

PERIYAR MANIAMMAI INSTITUTE OF SCIENCE & TECHNOLOGY
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
M.Tech. Power Electronics and Drives
CURRICULUM – REGULATIONS 2024

Category of courses and minimum credit requirement for M.Tech. Power Electronics and Drives programme as per Regulations 2024 are outlined below:

Sl. No.	Category of Courses	Credits
1.	Foundation Courses	04
2.	Professional Core Courses	33
3.	Professional Elective Courses	12
4.	Online Courses	03
5.	Employability Enhancement Courses (Internship, Field Visit / Professional Practices / Project / Research / Thesis / Dissertation)	20
6.	Value Added/ Value Addition Courses (IKS, Community Engagement, Research Methodology and IPR, Cybersecurity)	08
	Total	80

Sl. No.	Course Code	Course Name	Credits			
			L	T	P	C
Theory						
1	P24PE101	Applied Mathematics for Power Electronics Engineers	3	1	0	4
2	P24PE102	System Theory	3	0	0	3
3	P24PE103	Analysis of Power Converters	3	1	0	4
4	P24PE104	Modeling and Design of SMPS	3	0	0	3
5	P24PE9XX	Professional Elective - I	3	0	0	3
6	P24VA008	Indian Knowledge System – Concepts And Applications In Engineering	3	0	0	3
Practical						
7	P24PE105	Power Converters Laboratory	0	0	4	2
8	P24PE106	Design Laboratory for Power Electronics Systems	0	0	4	2
Total			18	2	8	24

SEMESTER II

Sl. No.	Course Code	Course Name	Credits
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			L	T	P	C
Theory						
1	P24PE151	Analysis of Electrical Drives	3	1	0	4
2	P24PE152	Special Electrical Machines	3	0	0	3
3	P24PE153	Electric Vehicles and Power Management	3	0	0	3
4	P24PE154	Modern Rectifiers and Resonant Converters	3	1	0	4
5	P24PE9XX	Professional Elective - II	3	0	0	3
6	P24PE9XX	Professional Elective - III	3	0	0	3
7	P24VAXXX	Community Engagement and Social Responsibility	1	0	2	2
Practical						
8	P24PE155	Power Electronics and Drives Laboratory	0	0	4	2
Total			19	2	6	24

SEMESTER III

Sl. No.	Course Code	Course Name	Credits			
			L	T	P	C

Sl. No.	Course Code	Course Name	Credits			
			L	T	P	C
Theory						
1	P24PE201	Grid Integration of Renewable Energy Sources	3	0	0	3
2	P24PE9XX	Professional Elective – IV	3	0	0	3
3	P24PE9XX	Online Course	3	0	0	3
4	P24VAXXX	Research Methodology and Publication Ethics	3	0	0	3
5	P24PE203	Internship / Field Visit	0	0	4	2
Practical						
6	P24PE204	Project Phase - I	0	0	12	6
Total			12	0	16	20

SEMESTER IV

Sl. No.	Course Code	Course Name	Credits			
			L	T	P	C
Practical						
1	P24PE251	Project Phase - II	0	0	24	12
Total			0	0	24	12

The number of credits in each semester is summarized as follows:

Course	I	II	III	IV

M.Tech. Power Electronics and Drives	24	24	20	12
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Semester wise Credit Distribution (in all categories of courses)

Sl. No.	Category of Courses	Credits	I	II	III	IV
1.	Foundation Courses	4	4	-	-	-
2.	Professional Core Courses	33	14	16	3	-
3.	Professional Elective Courses	12	3	6	3	-
4.	Professional Elective Courses (Online)	3	-	-	3	-
5.	Employability Enhancement Courses (Internship / Field Visit / Professional Practices / Project / Research / Thesis / Dissertation)	20	-	-	8	12
6.	Value Added Courses / Value Addition Courses (IKS, Community Engagement, Research Methodology and IPR, Cybersecurity)	8	3	2	3	-
	Total	80	24	24	20	12

Suggested List of Professional Elective Courses

Elective – I

S. No.	Course	Course Name	Credits
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	Code		L	T	P	C
1	P24PE901	Power Semiconductor Devices	3	0	0	3
2	P24PE902	Soft Computing Techniques	3	0	0	3
3	P24PE903	Analysis of Electrical Machines	3	0	0	3
4	P24PE904	IoT for Smart Systems	3	0	0	3

Elective – II

S. No.	Course Code	Course Name	Credits			
			L	T	P	C
1	P24PE905	Power Electronics for Renewable Energy Systems	3	0	0	3
2	P24PE906	EV Batteries and Charging Systems	3	0	0	3
3	P24PE907	Advanced Power Converters	3	0	0	3
4	P24PE908	Battery Management Systems	3	0	0	3

Elective - III

Sl. No.	Course Code	Course Name	Credits			
			L	T	P	C
1	P24PE909	Energy Storage Technologies	3	0	0	3
2	P24PE910	Power Quality	3	0	0	3
3	P24PE911	Machine Learning and Deep Learning	3	0	0	3
4	P24PE912	Electrical Energy Conservation and Management	3	0	0	3

Elective – IV

Sl. No.	Course Code	Course Name	Credits			
			L	T	P	C
1	P24PE913	Optimization Techniques	3	0	0	3

2	P24PE914	Smart Grid	3	0	0	3
3	P24PE915	HVDC Transmission	3	0	0	3
4	P24PE916	Renewable Energy Technology	3	0	0	3

Elective - V

S. No.	Course Code	Course Name	Credits			
			L	T	P	C
1	P24PE917	Distributed Generation and Micro Grid	3	0	0	3
2	P24PE918	Power Electronics for Wind and Solar Energy Systems	3	0	0	3
3	P24PE919	Industry 4.0 And Industrial Internet Of Things (IIoT)	3	0	0	3
4	P24PE920	Digital control in Power Electronics	3	0	0	3

SYLLABUS 2024

Course Code	Course Name	L	T	P	C
P24PE101	Applied Mathematics For Power Electronics Engineers	3	1	0	4

Category: Foundation Courses

a. Preamble

This course offers a comprehensive exploration of advanced mathematical techniques and their practical applications across various domains. The primary focus is to equip students with a solid foundation in core areas of mathematics, including matrices, infinite series, differential calculus, multivariable calculus, and differential equations. Also, use effective mathematical tools for the solutions of partial differential equations that model several physical processes and to develop Z transform techniques for discrete time systems.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Apply the concepts of matrix theory in Electrical Engineering problems.	K4
CO2	Solve boundary value problems associated with engineering applications.	K3
CO3	Solve problems using Laplace transform associated with engineering applications.	K3
CO4	Use the effective mathematical tools for the solutions of partial differential equations that model several physical processes and to develop Z transform techniques for discrete time systems.	K4
CO5	Solve problems using Fourier series associated with engineering applications.	K4
CO6	Apply appropriately various mathematical concepts for Power Electronics Applications	K4

c. Course Syllabus

Total: 60 Hours

MATRIX THEORY

12

The Cholesky decomposition - Generalized Eigenvectors - Canonical basis - QR factorization - Singular value decomposition - Pseudo inverses - Least square approximation

