mathematical approach to manipulate discrete time signals, which are useful to learn digital systems.
2. To study the transformations on digital signals.
3. To understand the concepts of digital filters.

Course Content

Unit-I Introduction **(10 hours)**

A basic review of Signals and Systems, Basic elements of digital signal processing, Time domain representation of discrete time signals, Basic Operations on sequences including Sampling rate alteration, Classification of sequences. Discrete time systems, Time domain characterization of LTI DTS: Convolution sum, Impulse & Step Responses, Simple Interconnection schemes, Linear Constant Coefficient Difference Equations (of Finite- dimensional LTI DTS), Classification of LTI DTS: FIR & IIR, Recursive, & Non- recursive.

Unit-II Discrete Time Fourier Transform (DTFT) **(10 hours)**

Introduction, Fourier Transform Representation of aperiodic Discrete-Time Signals, Periodicity-convergence of DTFT, Properties of DTFT, Signal Transmission Through LTI Systems, Ideal and Practical Filters, energy spectral Density, Power spectral Density.

Unit-III Discrete Fourier Transform (DFT) **(12 hours)**

Sampling of DTFT, Discrete Fourier Transform(DFT) and its Inverse, DFT as a Linear Transformation, Properties of DFT, Linear Convolution Using the DFT, Filtering of Long Data Sequences Using DFT, Spectrum analysis Using DFT.

Fast Fourier Transform (FFT)

Introduction ,Computational Complexity of the Direct Computation of the DFT , Decimation- In-Time (DIT) FFT Algorithm, Decimation-in-Frequency (DIF) FFT Algorithm and their comparison, Inverse DFT using FFT Algorithm, A Linear Filtering approach to Computation of the DFT-The Goertzel Algorithm ,The Chirp-z Transform Algorithm.

Unit IV: Z transforms **(10hours)**

Introduction ,Bilateral (Two-sided) Z-transform , Relationship Between Z-transform and DTFT,Z-Plane, Region-of-Convergence for Z-transforms and their properties, properties of Z-transform, Z-Transform of Causal Periodic Signals, Inversion of the Z-transform, Analysis and Characterization of LTI Systems using the Z-transform. Unilateral (One-Sided) Z-transform, Properties of unilateral Z-Transform. Transient response and steady-State response, Block Diagrams Representation. Applications of Z- Transform in Signal Processing.

Unit-V: Filter Concepts **(10 hours)**

Introduction, Frequency Response and Filter Characteristics, Zero-Phase Filter, Linear phase Filter, simple FIR and IIR Digital Filter, All pass Filters, Minimum-Phase, Maximum-Phase and

Non-minimum (Mixed) Phase Systems, averaging filter, comb filter, Notch filter.

Unit-VI: Realization of Digital Filters **(10 hours)**
Introduction, FIR Filter, IIR Filter, Non-recursive and Recursive Structures, FIR Filter Structures, Basic Structures for IIR Systems , Lattice Structures for FIR and IIR systems.

Learning Resources

Text Books

1. A.V. Oppenheim and R.W. Schaffer, '*Discrete Time Signal Processing'*, 3rd edition, Pearson Education/PHI,2014.
2. John G. Proakis, Dimitris G.Manolakis, '*Digital Signal Processing, Principles, Algorithms, and Applications*', 4th edition, Pearson Education / PHI, 2007.

Reference Books

1. B. P. Lathi, Roger Green, '*Essential of Digital Signal Processing', Cambridge University Press, 2014.*
2. Sanjit K Mitra, *'Digital signal processing: A computer base approach',* 4th edition, Tata McGraw Hill, 2013.
3.

Web Resources

1. Prof Alan V. Oppenheim, OCW- Massachusetts Institute of Technology(MIT), '*Digital Signal Processing'*
URL:https://ocw.mit.edu/resources/res-6-008-digital-signal-processing-spring- 2011/index.html
2. Prof S C Dutta Roy, NPTEL-IIT-Delhi, *Digital Signal Processing*
URL:http://nptel.ac.in/courses/117102060/
3. Prof T K Basu, NPTEL, IIT-Kharagpur, *Digital Signal Processing*
URL:http://nptel.ac.in/courses/108105055/

Course Outcomes:

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

CO1	Interpret ,represent and process discrete/digital signals and systems
CO2	Understand the spectral analysis of signals
CO3	Design &analyze DSP systems like FIR and IIR Filter etc
CO4	Familiarize with multirate signal processing
CO5	Familiarize with applications of Digital Signal Processing

20EC2203	Linear Integrated Circuits	PCC	3L: 1T: 0P	4 credits

Course Learning Objectives

1. To study the basic principles, configurations and practical limitations of an op-amp.
2. To understand the various linear and non-linear applications of op-amp
3. To analyze and design op-amp oscillators, single chip oscillators and frequency generators
4. To understand the operation of the most commonly used D/A and A/D converter types and its applications

Course content

Unit-I: Feedback Amplifiers (10hours)

Feedback concept, General characteristics of Negative feedback amplifier, Different feedback amplifiers (Voltage-series feedback, Current-series feedback, Current-shunt feedback, Voltage-shunt feedback), Effect of negative feedback on input and output impedances, gain & bandwidth.

Unit-II: Operational Amplifiers (10hours)

Ideal op-amp parameters, non-ideal op-amp, op-amp in negative feedback, bandwidth and slew rate on circuit performance. Op-amp applications - summing amplifier, integrator, differentiator, Instrumentation amplifier, V to I and I to V converter, comparator, precision Rectifier, log and antilog amplifier. Active filters.

Unit-III: Wave shaping circuits & Oscillators (12hours)

Positive feedback concept, Barkhausen criterion and design of RC phase oscillators, Wien Bridge oscillator. Ring oscillator, LC oscillators and crystal oscillators, Multivibrators Astable, Monostable and Bistable Multivibrators, Schmitt trigger, square generators.

Unit-IV: DC-DC Converters (8hours)

Introduction, Performance parameters of DC-DC converters, Frequency limiting parameters, Types of converters: Buck, boost and buck-boost.

Unit-V: PLL (10hours)

Basic PLL topology and principle, Major building blocks of PLL- analog and digital phase detector, VCO, applications of PLL.

Unit-VI: Data Converters (10hours)

Analog vs. discrete time signals, Sample-and-Hold circuits, ADC architectures (Flash ADC, Successive Approximation ADC, Dual slope ADC. DACs (Binary weighted resistors, R-2R DAC and current steering DAC). INL &DNL

Learning Resources

Textbooks

1. Behzad Razavi, '*Fundamentals of Microelectronics*', Wiley Publications
2. Sedra and Smith, '*Microelectronics Circuits*', Oxford Publications, 6th Edition.
3. Jacob R Baker, *'CMOS Mixed Signal Circuit Design'* Wiley Publications.

Reference Books

1. Boylestad R. L. and L. Nashelsky, '*Electronic Devices and Circuit Theory*', 11th edition, Pearson, 2009.
2. Millman J. and C. Halkias, '*Integrated Electronics*', 2nd edition, TMH, 2010.
3. Neamen D., '*Electronic Circuit Analysis and Design*', 3rd edition, TMH, 2006
4. Spencer R. R. and M. S. Ghausi, '*Introduction to Electronic Circuit Design*', Pearson, 2003

Web Resources

1. Prof D Nagendra Krishnapura, NPTEL-IIT Madras, '*Analog Integrated Circuit Design*' URL:https://nptel.ac.in/courses/117106030/
2. Prof K Radhakrishna Rao, NPTEL-IIT Madras, '*Electronics for Analog Processing-II*', URL:https://nptel.ac.in/courses/117106088/

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

CO1	Infer the DC and AC characteristics of operational amplifiers and its effect on output and their compensation techniques.
CO2	Elucidate and design the linear and nonlinear applications of an op-amp and special application ICs.
CO3	Explain and compare the working of multi vibrators using special application IC 555 and general purpose op-amp.
CO4	Classify and comprehend the working principle of data converters.
CO5	Illustrate the function of application specific ICs such as Voltage regulators, PLL and its application in communication.