CALCULUS OF VARIATIONS

12

Concept of variations and its properties - Euler's theorem - Functional dependent on first and higher order of derivatives - Functional dependent on functions of several independent variables - Variational problems with moving boundaries - Isoperimetric problems - Direct methods : Rayleigh Ritz method and Kantorovich problems

LAPLACE TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS

12

Definitions - Properties - Transform error function - Bessel's function - Dirac Delta function - Unit step function - Convolution theorem - Inverse Laplace transform - Complex inversion formula - Solutions to partial differential equations: Heat and Wave equations.

TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS

12

Z-transforms - Elementary properties – Convergence of Z-transforms - Initial and final value theorems - Inverse Z - transform (using partial fraction and residues) - Convolution theorem - Formation of difference equations – Solution of difference equations using Z – transforms

FOURIER SERIES

12

Fourier Trigonometric series: Periodic function as power signals - Convergence of series - Even and odd functions: Cosine and sine series - Non periodic function - Extension to other intervals - Power signals: Exponential Fourier series - Parseval's theorem and power spectrum - Eigenvalue problems and orthogonal functions - Regular Sturm –Liouville systems - Generalized Fourier series.

d. Activities

- Assignments on problems involving the computation of eigenvalues and eigenvectors for various matrices and verifying the Cayley-Hamilton theorem for given matrices by finding their characteristic polynomial and substituting it into the matrix.
- Use various convergence tests (Comparison test, Integral test, D'Alembert's ratio test) to determine the convergence or divergence of a series.
- Solve problems involving finding maxima and minima for functions of two variable using differentiation.
- Solve a set of linear differential equations of second and higher orders using appropriate methods

e. Learning Resources

1. Richard Bronson, "Matrix Operation", Schaum's outline series, Second Edition, McGraw Hill, New Delhi, 2011.
2. Elsgolc. L.D., "Calculus Of Variations", Dover Publications Inc., New York, 2007.
3. SankaraRao. K, "Introduction to Partial Differential Equations", Prentice Hall of India Pvt. Ltd, New Delhi, 1997.
4. Grewal.B.S., "Higher Engineering Mathematics", Khanna Publishers, New Delhi, 44th Edition, 2018.
5. Andrews .L.C, and Phillips. R.L, "Mathematical Techniques for Engineers And Scientists", Prentice Hall, New Delhi, 2005.

Course Code	Course Name	L	T	P	C
P24PE102	System Theory	3	0	0	3

Category: Professional Core Course

a. Preamble

This course offers a comprehensive exploration of the fundamental of physical systems in terms of its linear and nonlinear models. Also this gives a clear understanding of the properties of linear systems such as controllability and observability.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand and model physical systems using state vectors	K2
CO2	Analyze the stability of linear systems.	K4
CO3	Design state feedback controllers and observers.	K4
CO4	Understand and analyze non-linear systems using linear approximations	K4
CO5	Inspect the stability of non-linear systems by direct and indirect methods.	K4
CO6	Understand the various effects of state feedback on controllability and observability.	K2

c. Course Syllabus

Total: 45 Hours

STATE VARIABLE REPRESENTATION 9

Introduction to state space modeling - modeling of physical systems - Solution to vector differential equations and state transition matrix.

SOLUTION OF STATE EQUATIONS 9

Stability analysis of linear systems - Controllability and Observability definitions and Kalman rank conditions - Detectability and Stabilizability - Kalman decomposition.

PROPERTIES OF THE CONTROL SYSTEM 9

State feedback controller design using pole placement. Observer design using Kalman filter algorithm. LQR and LQG controller design

NON-LINEARITIES AND STABILITY ANALYSIS 9

Introduction to nonlinear systems. Phase plane analysis of nonlinear system using linear approximation. Limit cycle and periodic solutions. Singular points (equilibrium points) and qualitative behavior near singular points.

MODAL ANALYSIS 9

Stability of nonlinear systems. Lyapunov direct and indirect methods. Input-to-state stability and relative stability

d. Activities

- Problem solving exercise on linear and non-linear system
- Industry Interaction with Experts
- Use simulation software (e.g., MATLAB/Simulink, PSpice) to model and analyze power electronic circuits. Students will simulate different scenarios and evaluate system responses, relating outcomes to theoretical principles.

e. Learning Resources

1. Ogata, K., 'Modern Control Engineering', Prentice Hall of India, 2010.
2. C.T. Chen, 'Linear Systems Theory and Design', Oxford University Press, 3rd Edition, 1999.
3. M. Vidyasagar, 'Nonlinear Systems Analysis', 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey 07632.
4. Hassan K. Khalil, 'Nonlinear Systems', Pearson Educational

International Inc. Upper Saddle River, 3rd Edition.

Course Code	Course Name	L	T	P	C
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P24PE103	Analysis Of Power Converters	3	1	0	4
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Category: Professional Core Course

a. Preamble

This course will provide the mathematical fundamentals necessary for deep understanding of power converter operating modes and introduce the electrical circuit concepts behind the different working modes of power converters so as to enable deep understanding of their operation. The student shall acquire the required skills to formulate and design inverters for generic load and for machine loads and derive the criteria for the design of power converters starting from basic fundamentals.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Acquire and apply knowledge of mathematics in power converter analysis	K4
CO2	Model, analyze and understand power electronic systems and equipment.	K3
CO3	Formulate, design and simulate phase controlled rectifiers for generic load and for machine loads	K3
CO4	Design and simulate switched mode inverters for generic load and for machine loads	K4
CO5	Select device and calculate performance parameters of power converters under various operating modes	K4
CO6	Give a systematic approach for transient and steady state analysis of all power electronic converters with passive and active loads	K4

c. Course Syllabus

Total: 60 Hours

SINGLE PHASE AC-DC CONVERTER 12

Static Characteristics of power diode, SCR and GTO, half controlled and fully controlled converters with R-L, R-L-E loads and freewheeling diodes – continuous and discontinuous modes of operation -inverter operation and its limit –Sequence control of converters – performance parameters – effect of source impedance and overlap-reactive power and power balance in converter circuit.