20EC2283	**Linear Integrated Circuits Laboratory**	**PCC**	**0L: 0T: 3P**	**1.5 credits**

Course Learning Objective

1.Experimentally demonstrate the frequency response of amplifiers
2.Practical knowledge on different types of multivibrators and their applications
3.Introductory designs on Analog to Digital Converters
4.Practical exposure to CMOS circuit design especially operational amplifiers
5.Familiarization with CAD tool for analog circuit design

List of Experiments

1. Design and analysis of Feedback amplifiers.
2. Frequency response of inverting & non-inverting amplifier.
3. Design of an Instrumentation amplifier.
4. Schmitt trigger & Noise suppression using Bistable multivibrator.
5. Monostable & Astable multivibrator using opamp.
6. Design of amplifier using CMOS inverters.
7. Two-bit flash ADC design.
8. Design of a typical CMOS inverter (sizing) using EDA tool and finding transfer characteristics & finding the propagation delay.
9. Design of a two input CMOS NAND & NOR gates (sizing) using EDA tool.
10. Design of a fully differential single stage opamp using resistive loads using EDA tool
11. Design of a single stage opamp using diode connected load using EDA tool
12. Term Project (Designing Public Addressing System).

***EDA tool may be Mentor Graphics/Synopsys/Cadence tools**

Note: It is mandatory to perform experiments (1-7) on LT spice tool before the experiment is done on hardware. All experiments must be unique, design specifications should not be common in the lab.

Course outcome:

After the completion of this Laboratory course, the student will be able to

CO 1	To analyze the frequency response of amplifiers
CO 2	Experimentally know the noise suppression in bistable multivibrators
CO 3	Utilization of IC 555 timer
CO 5	Design of Analog to Digital Converters
CO 6	Design of CMOS circuits using CAD tool

20EE3101	Power Electronics	PCC	3L: 1T: 0P	4 credits

Course Learning Objectives:

1.To introduce the concept of semiconductors devices for high power supply and their applications.
2.To understand the need for Power Electronics Devices and Circuits and their basic operation.

Course content

Unit-I: Introduction **(10 hours)**
Introduction to Power Electronics, Power Semi-Conductor Devices: Power Diodes, power Transistors, power MOSFETs, IGBTs, GTOs, Thyristors, Basic theory of operation, characteristics, Ratings, Protection and cooling, line commutation and forced commutation circuits.

Unit II: Converters **(10 hours)**
Power Electronic converters: 1-phase / 3 phase rectifier circuits, 1-phase / 3 phase phase-controlled converters (Semi-converters, full–converters and Dual converters). Analysis and performance with passive and active load, Harmonics and power factor, Introduction to power quality.

Unit III: D.C converters **(6 hours)**
D.C-to-D.C converters (choppers): Buck, Boost and Buck-Boost type and various chopper configurations.

Unit IV: A.C converters **(8 hours)**
A.C-to-A.C converters: A.C voltage controllers, Cyclo-converters, Introduction to matrix converters

Unit V: Inverters **(10 hours)**
D.C–to-A.C converters (Inverters): 1-phase VSI in half bridge and full bridge configuration, CSI, Frequency and voltage control, Line-commutated inverters (LCIs).

Unit-VI: APPLICATIONS **(8 hours)**
Power system applications- Static AC circuit breaker, interconnection of renewable energy sources and energy storage systems to the utility, Industrial applications -Switch mode welder, Voltage source series resonant inverters in induction heating, solid state relay.

Learning Resources

Text Books

1. Daniel W Hart, *Power Electronics* Tata Mc Graw Hill

2. Issah Batterseh, *Power Electronic Circuits*, Wiley.

3. N. Mohan, T.M. Undeland& W.P. Robbins, *Power Electronics: Converter, Applications & Design*, John Wiley & Sons, 1989

4. Muhammad H. Rashid, *Power Electronics: Circuits, Devices, and Applications*, Pearson, 2009

Reference Books

2. Bimal K Bose, *Modern Power Electronics and AC motor Drives*, Pearson Publishers.

3. Joe H. Chow, Alex M. Stankovic, David J. Hill, *Power Electronics and Power Systems* Springer Publications.

Web Resources:

1. Prof. G. Bhuvaneshwari, NPTEL-IIT-Delhi, Power Electronics.
URL:https://archive.nptel.ac.in/courses/108/102/108102145/

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

CO1	Understand the need for Power Electronics Devices and Circuits and their basic operation.
CO2	Perform an analysis of driving and control and triggering circuits for Power Electronic converters
CO3	Perform an analysis of AC to DC converters (Single phase and three phase, controlled and uncontrolled), A.C Voltage controllers, DC to DC converters(choppers), and single phase D.C to A.C converters (Inverters) in square wave mode.
CO4	Perform Fourier analysis and knowledge of Power Quality issues associated with power electronic circuits.
CO5	Understand different applications of power electronics.

20EE3102	**Power Electronics Lab**	**PCC**	**0L: 0T: 3P**	**1.5 credits**

Course Learning Objective:

The course is introduced to the students to enable laboratory scale practical knowledge about power system operation and performance analysis of both hardware and software.

List of Experiments:

1. To study the characteristics of Silicon Controlled Rectifier (SCR) and to find its holding and latching current
2. To study the resistance triggering technique for SCRs
3. To study the RC triggering technique of SCRs
4. To study the characteristics of Uni-Junction Transistor (UJT) and to determine its peak and valley points
5. To study the half-wave converter circuit at different loads and firing angles
6. To study the full wave bridge rectifier circuit and understand its effects on power quality
7. To study the single phase semi-converter circuit at different loads and firing angles
8. To study the single phase full-converter circuit at different loads and firing angles
9. To study the single phase AC voltage controller circuit at different loads and firing angles
10. To study the performance of DC-DC buck converter circuit at different duty ratios
11. To study the performance of single phase full bridge inverter circuit operating in square wave mode

Course Outcomes: Upon successful completion of the course, student should be able to

CO1	Understand the basic concepts of device characteristics and triggering techniques
CO2	Understand the operation of different type of rectifier/converter circuits with different loads
CO3	Understand the operation of choppers, AC voltage controllers and inverters

20EE3103	Control Systems	PCC	4L: 0T: 0P	4

Course Learning Objective

1. To explore the modeling of linear dynamic systems via differential equations and transfer functions utilizing state- pace and input-output representations.
2. Analysis of control systems in the time and frequency domains and using transfer function and state-space methods.
3. Study of the classical stability tests, such as the Routh-Hurwitz and Nyquist criterions, and design methods using root-locus plots and Bode plots.

Course content

Unit-I: Introduction **(6 hours)**

Introduction-Open loop and closed loop control systems- Transfer functions- Block diagrams and their reduction-Signal flow graphs-formula.

Unit-II: Mathematical modeling **(6 hours)**

Mathematical modeling and transfer functions of electrical circuits and mechanical systems. Principle and operation of Servo motors and Stepper motors.

Unit-III: Time response analysis **(10 hours)**

Standard test signals, step response of first and second order systems Time response specifications steady state error static error and generalized error coefficients response with proportional, derivative and integral controllers.

Unit-IV: Stability analysis **(8 hours)**

Stability oncept, characteristic equation, location of roots in the s-plane for stability Routh-Hurwitz criterion, Root locus rules for the construction of root locus- construction of root locus using MATLAB/SIMULINK.

Unit-V: Stability analysis cntd. **(8 hours)**

Introduction-Bode Plots Gain margin and Phase margin - Polar plots - Nyquist stability criterion Need for compensators. Introduction to Lag and lead compensators in frequency domain.

Unit-VI State space Analysis **(10 hours)**

Concepts of state, state variables and state model, derivation of State models from block diagrams, Diagonalization, Solving the Time invariant state Equation, state transition Matrix and its Properties Concepts of Controllability and Observability.

Learning Resources

Text Books:

1. B.C. Kuo, *Automatic control systems*, John Wiley and Sons, 8th edition, 2003.

2. K. Ogata, *Modern control systems*, Prentice Hall of India Pvt. Ltd., 5th edition, 2010.

References

1. I. J. Nagrath and M. Gopal, *Control System Engineering*, New Age International (P) Limited Publishers, 5th edition,2007.
2. Norman S. Nise, *Control System Engineering*, Wiley India, 5th edition2000.

Web Resources:

1. Prof. C.S. Shankar Ram, NPTEL, IIT-Madras, Control Systems.
URL: https://archive.nptel.ac.in/courses/107/106/107106081/

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

CO 1	Analyze controllability and observability of linear systems.
CO 2	Design state-space controller and appropriate (deterministic) observer.
CO 3	Design controller with frequency design methods.
CO 4	Apply root-locus method for analysis and synthesis.
CO 5	Apply pole placement controller design approach.
CO 6	Design linear quadratic regulator for discrete-time systems.

20EE3104	**Control Systems Lab**	**PCC**	**0L: 0T: 3P**	**1.5 credits**

Course learning objective:
The objective of the lab is to design a system and calculate the transfer function, analyzing the stability of the system (both open and closed loop, with positive and negative feedback) with time domain approach and frequency response analysis, using MATLAB and also developing the system which is dynamic in nature with state space analysis approach.

List of Experiments:

1. Time response of Second Order systems
2. Characteristics of Synchros
3. Programmable Logic Controller-Study and verification of truth tables of logic gates, simple Boolean expressions and application of speed control of motor
4. Effect of feedback on DC servo motor
5. Transfer function of DC motor
6. Effect of P, PD, PI, PID Controller on second order systems.
7. Lag and Lead compensation - Magnitude and phase plot
8. Position control of DC motor.
9. Temperature controller using PID
10. Characteristics of AC Servo motor.
11. PSPICE simulation of of P, PD, PI, PID Controller using Op-Amp for second order systems
12. Stability analysis (Bode, Root Locus, Nyquist) of Linear Time Invariant system using MATLAB.
13. State space model for classical transfer function using MATLAB

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

CO1	Recognize the symbols for the different parts of a block diagram: functional blocks, summing blocks and branch points
CO2	Model a mechanical (masses, dampers and springs) and electrical system (inductors, resistors, capacitors) in the form of a transfer function
CO3	Determine the impulse, step, and ramp response of a system, given a transfer function model
CO4	Perform Routh's stability criterion and root locus of a system to determine stability
CO5	For systems with unknown values, determine the range of values for which the system will be stable and explain how adding a pole or a zero affects the stability
CO6	Analyze feedback control systems in the time and frequency domain to use state space concepts to describe systems
CO7	Recognize the "type" of a system (based on the number of free integrators) and discuss the expected error characteristics as related to step, ramp, and acceleration inputs
CO8	Interpret design criteria as related to the closed loop pole location on the complex plane

CO9	Draw the Frequency response plots like Bode, Nyquist and Polar plots (magnitude and phase) for a given transfer function
CO10	Design feedback compensators to achieve a set of desired closed loop system characteristics and design a compensator in the frequency domain to meet specific design requirements using a lead compensator, lag compensator, or lead-lag compensator

20EE3105	**Internet of Things Lab**	**ESC**	**0L: 0T: 3P**	**1.5 Credits**

Course Learning Objectives

1. To assess the vision and introduction of IoT.
2. To understand IoT Market perspective.
3. To implement Data and Knowledge Management and use of Devices in IoT Technology
4. To indulge in designing of prototype hardware for different IoT application.

Exercise-I

Introduction & Overview of Internet of things

The Internet of things today and tomorrow, IoT architecture outline , Functional blocks of IOT , industrial IOT, IOT enabled Smart devices in market, Application areas for IOT, Challenges in IOT. Hardware and Software tools required for IOT application development.

Exercise - II

Exploring the arduino board and its software IDE

The Arduino board, The command area, text area and message window area. Setup function, Controlling the hardware, loop functionality, verifying your sketch, uploading and running your sketch and finally modifying your sketch according to your requirement.

Exercise - III

Introduction to sensors and displays

Interfacing sensors to Arduino boards about the sensor, the circuit connections, sketch (software program), Application.And interfacing displays to arduino board

Exercise - IV Communication

Wireless communication, introduction to Bluetooth module, interfacing to Arduino in both one way communication and two way communication, controlling an LED in wireless mode, interfacing wifi module with arduino controlling things by using local network.

Exercise - V

Introduction to NodeMCU (ESP32 Wi-Fi SoC)

Controlling the things with NodeMCU using wifi communication in both ways and interfacing nodemcu with various peripheral devices. Compare Esp8266 with other arduino boards

Exercise-VI

Introduction to Cloud platforms

IOT device to cloud storage communication Model, need of Cloud services in IOT, different Cloud storage services available today, Cloud Data processing and frame format, Role of Smart phones in IOT, Examples on Home automation and Smart city development, Introduction to clouds like Temboo, Blynk, Pubnub etc.

Exercise -VII

Introduction to GSM, GPS Module

Interfacing Arduino (uno) with GSM, Module 2G communication and interfacing GPS module for tracking location.

Exercise -VIII

Interfacing to External devices

Interfacing Arduino with External storage, Ex: SD card (reading, writing) Handling Interrupts and memory management and Ethernet communication.

Exercise-IX

Introduction to Raspberry pi

Features, Comparison with Arduino, Hardware details and Programming.

Exercise-X

App Inventor

Create apps with coding, Designing apps and interfacing with Arduino.

Exercise-XI

Any one of the project from the list below

Project -I

1.Home Automation with blue tooth and WIFI and controlling the things with Mobile Apps

2.Designing water level controller.

Project -II

1.Designing women safety system with GPS and GSM module

2.Designing secured car parking system using GPS and GSM module

Project -III

1.Uploading sensor information to cloud, operating and Monitoring

2.Designing Smart Hospital with IoT devices.

Web resources:

1. Prof Sudip Misra, NPTEL-IIT Kharagpur, Intorducton to Internet of Things,

   URL: https://nptel.ac.in/courses/106105166/

Course outcomes: At the end of the course, the student will

CO1	Understand and analyze concepts of Internet of Things
CO2	Familiar with arduino board and its software
CO3	Interfacing sensors with arduino board and its working
CO4	Analyze basic protocols in wireless sensor network
CO5	Understand Node MCU arduino board for global communication
CO6	Understand cloud platform to operate our devices through controller
CO7	Design IoT applications in different domain and be able to analyze their Performance

List of Electives:

1. Power system protection and switchgear
2. Measurements and instrumentation
3. High Voltage Engineering
4. Embedded Systems
5. Electric Drives
6. Advanced Control Systems
7. Wind and solar energy systems
8. HVDC and FACTS
9. Distribution System Planning and Automation
10. Power system Protection
11. Switched mode power conversion
12. Smart electric grid
13. Introduction to Machine Learning
14. AI Techniques in Electrical Engineering
15. EV Batteries & Battery Management System
16. Fundamentals of Electric and Hybrid Vehicles

20EE3201	**Power system operation and control**	**PCC**	**4L:0T:0P**	**4 Credits**

Course objectives:

1. To understand optimal dispatch of generation with and without losses.
2. To study the optimal scheduling of hydro thermal systems.
3. To study the optimal unit commitment problem.
4. To understand the reactive power control and compensation of transmission lines.

Course contents:

Unit-I: Economic Operation of Power Systems **(10 hours)**

Optimal operation of Generators in Thermal Power Stations, - heat rate Curve – Cost Curve – Incremental fuel and Production costs, input-output characteristics, Optimum generation allocation with line losses neglected. Optimum generation allocation including the effect of transmission line losses – Loss Coefficients, General transmission line loss formula.

Unit-II: Hydrothermal Scheduling **(10 hours)**

Optimal scheduling of Hydrothermal System: Hydroelectric power plant models, scheduling problems-Short term hydrothermal scheduling problem.

Unit-III: Modeling **(10 hours)**

Modeling of Turbine: First order Turbine model, Block Diagram representation of Steam Turbines and Approximate Linear Models. Modeling of Governor: Mathematical Modeling of Speed Governing System – Derivation of small signal transfer function. Modeling of Excitation System: Fundamental Characteristics of an Excitation system, Transfer function, Block Diagram Representation of IEEE Type-1 Model.

Unit-IV: Single Area & Two-Area Load Frequency Control **(10 hours)**

Necessity of keeping frequency constant. Definitions of Control area – Single area control – Block diagram representation of an isolated power system – Steady state analysis – Dynamic response – Uncontrolled case

Unit-V: Reactive Power Control **(10 hours)**

Overview of Reactive Power control – Reactive Power compensation in transmission systems – advantages and disadvantages of different types of compensating equipment for transmission systems. `

Unit-VI: Load compensation **(10 hours)**

Specifications of load compensator, Uncompensated and compensated transmission lines: shunt and Series Compensation. (Qualitative treatment)

Text books:

1. Dr. K. Uma Rao, *Power System Operation and Control*, Wiley India Pvt. Ltd.

2. Grainger and Stevenson, *Power System Analysis*, Tata McGraw Hill.

Reference books:

1. P S R Murthy, *Operation and Control in Power Systems*, BS Publications.

2. Prabha Kundur, *Power systems stability and control*, The McGraw Hill.

3. C.L.Wadhwa, *Power System Analysis*, New age International.

4. I.J.Nagrath & D.P.Kothari, *Modern Power System Analysis*, Tata McGraw Hill Publishing Company Ltd.

5. J.Duncan Glover and M.S.Sarma, *Power System Analysis and Design*, Cengage Learning.

Course Outcomes: After the completion of course the student will be able to,

CO1	Compute optimal scheduling of Generators.
CO2	Understand hydrothermal scheduling.
CO3	Understand importance of PID controllers in single area and two area systems.
CO4	understand reactive power control and compensation for transmission line.
CO5	understand importance of PID controllers in single area systems.