THREE PHASE AC-DC CONVERTER 12

Half controlled and fully controlled converters with R, R-L, R-L-E loads and freewheeling diodes – inverter operation and its limit – performance parameters – effect of source impedance and overlap -12 pulse converter –Applications – Excitation system, DC drive system.

SINGLE PHASE INVERTERS 12

Introduction to self-commutated switches : MOSFET and IGBT – Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single phase inverters using various PWM techniques – various harmonic elimination techniques – Design of UPS – VSR operation

THREE PHASE INVERTERS 12

180 degree and 120-degree conduction mode inverters with star and delta connected loads – voltage control of three phase inverters: single, multi pulse, sinusoidal, space vector modulation techniques – VSR operation-Application – Induction heating, AC drive system – Current source inverters.

MODERN INVERTERS 12

Multilevel concept – diode clamped – flying capacitor – cascaded type multilevel inverters – Comparison of multilevel inverters – application of multilevel inverters – PWM techniques for MLI – Single phase & Three phase Impedance source inverters – Filters.

d. Activities

- Conceptual quiz to identify the converter types
- Assignments to Simulate Power Converter Systems
- Report based on Troubleshooting in Power Converter
- Case Study on Analysis of Real World Power Converter Applications

e. Learning Resources

1. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Pearson, fourth Edition, 10th Impression 2021.
2. Jai P. Agrawal, "Power Electronics System Theory and Design", Pearson Education, First Edition, 2015.
3. Bimal.K.Bose "Modern Power Electronics and AC Drives", Pearson Education, Second Edition, 2003.
4. Ned Mohan, T.M.Undeland and W.P.Robbins, "Power Electronics: converters, Application and design", 3rd edition Wiley, 2007.
5. Philip T. Krein, "Elements of Power Electronics" Indian edition Oxford University Press-2017.
6. P.C.Sen, "Modern Power Electronics", S.Chand Publishing 2005.
7. P.S.Bimbira, "Power Electronics", Khanna Publishers, Eleventh Edition, 2003.
8. Bin Wu, Mehdi Narimani, "High-Power Converters and AC Drives", Wiley, 2nd Edition, 2017.

Course Code	Course Name	L	T	P	C
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P24PE104	Modeling And Design Of SMPS	3	0	0	3
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Category: Professional Core Course

a. Preamble

This course will inculcate knowledge on steady state analysis of Non-Isolated DC-DC converter and enable the students to perform steady state analysis of Isolated DC-DC converter. They will learn about different converter dynamics as well as gain knowledge on the design of controllers for DC-DC converters and familiarize the design magnetics for SMPS applications.

b. Course Outcomes

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

c. Course Syllabus

COs	Course Outcomes	Knowledge Level
CO1	Analyze and design Non-Isolated DC-DC converter	K4
CO2	Analyze and design Isolated DC-DC converter	K4
CO3	Derive transfer function of different converters	K4
CO4	Design controllers for DC-DC converters	K4
CO5	Design magnetics for SMPS application	K4
CO6	Design and assembly of Power Supplies and apply the Necessary recent technology to comply the standards and certification requirements.	K4

c. Course Syllabus

Total: 45 Hours

ANALYSIS OF NON-ISOLATED DC-DC CONVERTERS 8

Buck, Boost, Buck- Boost and Cuk converters: Principles of operation – Continuous conduction mode– Concepts of volt-sec balance and charge balance – Analysis and design based on steady- state relationships – Introduction to discontinuous conduction mode - SEPIC topology - design examples - Applications to Battery operated vehicle, PV system.

ANALYSIS OF ISOLATED DC-DC CONVERTERS 8

Introduction - classification- forward- fly back- push pull – half bridge – full bridge topologies- design of SMPS - Applications to Battery operated vehicle

CONVERTER DYNAMICS 8

AC equivalent circuit analysis – State space averaging – Circuit averaging – Averaged switch modeling – Transfer function model for buck, boost, buck-boost and cuk converters – Input filters.

CONTROLLER DESIGN 8

Review of P, PI, and PID control concepts – gain margin and phase margin – Bode plot based analysis – Design of controller for buck, boost, buck-boost and cuk converters

DESIGN OF MAGNETICS 13

Basic magnetic theory revision – Inductor design – Design of mutual inductance – Design of transformer for isolated topologies – Ferrite core table and selection of area product – wire table – selection of wire gauge

d. Activities

- Implement quizzes and flashcards to reinforce knowledge of basic SMPS principles and topologies.
- Provide lab sessions where students build and test their SMPS designs on breadboards or with development kits.
- Assign projects where students design an SMPS circuit to meet specific requirements
- Assign projects that involve designing SMPS systems with integrated control circuits or multiple outputs.
- Use in-class problem-solving exercises and quick polls to assess understanding of key concepts and modeling techniques.

e. Learning Resources

1. Robert W. Erickson & Dragon Maksimovic,” Fundamentals of Power Electronics”, Third Edition, 2020.
2. John G. Kassakian, Martin F. Schlecht, George C. Verghese, “Principles of Power Electronics”, Pearson, India, New Delhi, 2010
3. Simon Ang and Alejandra Oliva, “Power-Switching Converters”, CRC press, 3rd edition, 2011.
4. Philip T Krein, “Elements of Power Electronics”, Oxford University Press, 2017.
5. Ned Mohan, “Power Electronics: A first course”, Wiley, 2011, 1st edition.
6. IssaBatarseh, Ahmad Harb, “Power Electronics- Circuit Analysis and Design, Second edition, 2018.
7. V.Ramanarayanan, “Course material on Switched mode power conversion”, 2007.
8. Alex Van den Bossche and Vencislav Cekov Valchev, “Inductors and Transformers for Power Electronics”, CRC Press, 1st edition, 2005.

Course Code	Course Name	L	T	P	C
P24PE105	Power Converters Laboratory	0	0	4	2

Category: Professional Core Course

a. Preamble

The Power Converters Laboratory is designed to provide students with hands-on experience in the principles, design, and operation of various power converter systems, ensuring they are equipped with the necessary skills and knowledge to meet industry demands.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Clear understanding on the switching behaviour of Power Electronic Switches	K4
CO2	Clear understanding on mathematical modelling of power electronic system and ability to implement the same using simulation tools	K4
CO3	Ability of the student to use Arduino/microcontroller for power electronic applications	K4
CO4	Design and simulate various topologies of inverters and analyse their harmonic spectrum	K4
CO5	Design and fabricate the gate drive power converter circuits.	K4
CO6	Analyse the three-phase controlled rectifiers and isolated DC-DC converters for designing the power supplies	K4

LIST OF EXPERIMENTS	
1.	Study of switching characteristics of Power MOSFET & IGBT.