20EE3202	Measurements and Instrumentation	PEC	3L: 1T: 0P	3 credits

Course Objectives:

1. To understand the basic operation of different measuring instruments and thereby able to choose appropriate instruments for measuring different parameters.

Course Contents:

Unit-I: Measurements **(10 hours)**

Errors & classification, Measurement of voltage & current - permanent magnet moving coil and moving iron meters, Digital voltmeters and automation, guarding techniques.

Unit-II: Measurement of power and energy **(8 hours)**

Dynamometer and induction instruments, kVAh and kVARh meters, maximum demand indicators, digital multi-meters.

Unit-III: Instrument transformers **(8 hours)**

Current and Potential transformers. Spectrum Analyzers, Data & Logic Analyzers.

Transducers Position transducers, force transducers, piezo-electric transducers, Hall effect transducers. Temperature measurement.

UNIT- IV: DC & AC Bridges **(12 hours)**

Method of measuring low, medium and high resistance – sensitivity of Wheat-stone's bridge – Carey Foster's bridge, Kelvin's double bridge for measuring low resistance, measurement of high resistance – loss of charge method. Measurement of inductance- Maxwell's bridge, Hay's bridge, Anderson's bridge - Owen's bridge. Measurement of capacitance and loss angle – Desaunty's Bridge - Wien's bridge – Schering Bridge.

Unit-V: Signal sources **(10 hours)**

Oscillators, Function generator & pulse generators. Oscilloscopes - CRO, Digital storage and Analog storage Oscilloscope, Digital Phosphor Oscilloscopes. Analog & Digital Recorders and printers.

Unit-VI: Signal conditioners **(10 hours)**

Instrumentation amplifiers, voltage–current converters, voltage-frequency converters, analog multiplexers and de-multiplexers. Microprocessor Based Measurements, Case Studies in Instrumentation.

Text Books:

1. A. K. Sawhney, 'A Course in Electrical and Electronic Measurements and Instrumentation', Dhanpat Rai & Co., 9th Edition, 2015.
2. Bouwens A. J., 'Digital Instrumentation', Tata McGraw Hill Publications, 16th Reprint (2008).
3. Kalsi H.S, 'Electronic Instrumentation', Tata McGraw-Hill Education, 3rd Edition, 2010.
4. Deobelin, 'Measurements Systems', Tata McGraw Hill Publications, 2nd Edition, 2010.

Reference Books:

1. W. D. Cooper, 'Electronic Instrumentation and Measurement Techniques', Prentice Hall of India Publications, 1st Edition, 2009.
2. Rangan C.S., 'Instruments Devices and System', Tata McGraw Hill Publications, 2nd Edition, 2009

Course outcomes: Upon completion of the course, the student will be able to

CO 1	Describe the working principle of different measuring instruments.
CO 2	Choose appropriate measuring instruments for measuring various parameters in their laboratory courses.
CO 3	Correlate the significance of different measuring instruments, recorders and oscilloscopes
CO 4	Develop a micro-processor based measuring unit for any practical application.

20EExxxx	**High Voltage Engineering**	**PEC**	**4L: 0T: 0P**	**3 credits**

Course Objectives:
1. To deal with the detailed analysis of Breakdown occurring in gaseous, liquids and solid dielectrics
2. To inform about generation and measurement of High voltage and current
3. To introduce High voltage testing methods

UNIT – I: Breakdown in Gases (8 hours)
Ionization processes and de-ionization processes, Types of Discharge, Gases as insulating materials, Breakdown in Uniform gap, non-uniform gaps, Townsend's theory, Streamer mechanism, Corona discharge.

Unit-II: Breakdown in Liquids (8 hours)
Breakdown in Liquids and Solid Insulating Materials Breakdown in pure and commercial liquids, Solid dielectrics and composite dielectrics, intrinsic breakdown, electromechanical breakdown and thermal breakdown, Partial discharge, applications of insulating materials.

UNIT – III: Generation of High Voltages (6 hours)
Generation of high voltages, generation of high D. C. and A.C. voltages, generation of impulse voltages, generation of impulse currents, tripping and control of impulse generators.

UNIT- IV: Measurements of High Voltages (6 hours)
Measurements of High Voltages and Currents Peak voltage, impulse voltage and high direct current measurement method, cathode ray oscillographs for impulse voltage and current measurement, measurement of dielectric constant and loss factor, partial discharge measurements.

UNIT – V: Lightning and switching (8 hours)
Lightning and switching over-voltages Charge formation in clouds, Stepped leader, Dart leader, Lightning Surges. Switching over voltages, Protection against over-voltages, Surge diverters, Surge modifiers.

UNIT – VI: High Voltage Testing of Electrical Apparatus (8 hours)
High Voltage Testing of Electrical Apparatus and High Voltage Laboratories Various standards for HV Testing of electrical apparatus, IS, IEC standards, Testing of insulators and bushings, testing of isolators and circuit breakers, testing of cables, power transformers and some high voltage equipment, High voltage laboratory layout, indoor and outdoor laboratories, testing facility requirements, safety precautions in H. V. Labs.

Text books:
1. C. L. Wadhwa, "High Voltage Engineering", New Age International Publishers, 2007.

Reference books:
1. D. V. Razevig (Translated by Dr. M. P. Chourasia), "High Voltage Engineering Fundamentals", Khanna Publishers, 1993.
2. E. Kuffel, W. S. Zaengl and J. Kuffel, "High Voltage Engineering Fundamentals", Newnes Publication, 2000.

3. R. Arora and W. Mosch "High Voltage and Electrical Insulation Engineering", John Wiley & Sons, 2011.

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

1. Understand the basic physics related to various breakdown processes in solid, liquid and gaseous insulating materials.
2. Knowledge of generation and measurement of D. C., A.C., & Impulse voltages.
3. Knowledge of tests on H. V. equipment and on insulating materials, as per the standards.
4. Knowledge of how over-voltages arise in a power system, and protection against these over voltages.

20ECXY26	**Embedded Systems**	**PEC**	**3L: 0T: 0P**	**3 credits**

Course Learning Objectives:

1. Students shall learn about evaluation of embedded systems
2. Students shall learn about PIC Unit
3. Students shall learn about ARM processors
4. Students shall learn about DSP processors
5. Students shall learn about software limitations in embedded systems
6. Students shall learn about networking of embedded systems

Course Content

Unit I: Overview of Embedded Systems (6 hours)

Overview of Embedded Systems, Embedded System Architecture, Processor examples: ARM, PIC etc, Introduction to Embedded Hardware, Overview of micro controller and micro-processor, Von Neumann Architecture, Harvard Architecture, Advanced Harvard Architecture, Introduction to PIC microcontroller.

Unit-II: Instruction set (10 hours)

Instruction format, Addressing modes, Instructions, Data transfer instructions, Arithmetic and Logical instructions, Bit oriented instructions, Control instructions, Assembly language programming, Interrupts in PIC, Interrupts timing, PIC input output pins, PIC timers, Watchdog timer, PWM mode in PIC, PIC peripherals, PIC examples.

Unit-III: ARM (10hours)

History, ARM Architecture and its versions, Basic ARM organization, Registers and its organization, Processor modes, Memory Organization, ARM Instruction set, ARM Data types, ARM interrupt processing, Stack organization, ARM input output system, Pipeline operation in ARM, Simple ARM based systems.

Unit-IV: DSP (8 hours)

Features of digital signal processors, DSP applications and DSP algorithms, DSP memory, Instruction sets and parallel instructions, System on chip, Memory, Memory organization, Virtual memory, Memory management Unit, BUS structure, Serial interfaces, Power aware architecture.

Unit-V: Software for embedded systems **(6 hours)**

Requirement and features of software for embedded systems, Usage of C and java and its limitations, Fundamentals of embedded operating systems, Scheduling policies, Resource management, Embedded OS.

Unit-VI: Network embedded systems **(5 hours)**

Network embedded systems, Distributed embedded systems and its Architecture, Multi-processor networks, Ethernet and its features, Hardware modules, Protocols.

Learning Resources:

Textbooks

1. Wayne Wolf, ‘Computers as components: Principles of Embedded Computing System Design’, Morgan Kaufman publication, 2000.
2. A. K. Ray and K. M. Bhurchandani, Advanced Microprocessors and Peripherals, TMH, 2nd Edition 2006

Reference books:

1. Microprocessors and Interfacing, D. V. Hall, TMH, 2nd Edition 2006.

Web resources:

1. Dr. Santanu Chaudhury, NPTEL-IIT Delhi, 'Embedded Systems',
URL: URL: https://nptel.ac.in/courses/108102045/

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

CO 1	Understand evaluation of embedded systems
CO 2	Analyse the PIC Unit
CO 3	Analyse the ARM processors
CO 4	Analyse the DSP processors
CO 5	Understand the software limitations in embedded systems
CO 6	Understand the networking of embedded systems

20EExxxx	**Electric Drives**	**PEC**	**3L: 1T: 0P**	**3 Credits**

Course Learning Objectives:

1. To introduce the drive system and operating modes of drive and its characteristics
2. To understand Speed – Torque characteristics of different motor drives by various power converter topologies
3. To appreciate the motoring and braking operations of drive.
4. To differentiate DC and AC drives

Course Content:

Unit-I: Review of Conventional Drives (6 hours)

Speed–torque relation, Steady state stability, methods of speed control, braking for DC motor, Multi quadrant operation, Speed torque relation of AC motors, Methods of speed control and braking for Induction motor, Synchronous motor. Criteria for selection of motor for drives.

UNIT-II: Converter Control of DC Drives (8 hours)

Analysis of series and separately excited DC motor with single phase and three phase converters operating in different modes and configurations.

Unit-III: Chopper Control of DC Drives (8 hours)

Analysis of series and separately excited DC motors fed from different choppers for both time ratio control and current limit control, four quadrant control.

Unit-IV: Design of DC Drives (6 hours)

Single quadrant variable speed chopper fed DC drives, Four quadrant variable speed chopper fed DC Drives, Single phase/three phase converter, Dual converter fed DC Drive, current loop control, Armature current reversal, Field current control, Different controllers and firing circuits, simulation.

Unit-V: Inverter fed AC Drives (8 hours)

Analysis of different AC motor with single phase and three phase inverters Operations in different modes and configurations., Problems and strategies. Analysis of different AC motor with single phase and three phase cycloconverters Operations in different modes and configurations.

Unit-VI: AC Voltage controller fed AC Drives (6 hours)

Speed Control and braking, Analysis of different AC motor with single phase and three phase ac voltage controllers. Operations in different modes and configurations. Problems and strategies.

Learning Resources:

Text Books:

1. G K Dubey, Fundamentals of Electric Drives, CRC Press, 2002.
2. Murphy J.M.D, Turnbull, F.G, “Thyristor control of AC motor, Pergamon press, Oxford,

1988.
3. M.H. Rashid, "Power Electronics Circuits, Devices and Applications", P.H.I Private Ltd. New Delhi, Second Edition, 1994
4. N. Mohanet.al."Power Electronics-Converters, Applications and Design”, John Wiley & Sons(Asia)Private Ltd.,Singapore,1996.

5. R. Krishnan, “Electric motor drives: modeling, analysis and control, Pearson.

Reference:

1. Sheperal, Wand Hully, L.N. “Power Electronic and Motor control” Cambridge University Press Cambridge 1987
2. Dewan S. Slemon B., Straughen, A.G.R., “Power Semiconductor drives”, John Wiley and Sons, New York 1984.

Course outcomes: Upon completion of the course, the student will be able to

CO 1	Identify the drawbacks of speed control of motor by conventional methods
CO 2	Differentiate Phase controlled and chopper-controlled DC drives speed-torque characteristics merits and demerits
CO 3	Understand Ac motor drive speed–torque characteristics using different control strategies its merits and demerits
CO 4	

20EExxxx	Advanced Control Systems	PEC	3L: 1T: 0P	3 Credits

Course Learning Objectives:

1. To understand and design discrete time control system.
2. To design PID controller using Ziegler-Nichols method.

Course Content :

Unit-I: Review of Modeling and Analysis of LTI Systems
Modeling of physical Systems. Design specifications and performance indices, Motion control systems, Transportation lags. Approximation of time-delay functions, Sensitivity of control systems to parameter variations. Effects of disturbance of signals. Disturbance rejection.

Unit-II: Analysis in state-space
A perspective on state-space design. State variables. State models for physical systems. SISO and MIMO systems. Solution of state equations. Transfer function. Eigen values and Eigen vectors. Jacobian linearization technique. State transformations and diagonalization. Transformation to phase-variable canonical form Controllability and observability. Duality property Stability.

Unit-III: Introduction to Discrete-time Systems
Basic elements of discrete-time control system. Z-transform and properties. Inverse Z-transform. Difference equation and its solution by Z-transform method. Z-transfer function. State diagram of digital systems. Time delay. Direct, cascade and parallel decomposition of Z-transfer functions.

Unit-IV: Feedback control design
Continuous control design Proportional, derivative and integral control action. PID controller tuning rules Ziegler-Nichols method. Two degree of freedom control systems. Compensator design using Bode diagram in frequency response approach. Lag-Lead, Lag-lead compensator. Control law design for full state feedback by pole placement. Full order observer system. Observer based state feedback. Separation principal.

Unit-V: Non-linear system
Classification and types of non-linearity. Phenomena peculiar to non-linear systems. Methods of analysis. Linearization based on Taylor’s series expansion Jacobian Linearization.

Unit-VI: Non-linear system cntd
Phase trajectory and its construction. Phase-plane analysis of linear and non-linear systems. Existence of limit cycles. Describing function of typical non-linearities. Stability analysis by DF method. Introduction to DIDF. Popov’s circle criterion. Stability analysis by Lyapunov’ direct and direct methods, Lypunov’stheorem.

Text Books:

1. Ogata. K , Modern Control Engineering, PHI Learning
2. Kuo B.C. , Automation Control Systems, Prentice Hall

Reference Books:

1. Roy Choudhury D , Modern Control Engineering, Prentice Hall
2. Nagrath J.J., Gopal M, Control System Engineering, New Age Pub.
3. Schulz, D.G. and Mels..L., State Functions and Linear Control Systems, McGraw-Hill.
4. Stepheni, Shahian, Savant, Hostetler Design of feedback control systems, Oxford University Press.

Course outcomes: Upon completion of the course, the student will be able to

CO 1	To understand control strategies for non linear systems
CO 2	To understand feedback control design
CO 3	To understand design of PID controller
CO 4	To understand discrete time control systems

20EExxxx	**Wind and solar energy systems**	**PEC**	**3L: 1T: 0P**	**3 Credits**

Course Objectives:
1. To study the physics of wind power and energy
2. To understand the principle of operation of wind generators
3. To know the solar power resources
4. To analyze the solar photo-voltaic cells
5. To discuss the solar thermal power generation
6. To identify the network integration issues

Course contents:

UNIT - I Wind Power **(10 hours)**

Physics of Wind Power History of wind power, Indian and Global statistics, Wind physics, Betz limit ratio, stall and pitch control, Wind speed statistics-probability distributions, and Wind power-cumulative distribution functions.

UNIT - II Wind Power cntd **(10 hours)**

Wind Generator Topologies Review of modern wind turbine technologies, Fixed and Variable speed wind turbine, Induction Generators, Doubly-Fed Induction Generators and their characteristics, Permanent Magnet Synchronous Generators, Power electronics converters. Generator configurations, Converter Control.

UNIT – III: Solar power **(10 hours)**

The Solar Resource Introduction, solar radiation spectra, solar geometry, Earth Sun angles, observer Sun angles, solar day length, Estimation of solar energy availability.

UNIT – IV: Solar power cntd. **(10 hours)**

Solar Photovoltaic Technologies-Amorphous, mono-crystalline, polycrystalline; V-I characteristics of a PV cell, PV module, array, Power Electronic Converters for Solar Systems, Maximum Power point Tracking (MPPT) algorithms. Converter Control.

UNIT - V Fuel Cells **(10 hours)**

The Fuel Cell-Low and High Temperature Fuel Cells Constructional Features of Proton Exchange-Membrane Fuel Cells–Reformers-Electrolyzer Systems and Related Precautions-Advantages and Disadvantages of Fuel Cells-Fuel Cell Equivalent Circuit-

UNIT - VI Network Integration Issues **(10 hours)**

Overview of grid code technical requirements. Fault ride-through for wind farms - real and reactive power regulation, voltage and frequency operating limits, solar PV and wind farm behavior during grid disturbances. Power quality issues. Power system interconnection experiences in the world. Hybrid and isolated operations of solar PV and wind systems.