2.	Circuit Simulation of Three-phase semi-converter with R, RL& RLE load.
3.	Circuit Simulation of Three-phase fully controlled converter with R, RL & RLE load.
4.	Circuit Simulation of Three-phase Voltage Source Inverter in 180° and 120° degree mode of conduction
5.	Circuit simulation of Three-phase PWM inverter and study of spectrum analysis for various modulation indices.
6.	Simulation of Four quadrant operation of DC Chopper.
7.	Generation of Gating pulse using Arduino/Micro Controller/PIC microcontroller for a DC-DC converter and single-phase voltage source inverter.
8.	Simulation of a single-phase Z-source inverter with R load.
9.	Simulation of three-phase AC voltage Controller with R load.
10	Simulation of a five-level cascaded multilevel inverter with R load.
11.	Simulation of a Flyback DC-DC converter
Total	
30 Hours	

Course Code	Course Name	L	T	P	C
P24PE106	Design Laboratory for Power	0	0	4	2

	Electronics Systems				
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Category: Professional Core Course

a. Preamble

This course focuses on the circuits that play a vital role in diverse applications, including renewable energy systems, electric vehicles, and industrial automation. The Design and Simulation of Power Electronic Circuits Laboratory aims to equip students with the practical knowledge and technical expertise necessary to navigate the complexities of power electronics.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Observe and analyse the operation and basic characteristics of various types of switching devices	K4
CO2	Apply knowledge about industrial applications of power electronics converter such as AC-AC and AC-DC converter	K3
CO3	Analyse various firing circuits of thyristor	K4
CO4	Simulate converters for various drives	K3
CO5	Design and simulate AC/DC and DC/AC converters on MATLAB software	K3
CO6	Simulate DC to DC and AC to AC converters on MATLAB	K4

LIST OF EXPERIMENTS	
1.	Simulation of Single-phase semi converter with R, RL and RLE loads.
2.	Simulation of Single-phase full-converter with R, RL and RLE loads.

3.	Simulation of three phase Semi and Full converter.
4.	Simulation of MOSFET, IGBT based CLASS A, B, C, D, E Choppers.
5.	Simulation of Single Phase dual converter fed R, RL and RLE loads.
6.	Simulation of Single phase IGBT based PWM inverter.
7.	Simulation of Single-phase semi converter fed DC drives.
8.	Simulation of Three-phase semi converter fed DC drives.
9.	Simulation of Single-phase full converter fed DC drives.
10.	Simulation of closed loop control of chopper fed DC motor.
11.	Simulation of Single-phase AC voltage controller fed AC drives.
Total	30 Hours

Course Code	Course Name	L	T	P	C
P24PE151	Analysis Of Electrical Drives	3	1	0	4

Category: Professional Core Courses

a. Preamble

This course will facilitate the learners to analyse the operation of the converter / chopper fed DC drive, both qualitatively and quantitatively as well as analyse and design the current and speed controllers for a closed loop solid state DC motor drive. Also, the students will understand the drive characteristics for different load torque profiles and quadrants of operation, speed control of induction motor drive from stator and rotor sides.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering.	K3
CO2	Formulate, design, and simulate power supplies for generic load and for machine loads.	K3
CO3	Analyze, comprehend, design and simulate direct current motor based adjustable speed drives.	K3
CO4	Analyze, comprehend, design and simulate induction motor based adjustable speed drives.	K3
CO5	Design a closed loop motor drive system with controllers for the current and speed control operations.	K3
CO6	Analyze the operation of VSI & CSI fed induction motor control and pulse width modulation technique	K4

c. Course Syllabus

Total: 60 Hours

DC MOTORS DRIVES AND MECHANICAL SYSTEMS

12

DC motor- speed-torque relations; Speed control – Armature and field speed control; Ward Leonard control – Constant torque and constant horse power operation- Introduction to high-speed drives and modern drives. Characteristics of mechanical system–Requirements of drives characteristics - stability of drives–multi-quadrant operation

CONVERTER AND CHOPPER CONTROL

12

Principle of phase control – Fundamental relations; Analysis of series and separately excited DC motor with single-phase and three-phase converters – performance parameters, performance characteristics. chopper controlled DC motor – performance analysis, multi-quadrant control - Chopper based implementation of braking schemes; Related problems.

CLOSED LOOP CONTROL

12

Modeling of drive elements – Equivalent circuit, transfer function of self, separately excited DC motors; Linear Transfer function model of power converters; Sensing and feeds back elements - Closed loop speed control – current and speed loops– response comparison. Simulation of converter and chopper fed DC drive.

VSI STATOR CONTROLLED INDUCTION MOTOR CONTROL

12

AC voltage controller – six step inverter voltage control-closed loop variable frequency PWM inverter fed induction motor (IM) with braking- simulation of closed loop operation of stator controlled induction motor drives.

ROTOR CONTROLLED INDUCTION MOTOR DRIVES

12

Static rotor resistance control - injection of voltage in the rotor circuit – static Scherbius drives – static and modified Kramer drives – sub-synchronous and super-synchronous speed operation of induction machines – simulation of closed loop operation of rotor controlled induction motor drives.

d. Activities

- Design a control system for a specific motor application. They can create a basic control algorithm (e.g., PID control) and discuss challenges and solutions.
- Assign students to analyze the energy efficiency of a specific drive system. They can explore ways to improve efficiency through hardware or control strategies and present their recommendations.
- Organize a field trip to a facility that uses electrical drives or invite an industry expert to discuss current trends and challenges in electrical drive technology.

e. Learning Resources

1. Gopal K Dubey, "Power Semiconductor controlled Drives", Prentice Hall Inc., New Jersey, 1989.
2. R. Krishnan, "Electric Motor Drives – Modeling, Analysis and Control", Prentice-Hall of India Pvt. Ltd., New Delhi, 2010.
3. Bimal K Bose, "Modern Power Electronics and AC Drives", Pearson Education Asia2002.
4. Gopal K. Dubey, "Fundamentals of Electrical Drives", Narosa Publishing House, New Delhi, Second Edition, 2009.
5. Vedam Subramanyam, "Electric Drives – Concepts and Applications", Tata McGraw- Hill publishing company Ltd., New Delhi, 2002.
6. P.C Sen "Thyristor DC Drives", John Wiley and sons, New York, 1981.
7. W. Leonhard, "Control of Electrical Drives", Narosa Publishing House, 1992
8. Murphy J.M.D and Turnbull, "Thyristor Control of AC Motors", Pergamon Press, Oxford, 1988.