Text books:
1. T. Ackermann, "Wind Power in Power Systems", John Wiley and Sons Ltd., 2005.
2. G. M. Masters, "Renewable and Efficient Electric Power Systems", John Wiley and Sons, 2004.

Reference books:

1. S. P. Sukhatme, "Solar Energy: Principles of Thermal Collection and Storage", McGraw Hill, 1984.
2. H. Siegfried and R. Waddington, "Grid integration of wind energy conversion systems" John Wiley and Sons Ltd., 2006.
3. G. N. Tiwari and M. K. Ghosal, "Renewable Energy Applications", Narosa Publications, 2004.
4. J. A. Duffie and W. A. Beckman, "Solar Engineering of Thermal Processes", John Wiley & Sons, 1991.

Course Outcomes: At the end of this course, students will demonstrate the ability to
1.Understand the energy scenario and the consequent growths of the power generate renewable energy sources.
2.Understand the basic physics of wind and solar power generation.
3.Understand the power electronic interfaces for wind and solar generation.
4.Understand the issues related to the grid-integration of solar and wind energy systems

20EExxxx	**HVDC and FACTS**	**PEC**	**3L: 1T: 0P**	**3 Credits**

Course Learning Objective:

1. To compare EHV AC and HVDC systems .
2. To analyze Graetz circuit and also explain 6 and 12 pulse converters
3. To control HVDC systems with various methods and to perform power flow analysis in AC/DC systems.
4. To describe various protection methods for HVDC systems and Harmonics

Course Content:

Unit-I: HVDC Transmission:
DC Power Transmission: Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Types of DC links, relative merits, Components of a HVDC system, Modern trends in DC Transmission systems.

Unit-II: Analysis of HVDC Converters:

Pulse number, choice of converter configurations, Analysis of Graetz circuit with and without overlap, voltage waveforms, Analysis of two and three valve conduction mode, Converter Bridge characteristics, Inverter mode of operation, voltage waveforms

Unit-III: Converter and HVDC Control:

Principles of DC link control, Converter Control characteristics, Control hierarchy Constant current Control, CEA Control, firing angle control of valves, starting and stopping of a dc link, Power control

Unit-IV: Harmonics and Filters:

Ill effects of Harmonics, sources of harmonic generation, Types of filters–Design examples

Unit-V: Power Flow Analysis in AC/DC Systems:

Modelling of DC links, solutions of AC-DC Power flow

Unit-VI: Flexible AC Transmission Systems (FACTS):

FACTS concepts and general system conditions: Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers, Current source and Voltage source converters. Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Independent control of real and reactive power

Learning Recourses:

Text Books:

1. K.R. Padiyar, HVDC Power Transmission Systems–Technology and System Interactions” New Age International Publishers
2. Narain G. Honorani, Laszlo Gyugyi “Understanding FACTS–Concepts and Technology of Flexible AC Transmission Systems”

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

CO1	Evaluate HVDC and EHVAC transmission
CO2	Analyze converter configurations used in HVDC and list the performance metrics.
CO3	Understand controllers for controlling the power flow through a dc link and compute filter parameters
CO4	Apply impedance, phase angle and voltage control for real and reactive power flow in ac transmission systems
CO5	Analyze and select a suitable FACTS controller for a given power flow condition

20EExxxx	**Distribution System Planning and Automation**	**PEC**	**3L: 1T: 0P**	**3 Credits**

Course Learning Objective:

1. To distinguish between transmission and distribution systems.
2. To understand design considerations of feeders
3. To understand about Distribution transformers.
4. To examine the power factor improvement and voltage control

Course Content:

Unit-I: Power sector in India **(10 hours)**
An overview of distribution systems, Distribution system planning-issues and aspects, Introduction to Distribution system forecasting techniques, Stochastic and time series techniques for forecasting, intelligent techniques based load forecasting techniques, Definitions and importance of various terms that characterize loads, Load management and types of tariffs

Unit-II: Distribution transformers (DTRs): **(10 hours)**
Basic design considerations, 3-ph and 1-ph DTRs-types of connections and its relevance in operation, Need for special types of distribution transformers, Cast resin, CSP, Amorphous core DTRs, Regulation and efficiency of transformers-use of predetermined curves

Unit-III: Sub-transmission system: **(10 hours)**
Sub-stations site selection procedure, Sub-station capacity expansion, Location of new sub-stations and their rating, Sub-station bus schemes, VD and PL calculations for a service area with four and six feeders, VD and PL calculations for a service area with n-feeders, Characteristics of primary systems, Voltage drop(VD) and power loss(PL) calculations, Importance of power factor in distribution systems, Capacitors and their role in improving

Unit-IV: Power factor Distribution system protection: **(6 hours)**
Distribution system protection devices, Problems in distribution systems and the need for automation.

Unit-V: Distribution system automation(DSA): **(8 hours)**

General schematic, DSA-Hardware modules and their functions, DSA-Software modules and their functions, DSA-Alternatives in Communication media, Communication protocols for DSA schemes and need for OSA, Examples of DSA schemes, Distribution system grounding.

Learning Resources:

Text Books:

1. Turan Gonen, Electric power Distribution System Engineering, CRC Press, II Edition
2. A. S. Pabla, Electric Power Distribution, TMH, Fifth Edition
3. James A Momoh: Electric Power Distribution, Automation, Protection and Control, CRC Press

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

CO1	Understand the characteristics and components of electric power distribution systems.
CO2	Analyze and evaluate the impact of geographical, demographical and economic factors on distribution systems
CO3	Understand the components of distribution automation systems.
CO4	Design, analyze and evaluate distribution system design based on forecasted data

20EEXXXX	**Power System Protection**	**PEC**	**3L: 1T: 0P**	**3 credits**

Course Learning Objectives: Describe how electric power systems are protected and how speed, dependability, and security are ensured. Be familiar with the protection requirements for generators, power lines, and transformers in an electric energy system. The main protection functions and their protection schemes are described in detail and the settings for them are computed.

Course Content

Unit-I :Numerical Relaying **(6 Hours)**
Introduction to Numerical Relaying- Faults in power system, Elements and features of protection scheme, Fault analysis review-sequence components, Numerical relaying concept. Phasor estimation-Discrete Fourier transform(DFT), recursive and Half cycle DFT, Least square technique, Frequency response of phasor estimation techniques in the presence of decaying DC.

Unit-II: Overcurrent protection **(6 Hours)**
Overcurrent protection-Overcurrent Relay Characteristics, Overcurrent Relay Coordination, Relay Coordination with Fuse. Directional Relaying- Introduction to Directional Relaying, Positive Sequence Directional Relay, Negative and Zero Sequence Directional Relay, Superimposed Component Based Directional Relaying

Unit-III: Distance Relaying **(8 Hours)**
Distance Relaying- Introduction to Distance Relay, Fault Classification, Apparent Impedance Calculation, Distance Relay Implementation, Application to Double Circuit Line, Multi-terminal Lines, Protection of series compensated lines. Effect of Fault Resistance, Load Encroachment, Power Swing, Power Swing Detection Techniques, Adaptive Distance Relaying, Communication Assisted Relaying Scheme

Unit-IV: Transformer protection **(8 Hours)**
CT and CVT response, Fiber Optic Sensors, Transformer protection-Introduction to Transformer Protection, Differential Relay, Steps in Differential Relay Processing, Inrush Detection, CT Saturation, Negative Sequence Differential and Restricted Earth Fault Relay

Unit-V: Differential protection **(8 Hours)**
Differential protection of Line, Bus bar protection, Network Protection with Renewable sources- Fault Characteristics of Renewable Sources, Protection Challenges of Distribution Systems with Renewables, Protection challenges of transmission systems with renewable sources

Unit-VI:Wide Area Measurement **(7 Hours)**
Traveling wave approach-Traveling Wave Basics, Protection using Traveling Waves, Fault Location using Traveling Wave. Wide Area Measurement Basics, Wide Area Measurement for Protection

Learning Resources:
Text Books

1. *Computer relaying for power systems*- A. G. Phadke and J S Thorp, John Wiley and Sons Ltd 2009
2. Modern solutions for protection, control, and monitoring of electric power systems

Reference Books

1. *Power system relaying*- S. H. Horowitz and A. G. Phadke, John Wiley and Sons Ltd 2008
2. *Numerical differential protection*: Principles and Applications. G. Ziegler, 2012, Wiley

Web Resources

1. https://onlinecourses.nptel.ac.in/noc22_ee101/course

Course outcomes: On successful completion of the course students will able to

CO 1	By identifying and formulating advanced problems and applying mathematics and science knowledge, students will demonstrate their ability to solve them
CO 2	Demonstrate the operation of a protective relay with simulated data by designing and coding i
CO 3	Analyze fault conditions for a small electric energy system under transient and steady state faults by developing algorithms and implementations
CO 4	Understand the main protection functions for component protection, such as overcurrent, directional, differential, distance, over/under voltage, over/under frequency, volts over hertz, and out-of-step protection.
CO 5	Developing and implementing special protection systems using traveling wave phenomena; developing and implementing special protection systems using state estimation

20EExxxx	**Switched Mode Power Conversion**	**PEC**	**3L:1T:0P**	**3 Credits**

Course Learning Objective:

1. To understand different non isolated and transformer-isolated power converters.
2. To understand analysis and design of switching regulator control.
3. To understand advanced techniques to improve efficiency and power density, such as use of resonant and soft-transition power converters.