Course Code	Course Name	L	T	P	C
P24PE152	Special Electrical Machines	3	0	0	3

Category: Professional Core Courses

a. Preamble

This course will facilitate the learners to understand the working, characteristics and speed control principles of stepper motor as well as the construction, working, characteristics and speed control methods of switched reluctance motors. In addition students will comprehend the principle of operation, construction, characteristics and speed control methods for the permanent magnet brushless DC motors. Also, they will understand the concepts related with permanent magnet synchronous motors and synchronous reluctance motors and come to know the features of axial flux machines and its working principles.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Model and analyze power electronic systems and equipment using computational software.	K3
CO2	Optimally design magnetics required in special machines based drive systems using FEM based software tools.	K3
CO3	Analyze the dynamic performance of special electrical machines	K3
CO4	Understand the operation and characteristics of other special electrical machines.	K3
CO5	Design and conduct experiments towards research.	K3
CO6	Understand the features of axial flux machines in comparison with radial flux machines and to know the principles of axial flux machines.	K3

c. Course Syllabus

Total: 45 Hours

PERMANENT MAGNET BRUSHLESS DC MOTORS

9

Fundamentals of Permanent Magnets- Types- Principle of operation- Magnetic

circuit analysis- EMF and Torque equations- Characteristics and control.

PERMANENT MAGNET SYNCHRONOUS MOTORS **9**

Principle of operation – EMF and Torque equations - Phasor diagram - Power controllers – Torque speed characteristics – Digital controllers – Constructional features, operating principle and characteristics of synchronous reluctance motor.

SWITCHED RELUCTANCE MOTORS **9**

Constructional features –Principle of operation- Torque prediction–Characteristics Power controllers – Control of SRM drive- Sensor less operation of SRM – Applications.

STEPPER MOTORS **9**

Constructional features –Principle of operation –Types – Torque predictions – Linear and Non- linear analysis – Characteristics – Drive circuits – Closed loop control –Applications.

OTHER SPECIAL MACHINES **9**

Principle of operation and characteristics of Hysteresis motor – AC series motors – Linear motor – Applications.

d. Activities

- Model and simulate basic special electrical machines, such as stepper motors or BLDC motors, focusing on their operation and performance metrics.
- Analyse case studies of special electrical machines used in various industries, such as robotics, aerospace, and automotive applications.
- Regularly assign problems and projects that build towards the final project, providing feedback to guide improvement
- Problem-solving exercises to assess understanding of special electrical machines and their design.

c. Learning Resources

1. T.J.E. Miller, “Brushless magnet and Reluctance motor drives”, Clarendon press,

London, 1989.

2. R. Krishnan, 'Switched Reluctance motor drives', CRC press, 2001.
3. T. Kenjo, 'Stepping motors and their microprocessor controls', Oxford University press, New Delhi, 2000.
4. T. Kenjo and S. Nagamori, 'Permanent magnet and Brushless DC motors', Clarendon press, London, 1988.
5. R. Krishnan, "Electric motor drives", Prentice Hall of India, 2002.
6. D.P. Kothari and I.J. Nagrath, "Electric machines", Tata McGraw hill publishing company, New Delhi, Third Edition, 2004.
7. Irving L. Kosow, "Electric Machinery and Transformers" Pearson Education, Second Edition, 2007.

Course Code	Course Name	L	T	P	C
P24PE153	Electric Vehicles And Power Management	3	0	0	3

Category: Professional Core Course

a. Preamble

This course will facilitate the learners to understand the concept of electric vehicles and its operations be able to get an overview of Electric Vehicle (EV), Hybrid Electric vehicle (HEV) and their architecture. The students will understand energy storage and how power flows in hybrid vehicles.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Learn about the electric vehicle architecture and power train components.	K2
CO2	Acquire the concepts of dynamics of electrical vehicles	K2
CO3	Understand the vehicle control for standard drive cycles of hybrid electrical vehicles (HEVs).	K2
CO4	Explain the principles of power converters and electrical drives	K2
CO5	Design and select energy storage systems.	K3
CO6	Acquire the knowledge of different energy sources and energy management in HEVs.	K2

HYBRID ELECTRIC VEHICLE ARCHITECTURE AND POWER TRAIN COMPONENTS 9

History of evolution of Electric Vehicles - Comparison of Electric Vehicles with Internal Combustion Engines - Architecture of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) – Plug-in Hybrid Electric Vehicles (PHEV)- Power train components and sizing, Gears, Clutches, Transmission and Brakes

MECHANICS OF HYBRID ELECTRIC VEHICLES 9

Fundamentals of vehicle mechanics - tractive force, power and energy requirements for standard drive cycles of HEV's - motor torque and power rating and battery capacity.

CONTROL OF DC AND AC MOTOR DRIVES 9

Speed control for constant torque, constant HP operation of all electric motors - DC/DC chopper based four quadrant operation of DC motor drives, inverter based V/f Operation (motoring and braking) of induction motor drives, vector control operation of Induction motor and PMSM, Brushless DC motor drives, Switched reluctance motor (SRM) drives

ENERGY STORAGE SYSTEMS 9

Battery: Principle of operation, types, models, estimation of parameters, battery modeling, SOC of battery, Traction Batteries and their capacity for standard drive cycles, Vehicle to Grid operation of EV's. Alternate sources: Fuel cells, Ultra capacitors, Flywheels.

HYBRID VEHICLE CONTROL STRATEGY AND ENERGY MANAGEMENT 9

HEV supervisory control - Selection of modes - power spilt mode - parallel mode - engine brake mode - regeneration mode - series parallel mode - energy management of HEV's.

d. Activities

- Use quizzes to test understanding of EV components, power management principles, and system integration.
- Analyze case studies of real-world EVs and power management systems, examining design choices, performance, and challenges.
- Provide lab sessions where students build and test small-scale models or components of EV systems, such as battery management systems or motor controllers.
- Assign tasks to optimize EV designs for factors like efficiency, cost, or performance, considering real-world constraints and requirements.

e. Learning Resources

1. Iqbal Husain, 'Electric and Hybrid Electric Vehicles', CRC Press, 2011.
2. Wei Liu, 'Hybrid Electric Vehicle System Modeling and Control', Second Edition, WILEY, 2017.
3. James Larminie and John Lowry, 'Electric Vehicle Technology Explained', Second Edition, 2012.

Course Code	Course Name	L	T	P	C
P24PE154	Modern Rectifiers And Resonant Converters	3	1	0	4

Category: Professional Core Course

a. Preamble

The course on Modern Rectifiers and Resonant Converters is designed to provide students with a deep understanding of the principles, design, and practical implementation of these essential power electronic components. As energy efficiency and conversion technology are paramount, modern rectifiers and resonant converters play a crucial role in various applications, including renewable energy systems, electric vehicles, and power supplies for electronic devices.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Acquire and apply knowledge of mathematics in power converter analysis and understanding of harmonic standards	K3
CO2	Analyze and understand power electronic systems and equipment	K3
CO3	Analyze, design and simulate resonant converters for low power applications	K3
CO4	Develop mathematical model of switching converters to carry out dynamic analysis	K6
CO5	Design and implement different controllers and switching schemes for the control of converters	K6
CO6	Designing a resonant converter for a specific application, including designing the resonant network and control strategy.	K6

c. Course Syllabus

Total: 60 Hours

POWER SYSTEM HARMONICS & LINE COMMUTATED RECTIFIER 12

Average power-RMS value of a waveform-Power factor-AC line current harmonic standards IEC 1000-IEEE 519- The Single phase full wave rectifier-Continuous Conduction Mode- Discontinuous Conduction Mode- Behaviour when C is large- Minimizing THD when C is small- Three phase rectifiers- Continuous Conduction Mode-Discontinuous Conduction Mode- Harmonic trap filters.

PULSE WIDTH MODULATED RECTIFIERS 12

Properties of Ideal rectifiers-Realization of non-ideal rectifier-Control of current waveform- Average current control-Current programmed Control- Hysteresis control- Nonlinear carrier control-Single phase converter system incorporating ideal rectifiers-Modelling losses and efficiency in CCM high quality rectifiers- Boost rectifier-expression for controller duty cycle-expression for DC load current- solution for converter Efficiency η .

RESONANT CONVERTERS 12

Review on Parallel and Series Resonant Switches-Soft Switching- Zero Current Switching - Zero Voltage Switching -Classification of Quasi resonant switches- Zero Current Switching of Quasi Resonant Buck converter, Zero Current Switching of Quasi Resonant Boost converter, Zero Voltage Switching of Quasi Resonant Buck converter, Zero Voltage Switching of Quasi Resonant Boost converter: Steady State analysis.

DYNAMIC ANALYSIS OF SWITCHING CONVERTERS 12

Review of linear system analysis-State Space Averaging-Basic State Space Average Model- State Space Averaged model for Buck Converter, Boost Converter, Buck Boost Converter and Cuk Converter.

CONTROL OF RESONANT CONVERTERS 12

Pulse Width Modulation-Voltage Mode PWM Scheme-Current Mode PWM Scheme-Design of Controllers: PI Controller, Variable Structure Controller, Optimal Controller for the source current shaping of PWM rectifiers.

d. Activities

- Assign tasks where students create and simulate models for various resonant converters, such as LLC converters, and analyze their operational characteristics.
- Instruct students to analyze key performance metrics such as efficiency,

ripple, and load regulation from their simulations.

- Task students with designing a resonant converter for a specific application, including designing the resonant network and control strategy.
- Provide lab sessions where students build and test rectifiers and resonant converters on breadboards or using development kits.

e. Learning Resources

1. Robert W. Erickson & Dragomir Maksimovic “Fundamentals of Power Electronics” Second Edition, 2001 Springer science and Business Media.
 2. William Shepherd and Li Zhang, “Power Converters Circuits”
 3. Marcel Ekkerin, C.Simon Ang and Alejandro Oliva “Power- Switching Converters” Taylor & Francis Group.
 4. John G. Kassakian, Martin F. Schlecht, George C. Verghese, “Principles of Power Electronics”, Pearson, India, New Delhi, 2010.
 5. Simon Ang and Alejandra Oliva, “Power Switching Converter”, Yesdee Publishers, New Delhi, 2 edition (First Indian Reprint), 2010.
 6. Philip T Krein, “Elements of Power Electronics”, Oxford University Press.
 7. Ned Mohan, “Power Electronics: A first course”, John Wiley, 2012.
- Issa Batarseh, Ahmad Harb, “Power Electronics- Circuit Analysis and Design, Second Edition.

Course Code	Course Name	L	T	P	C
P24PE155	Power Electronics And Drives Laboratory	0	0	4	2

Category: Professional Core Course

a. Preamble

This course will facilitate the learners to conduct load tests in an electrical drive system and understand the control the speed of DC motor-based drive system conduct. Also, they will conduct experiments to enhance the understanding of different power electronic controller for motor drive applications as well as control the speed of Stepper motor, BLDC motor-based drive systems, Induction motor and SRM motor-based drive systems.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Conduct load tests in an electrical drive system.	K3
CO2	Design and simulate various converters.	K6
CO3	Design and simulate various control strategies used for converters and various inverters.	K6
CO4	Formulate, design the speed controller for AC motor-based drive system.	K6
CO5	Design the control algorithm for the control of an electrical drive using Microcontroller and Digital signal processor.	K6
CO6	Assign Projects That Involve Designing Systems With Integrated Control Circuits Or Multiple Outputs	K6

c. Course Syllabus

Total: 30 Hours

LIST OF EXPERIMENTS

1.	Speed torque characteristics of Single phase semi- converter fed DC drive.
2.	Single phase full converter fed DC drive.
3.	Three phase Half controlled rectifier fed DC drive.
4.	Three phase fully controlled rectifier fed DC drive.
5.	Speed Control of Chopper fed DC drives.
6.	Speed control of three-phase induction motor using PWM inverter.
7.	DSP based closed loop drive for induction motor
8.	DSP based Speed control of Brush Less DC motor.
9.	DSP based Switched Reluctance Motor Drive.
10.	Three phase AC voltage controller fed AC Drive
11.	Mini Projects (Related to the above Experiments)
Total	
30 Hours	

Course Code	Course Name	L	T	P	C
P24PE201	Grid Integration Of Renewable Energy Sources	3	0	0	3

Category: Professional Core Course

a. Preamble

This course will facilitate the learners to study about the integration of various renewable energy resources. Students will focus on sustainable energy solutions, the integration of renewable energy sources into existing power grids has become a critical focus for engineers and policymakers alike. The Grid Integration of Renewable Energy Sources course aims to equip students with the knowledge and skills necessary to design, analyse, and implement effective strategies for incorporating renewable technologies such as solar, wind, and hydroelectric power into the grid.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Know about the integration of various renewable energy sources into the grid	K2
CO2	Analyze various grid issues due to renewable energy sources	K4
CO3	Analyze the dynamics of network due to windfarm	K4
CO4	Demonstrate about power system stabilizers.	K2
CO5	Design the grid connected and standalone PV system	K5
CO6	Explain about grid connected and standalone PV system	K5

c. Course Syllabus

Total: 45 Hours

INTRODUCTION TO RENEWABLE ENERGY GRID INTEGRATION 9

Concept of mini/micro grids and Smart grids - Different types of grid interfaces - Issues related to grid integration of small and large scale of synchronous generator based - induction generator based and converter based sources together - Network voltage management - Power quality management (voltage dips, harmonics, flickers, and reactive power control) - Frequency management - Influence of WECS on system transient response - Interconnection standards and grid code requirements for integration