Course Content:

Unit-I: DC/DC Converters (6 hours)
Basic topologies of buck, boost converters, buck-boost converters, and buck converter, isolated DC/DC converter topologies—forward, and fly-back converters, half and full bridge topologies, modeling of switching converters.

Unit-II: Current Mode and Current Fed Topologies (8 hours)
Voltage mode and current mode control of converters, peak and average current mode control, its advantages and limitations, voltage and current fed converters.

Unit-III: Resonant Converters (8 hours)
Need for resonant converters, types of resonant converters, methods of control, phase-modulation technique with ZVS in full-bridge topology, series resonant converter and resonant transition converter.

Unit-IV: Converter Transfer Functions (6 hours)
Application of state-space averaging to switching converters, derivation of converter transfer functions for buck, boost, and fly-back topologies.

Unit-V: Power Converter Design (8 hours)
Design of filter inductor& capacitor, and power transformer, Ratings for switching devices, current transformer for current sensing, design of drive circuits for switching devices, considerations for PCB layout.

Unit-VI: Controller Design (8 hours)
Introduction, mechanisms of loop stabilization, shaping E/A gain vs. frequency characteristic, conditional stability in feedback loops, stabilizing a continuous mode forward converter and discontinuous mode fly-back converter, feed-back loop stabilization with current mode control, the right-half plane zero.

Learning Resources:

Text Books:

1. Ned Mohan Tore M. Undeland: Power Electronics: Converters, Applications, and Design, Edition3, John Wiley & Sons, 2007.
2. Abraham I. Pressman, “Switching Power Supply Design”, Mc Graw Hill International, Second Edition, 1999.

Reference books:

1. P.C. Sen, Modern Power Electronics, S. Chand-2004.
2. Andrzej M. Trzynadlowski Introduction to Modern Power Electronics, 2nd Edition, illustrated Publisher John Wiley & Sons, 2010.
3. Muhammad H. Rashid, Power electronics hand book, ISBN: 81 8147 367 1

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

CO1	Understand isolated and non-isolated DC-DC converters and their operation in continuous conduction mode and discontinuous conduction mode.
CO2	Calculate minimum inductance, capacitance in single switch DC-DC converters.
CO3	Apply current control and voltage control methods to regulate the output power.
CO4	Design DC-DC converters and evaluate the stability of the system

20EExxxx	Smart Electric Grid	PEC	3L:1T:0P	3 Credits

Course learning objective:

This course mainly focuses on basic fundamentals of smart grid for its implementation in the existing power system network. This course provides an overview of smart grid and its applications in potential sectors of Modern power systems. It also provides detailed utility level analysis in terms of energy management, network analysis and operation of smart grids. The course also explores issues in management, control, protection and monitoring of the grid with renewable energy source integration as well as in micro grids at remote locations.

Course content:

Unit I: Introduction to Smart Grid: (6 hours)

Initial Overview of various smart grid measurement and communication technologies, smart grid protocols, Difference between conventional & smart grid, Architecture of Smart Grid, Smart Grid Initiative for Power Distribution Utility in India

Unit II: Enablers for Smart Grid Technology (6 Hours)

Overview of Multi-agent System, Distributed Intelligence, Big Data Analysis, Cloud Computing, Software-Defined Networks (SDN)

Unit III: Smart Grid Decision Support and operational technology (10 Hours)

Concepts of Visualization, Self-Healing, Congestion Management, Dynamic OPF, Security Assessment, Contingency Analysis, Dynamic State estimation, Stability Analysis, Intelligent Fault Management, Feeder Reconfiguration, Short Circuit Analysis, Topology Processing, Power Quality, Voltage VAR Control, advanced control of generators, improved FACTS devices

Unit IV: Smart Analytics (8 Hours)

Computational Intelligence, Wide Area Monitoring and Control Techniques, Demand Response Management, Predictive Asset Management, Forecasting Techniques

Unit V: New technology Integration (8 Hours)

Renewable Integration, Plug-in Electric Vehicle, Smart home and Smart City concepts, Cooperative grids

Unit VI: Smart Grid Market and Economics (7 Hours)

Energy market overview, Role of System Operators, DSO, and TSO under the smart grid, Transactive Energy

Learning Resources:

Text Books

1. Lars T. Berger and Krzysztof Iniewski, “Smart Grid Applications, Communications, And Security,” Wiley, New Delhi, Aug 2015
2. Buchholz, Bernd M., Styczynski, Zbigniew, “Smart Grids – Fundamentals and Technologies in Electricity Networks”, Springer, 2014
3. Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, and Nick Jenkins, “Smart Grid: Technology And Applications,” Wiley, New Delhi, Aug 2015.

Reference Books

1. James Momoh, “Smart Grid: Fundamentals of Design and Analysis,” (I E E Power Engineering Series)– Wiley-Blackwell, Apr 2012
2. Takuro Sato, Daniel M. Kammen, Bin Duan, Martin Macuha, Zhenyu Zhou, and Jun Wu, “Smart Grid Standards: Specifications, Requirements, and Technologies,” WileyBlackwell, Apr 2015.
3. Chen-Ching Liu, Stephen McArthur, Seung-Jae Lee, “Smart Grid Handbook”, 3 Volume Set, Wiley, USA, 2016

Web Resources:

1. https://nptel.ac.in/courses/108107113

Course outcomes: On successful completion of the course students will able to

CO 1	Summaries various aspects of the smart grid Technologies, Components, Architectures and Applications
CO 2	Study and compare modern communication infrastructure and justify the feasibility of the same for smart grid applications.
CO 3	An overview of smart grid and its applications in potential sectors of Modern power systems.
CO 4	Provides detailed utility level analysis in terms of energy management, network analysis and operation of smart grids.
CO 5	The course also explores issues in management, control, protection and monitoring of the grid with renewable energy source integration as well as in micro grids at remote locations.
CO 6	Provides overview of the Smart Grid Market and Economics

20ECXY53	**Introduction to Machine Learning**	**PEC**	**3L: 0T: 0P**	**3 credits**

Course Learning Objectives

1. To provide abroad survey of approaches and techniques in machine learning.
2. To develop a deeper understanding of several major topics in machine learning.
3. To develop the basic skills necessary to pursue research in machine learning.

Course Content:

Unit-I: Introduction **(6hours)**

Introduction, Different types of Learning, Hypothesis space and Cross-Validation, Linear Regression, Introduction to decision trees, learning decision trees, over fitting, Python exercise on decision trees and linear regression

Unit-II: KNN **(7 hours)**

K-Nearest neighbor, feature selection, feature extraction, collaborative filtering, python exercise on KNN and PCA.

Unit-III: Bayesian Learning **(8hours)**

Bayesian Learning, Naïve Bayes, Bayesian Network, Python exercise on Naïve Bayes

Unit-IV: SVM **(8 hours)**

Logistic regression, Introduction to Support Vector Machine, SVM: The Dual formation, SVM: maximum margin with noise, nonlinear SVM and Kennel function, SVM: solutions to the dual problem, Python exercise on SVM.

Unit-V: MLP **(8hours)**

Multilayer Neural network, neural network and back propagation algorithm, deep neural network, python exercise on neural network.

Unit-VI: Clustering **(8 hours)**

Introduction to computational learning theory, sample complexity: finite hypothesis space, VC Dimension, Introduction to Ensembles, Bagging and Boosting, Clustering, means clustering, agglomerative hierarchical clustering, python exercise on clustering.

Learning Resources:

Text Books:

1. Tom Mitchell, Introduction to Machine Learning, TMH 2nd Edition.

2.Ethem Alpaydin, Introduction to Machine Learning, PHI, 2nd Edition.