NETWORK INFLUENCE OF GENERATION TYPE 9

Starting – Network voltage management – Thermal/Active power management – Network power quality management – Transient system performance – Fault level issues – Protection

INFLUENCE OF WIND FARMS ON NETWORK DYNAMIC PERFORMANCE 9

Dynamic Stability and its Assessment – Dynamic characteristics of Synchronous Generation - A Synchronizing power and Damping power model of a Synchronous Generator – Influence of Automatic Voltage Regulator on Damping – Influence on Damping of Generator Operating Conditions – Influence of Turbine Governor on Generator Operation – Transient Stability – Voltage Stability – Influence of Generation Type on Network Dynamic Stability – Dynamic Interaction of Wind Farms with the Network – influence of Wind Generation on Network Transient Performance

POWER SYSTEM STABILIZERS AND NETWORK DAMPING CAPABILITY OF WIND 9

A Power System Stabilizer for a Synchronous Generator - A Power System Stabilizer for a DFIG - A Power System Stabilizer for a FRC Wind Farm

STAND ALONE AND GRID CONNECTED PV SYSTEM 9

Solar modules – storage systems – Basics of batteries – Batteries for PV Systems – Charge Controllers – MPPT and Inverters – Power Conditioning and Regulation – protection – Types of Solar PV systems - standalone PV systems design – sizing – PV systems in buildings – design issues for central power stations – safety – Economic aspect – efficiency and performance – International PV programs

d. Activities

- Simulate the integration of a large-scale solar farm into the grid and analyze issues like voltage stability and power balancing.
- Study the impact of renewable energy integration on grid stability and power quality, proposing solutions for grid management.
- Analyze the grid code requirements for renewable energy integration and design systems that comply with these regulations.
- Analyze case studies of real-world grid integration projects, examining design choices, performance, and challenges encountered.

e. Learning Resources

1. Stuart R. Wenham, Martin A. Green, Muriel E. Watt and Richard Corkish, 'Applied Photovoltaics', Earthscan, UK, 2007.
2. Joshua Earnest, 'Wind power technology', II Edition, PHI, 2015.
3. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright and Mike Hughes, 'Wind Generation Modelling and Control', A John Wiley and Sons, Ltd., Publication, 2009.
4. Brenden Fox, Damian Flynn and Leslie Bryans, 'Wind Power Integration Connection and system operational aspects', Published by The Institute of Engineering and Technology, London, United Kingdom, 2007.
5. Frank S. Barnes & Jonah G. Levine, 'Large Energy Storage Systems Handbook', CRC Press, 2011.
6. S.P. Sukhatme, 'Solar Energy', Tata McGraw Hill, 1987.
7. Chetan Singh Solanki, 'Solar Photovoltaic Technology and Systems' – A Manual for Technicians, Trainees and Engineers, PHI, 2014.

ELECTIVES - GROUP I

Course Code	Course Name	L	T	P	C
P24PE901	Power Semiconductor Devices	3	0	0	3

Category: Professional Elective Courses

a. Preamble

This course will facilitate the learners to gain in depth knowledge on power semiconductor devices that serve as the backbone of modern energy conversion systems. From electric vehicles to renewable energy systems and industrial applications, these devices are critical for efficient power management and control. The Power Semiconductor Devices course is designed to provide students with a comprehensive understanding of the principles, characteristics, and applications of these essential components.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Identify suitable device for various applications	K2
CO2	List the advantages of Silicon Carbide devices and Gallium Nitride devices.	K2
CO3	Understand the principles and characteristics of Silicon devices, Silicon Carbide devices and Gallium Nitride devices.	K2
CO4	Design proper driving circuits and protection circuits.	K6
CO5	Construct a proper thermal protective device for power semiconductor devices.	K6
CO6	Communicate Technical Information clearly through reports and presentations, demonstrating their understanding of power semiconductor technologies.	K6

c. Course Syllabus

Total Hours: 45

INTRODUCTION

9

Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Power diodes - Types, forward and reverse characteristics, switching characteristics – rating. Features and Brief History of Silicon Carbide- Promise and Demonstration of SiC Power Devices- Physical Properties of Silicon Carbide devices-Unipolar and Bipolar Diodes- GaN Technology Overview.

CURRENT CONTROLLED DEVICES

9

BJT's – Construction, static characteristics, switching characteristics; Negative temperature coefficient and second breakdown; - Thyristors – Construction, working, static and transient characteristics, types, series and parallel operation; comparison of BJT and Thyristor – steady state and dynamic models of BJT & Thyristor- Basics of GTO, SiC based Bipolar devices- Applications- Building a GaN Transistor - GaN Transistor Electrical Characteristics

VOLTAGE CONTROLLED DEVICES

9

Power MOSFETs and IGBTs – Principle of voltage controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs - and IGCT. New semiconductor materials for devices – Intelligent power modules- study of modules like APTGT100TL170G, MSCSM70TAM05TPAG. Integrated gate commutated thyristor (IGCT) – SiC based unipolar devices-applications

DEVICE SELECTION, DRIVING AND PROTECTING CIRCUITS

9

Device selection strategy – On-state and switching losses – EMI due to switching. Necessity of isolation, pulse transformer, optocoupler – Gate drive integrated circuit: Study of Driver IC – IRS2110/2113. SCR, MOSFET, IGBTs and base driving for power BJT. - Over voltage, over current and gate protections; Design of snubbers.

THERMAL PROTECTION

9

Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour – phase cooling; Guidance for heat sink selection – Thermal resistance and impedance -Electrical analogy of thermal components, heat sink types and design – Mounting types- switching loss calculation for power device.

d. Activities

- Projects Using simulation software (e.g., LTspice, PSpice) to design and simulate circuits incorporating different power semiconductor devices. Evaluate the efficiency and performance under varying load conditions.
- Analyze case studies of specific applications (e.g., electric vehicle powertrains, renewable energy inverters) focusing on the role of power semiconductor devices. Present findings on design choices and performance impacts.
- Invite Programmes working with power semiconductor devices to discuss current trends, challenges, and innovations. Encourage students to engage in Q&A sessions to deepen their understanding.

e. Learning Resources

1. Rashid M.H., “Power Electronics Circuits, Devices and Applications”, Pearson, 4th Edition, 10th Impression 2021.
2. Ned Mohan, T.M.Undeland and W.P.Robbins, “Power Electronics: converters, Application and design”, 3rd Edition Wiley, 2007.
3. Tsunenobu Kimoto and James A. Cooper, Fundamentals of Silicon Carbide Technology: Growth, Characterization, Devices, and Applications, First Edition, 2014 John Wiley & Sons Singapore Pte Ltd.
4. Alex Lidow, Johan Strydom, Michael de Rooij, David Reusch, GaN Transistors For Efficient Power Conversion, Second Edition, Wiley, 2015.
5. Biswanath Paul, Power Electronics, Universities Press 2019.