Reference Books:

1.Andreas C. Müller, Sarah Guido, Introduction to Machine Learning with Python O'Reilly Media, Inc. First Edition.

Web resources:

1. Prof. Sudeshna Sarkar, NPTE-IT-Kharagpur, Introduction to Machine Learning URL: http://nptel.ac.in/courses/106105152/

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

CO1	Understand the fundamental issues and challenges of machine learning like data, model selection, and model complexity.
CO2	Understand strengths and weaknesses of many popular machine learning approaches.
CO3	Design and implement various machine learning algorithms in a range of real world applications.

20EExxxx	AI Techniques in Electrical Engineering	PCC	3L:1T:0P	3 Credits

Course learning Objective:

1. To locate soft commanding methodologies, such as artificial neural networks, Fuzzy logic and genetic Algorithms.
2. To observe the concepts of feed forward neural networks and about feedback neural networks.
3. To practice the concept of fuzziness involved in various systems and comprehensive knowledge of fuzzy logic control and to design the fuzzy control
4. To analyze genetic algorithm, genetic operations and genetic mutations.

Course content:

Unit-I: Artificial Neural Networks:

Introduction, Models of Neuron Network-Architectures–Knowledge representation, Artificial Intelligence and Neural networks–Learning Process-Error correction learning, Hebbian learning– Competitive learning- Boltzmann learning, supervised learning-Unsupervised learning–Reinforcement learning-Learning tasks.

Unit-II: ANN Paradigms:

Multi-layer perceptron using Back propagation Algorithm (BPA), Self Organizing Map (SOM), Radial Basis Function Network-Functional Link Network(FLN), Hopfield Network.

Unit-III: Fuzzy Logic:

Introduction –Fuzzy versus crisp, Fuzzy sets-Membership function –Basic Fuzzy set operations, Properties of Fuzzy sets–Fuzzy cartesion Product, Operations on Fuzzy relations–Fuzzy logic–Fuzzy Quantifiers, Fuzzy Inference-Fuzzy Rule based system, Defuzzification methods

Unit-IV: Genetic Algorithms:

Introduction-Encoding–Fitness Function-Reproduction operators, Genetic Modeling–Genetic operators-Crossover-Single site crossover, Two point crossover–Multipoint crossover-Uniform crossover, Matrix crossover-Crossover Rate-Inversion& Deletion, Mutation operator–Mutation–Mutation Rate-Bit-wise operators, Generational cycle-convergence of Genetic Algorithm.

Unit-V: Applications of AI Techniques:

Load forecasting, Load flow studies, Economic load dispatch, Load frequency control, Single area system and two area system, Small Signal Stability (Dynamic stability), Reactive power control, Speed control of DC and AC Motors.

Learning Resources:

Text Books:

1. S. Rajasekaran and G.A.V.Pai Neural Networks, Fuzzy Logic & Genetic Algorithms, PHI, New Delhi,2003.
2. Rober J. Schalkoff, Artificial Neural Networks, Tata McGraw Hill, 2011

Reference books:

1. P.D. Wasserman; Neural Computing Theory & Practice, Van Nostr and Reinhold, NewYork, 1989.
2. Bart Kosko, Neural Network& Fuzzy System, PrenticeHall,1992
3. D.E. Goldberg, Genetic Algorithms, Addison-Wesley1999.

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

CO1	Understand concepts of ANNs, Fuzzy Logic and Genetic Algorithm.
CO2	Remember difference between knowledge based systems and Algorithmic based systems.
CO3	Understand operation of Fuzzy Controller and Genetic Algorithm.
CO4	Apply soft computing techniques for real-world problems

20EExxxx	**EV Batteries & Battery Management System**	**PEC**	**3L:1T:0P**	**3 Credits**

Course learning Objective:

1. To understand the operation of Battery Management Systems.
2. To understand the mathematical modeling of batteries.
3. To understand battery testing procedures.

Course content:

Unit-I: EV Batteries

Lead acid battery basics, Special characteristics of lead acid batteries, Battery life and maintenance, Battery charging, Summary. Nickel-based Batteries, Introduction, Nickel cadmium, Nickel metal hybrid batteries Sodium-based Batteries, Introduction, Sodium Sulphur batteries, Sodium metal chloride(Zebra) batteries Lithium Batteries, Introduction, the lithium polymer battery

Unit-II: Battery characteristics & parameters

Cells and Batteries, conversion of chemical energy to electrical energy, Battery Specifications: Variables to characterize battery operating conditions and Specifications to characterize battery nominal and maximum characteristics; Efficiency of batteries; Electrical parameters-Heat generation-Battery design-Performance criteria for Electric vehicles batteries-Vehicle propulsion factors-Power and energy requirements of batteries

Unit-III: Battery modeling

General approach to modelling batteries, simulation model of a rechargeable Li-ion battery, simulation model of are chargeable NiCd battery, Parameterization of the Ni Cd battery model, Simulation examples.

Unit-IV: Battery pack and battery management system

Selection of battery for EVs & HEVs, Traction Battery Pack design, Requirement of Battery Monitoring, Battery State of Charge Estimation methods, Battery Cell equalization problem, thermal control, protection interface, SOC Estimation, Energy & Power estimation, Battery thermal management system, Battery Management.

Unit-V: Battery testing, disposal & recycling

Chemical & structure material properties for cell safety and battery design, battery testing, limitations for transport and storage of cell sand batteries, Recycling, disposal and second use of batteries. Battery Leakage: gas generation in batteries, leakage path, leakage rates.

Unit-VI: Battery testing, disposal & recycling cntd.

Mechanical stress and pressure tolerance of cells, safety vents, Explosions: Causes of battery explosions, explosive process, Thermal Runway: High discharge rates, Short circuits, charging and discharging. Environment and Human Health impact assessment of batteries, General recycling issues and drivers, Methods of recycling of EV batteries.

Learning Resources:

Text Books:

1. Ibrahim Dinçer, HalilS. Hamut and Nader Javani, Thermal Management of Electric Vehicle Battery Systems, John Wiley & Sons Ltd., 2016.
2. T R Crompton, Battery Reference Book 3rd Edition, Newnes-Reed Educational and Professional Publishing Ltd., 2000.

Reference books:

1. G. Pistoia, J. P. Wiaux, S. P. Wolsky, Used Battery Collection and Recycling, Elsevier, 2001
2. Guangjin Zhao, Reuse and Recycling of Lithium Ion Power Batteries, John Wiley & Sons. 2017.

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

CO1	Understand Battery management systems
CO2	Available recycling methods of batteries
CO3	Understand Characteristics of different batteries.
CO4	Understand SOC, and SOH estimation

20EExxxx	**Fundamental of Electric and Hybrid Vehicles**	**PEC**	**3L: 1T: 0P**	**3 credits**

Course Content:

Unit-I: Introduction to EV&HEV:
Past, Present & Feature of EV, Current Major Issues, Recent Development Trends ,EV Concept, Key EV Technology, State-of-the Art EVs & HEVs, Comparison of EV Vs IC Engine.

Unit-II EV System:
EV Configuration: Fixed & variable gearing, single & multiple motor drive, In-wheel drives

Unit-III: EV Parameters:
Weight, size, force, energy & performance parameters.

Unit-IV: 4 EV Propulsion:
Electric Motor: Choice of electric propulsion system, block diagram of EV propulsion system, concept of EV Motors, single motor and multi-motor configurations, fixed &variable geared transmission, In-wheel motor configuration, classification of EV motors, Electric motors used in current vehicle applications, Recent EV Motors, Comparison of Electric Motors for EV applications

Unit-V: Required Power Electronics &Control:
Comparison of EV power devices, introduction to power electronics converter, four quadrant DC chopper, three-phase full bridge voltage-fed inverter, soft-switching EV converters, comparison of hard-switching and soft-switching converter, three-phase voltage-fed resonance dc link inverter, Basics of Microcontroller& Control strategies

Unit-VI: HEV (Hybrid Electric Vehicle):
Configuration of HEV (Series, Parallel, Series-parallel &Complex), Power Flow control, Examples. Power flow control in all HEV configurations, Examples of HEV system Performance.

Learning Resources:
Text books:

1. C.C Chan, K.T Chau, Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRCPress,2003.

Reference books:

1. Mehrdad Ehsani, Yimi Gao,Sebastian E.Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRCPress, 2004.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.

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

CO 1	Understand the models to describe hybrid vehicles and their performance.
CO 2	Understand the different possible ways of energy storage
CO 3	Understand the different strategies related to energy storage systems.
CO 4	Understand the difference between Electric and Hybrid Vehicles.