Course Code	Course Name	L	T	P	C
P24PE901	Soft Computing Techniques	3	0	0	3

Category: Professional Elective Courses

a. Preamble

This course will facilitate the learners about the integration of soft computing techniques that has emerged as a pivotal approach. Soft computing encompasses a variety of methodologies, including fuzzy logic, neural networks, genetic algorithms, and probabilistic reasoning, which are particularly suited for handling complex and uncertain problems.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand the basic architectures of NN and Fuzzy sets	K2
CO2	Design and implement ANN architectures, algorithms and know their limitations.	K6
CO3	Identify and work with different operations on the fuzzy sets.	K2
CO4	Develop ANN and fuzzy logic-based models and control schemes for non-linear systems.	K6
CO5	Understand and explore hybrid control schemes and PSO	K2
CO6	Implement algorithms for fault diagnosis and decision-making in complex power electronic systems.	K6

c. Course Syllabus

Total Hours: 45

INTRODUCTION AND ARTIFICIAL NEURAL NETWORKS

9

Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi- objective problems -Neuron- Nerve

structure and synapse- Artificial Neuron and its model- activation functions- Neural network architecture- single layer and multilayer feed forward networks- Mc Culloch Pitts neuron model- perceptron model- Adaline and Madaline- multilayer perceptron model- back propagation learning methods- effect of learning rule coefficient -back propagation algorithm- factors affecting back propagation training- applications.

ARTIFICIAL NEURAL NETWORKS AND ASSOCIATIVE MEMORY 9

Counter propagation network- architecture- functioning & characteristics of counter Propagation network- Hopfield/ Recurrent network configuration - stability constraints associative memory and characteristics- limitations and applications- Hopfield v/s Boltzman machine- Adaptive Resonance Theory- Architecture- classifications- Implementation and training - Associative Memory.

FUZZY LOGIC SYSTEM 9

Introduction to crisp sets and fuzzy sets- basic fuzzy set operation and approximate reasoning. Introduction to fuzzy logic modelling and control- Fuzzification inferencing and defuzzification- Fuzzy knowledge and rule bases-Fuzzy modelling and control schemes for nonlinear systems. Self-organizing fuzzy logic control- Fuzzy logic control for nonlinear time delay system.

GENETIC ALGORITHM 9

Evolutionary programs – Genetic algorithms, genetic programming and evolutionary programming - Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators - Optimization problems using GA-discrete and continuous - Single objective and multi-objective problems - Procedures in evolutionary programming

HYBRID CONTROL SCHEMES 9

Fuzzification and rule base using ANN–Neuro fuzzy systems-ANFIS – Fuzzy Neuron - Optimization of membership function and rule base using Genetic Algorithm –Introduction to Support Vector Machine- Evolutionary Programming- Particle Swarm Optimization - Case study –Familiarization of NN, FLC and ANFIS Tool Box.

d. Activities

- Assign projects where students apply soft computing techniques to real-world problems, such as data analysis, optimization, or pattern recognition.

- Analyze case studies that showcase successful applications of soft computing in various industries.
- Case study on controlling power converters and drives where system dynamics are complex and uncertain.

e. Learning Resources

1. Laurene V. Fausett, “Fundamentals of Neural Networks: Architectures, Algorithms And Applications”, Pearson Education.
2. Timothy J. Ross, “Fuzzy Logic with Engineering Applications” Wiley India, 2008.
3. Zimmermann H.J. "Fuzzy set theory and its Applications" Springer International Edition, 2011.
4. David E.Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Pearson Education, 2009.
5. W.T.Miller, R.S.Sutton and P.J.Webrose, “Neural Networks for Control” MIT Press”, 1996.
6. T. Ross, “Fuzzy Logic with Engineering Applications”, Tata McGraw Hill, New Delhi, 1995.
7. Ethem Alpaydin, “Introduction to Machine Learning (Adaptive Computation and Machine Learning Series)”, MIT Press, 2004.
8. Corinna Cortes and V. Vapnik, “Support - Vector Networks, Machine Learning”, 1995.

Course Code	Course Name	L	T	P	C
P24PE903	Analysis Of Electrical Machines	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The student will to understand the principles of electromechanical energy conversion in electrical machines and the dynamic characteristics of DC motors along with the concepts related with AC machines, magnetic noise and harmonics in rotating electrical machines.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand the principles of electromechanical energy conversion and characteristics of DC motors	K2
CO2	Identify concepts related with AC machines and modelling of 'n' phase machines	K3
CO3	Interpret the concepts of reference frame theory.	K5
CO4	Apply procedures to develop induction machine model in both machine variable form and reference variable forms	K3
CO5	Follow the procedures to develop synchronous machine model in machine variables form and reference variable form.	K6
CO6	Simulate the behavior of electrical machines under different conditions.	K6

ELECTROMECHANICAL ENERGY CONVERSION AND DC MACHINES 9

Magnetic circuits, permanent magnet, Energy conservation - stored magnetic energy, co-energy - force and torque in singly and doubly excited systems – Elementary DC machine and analysis of steady state operation - Voltage and torque equations – dynamic characteristics - DC motors – Time domain block diagrams - solution of dynamic characteristic by Laplace transformation

AC MACHINES - CONCEPTS 9

Distributed Windings - Winding Functions - Air-Gap Magnetomotive Force -Rotating MMF - Flux Linkage and Inductance -Resistance -Voltage and Flux Linkage Equations for Distributed Winding Machines-magnetic noise and harmonics in rotating electrical machines. Modeling of 'n' phase machine

REFERENCE FRAME THEORY 9

Phase transformation and commutator transformation – transformation of variables from stationary to arbitrary reference frame – transformation of balanced set-variables observed from several frames of reference.

INDUCTION MACHINES 9

Three phase induction machine and doubly fed induction machine- equivalent circuit and analysis of steady state operation – free acceleration characteristics – voltage and torque equations in machine variables and arbitrary reference frame variables – analysis of dynamic performance for load torque variations- Transformation theory for 'n' phase induction machine.

SYNCHRONOUS MACHINES 9

Three phase synchronous machine and analysis of steady state operation - voltage and torque equations in machine variables and rotor reference frame variables (Park's equations) – analysis of dynamic performance for load torque variations –Krons primitive machine

d. Activities

- Guest Lectures by industry experts to discuss recent advancements in electrical machines and their applications in power electronics.
- Simulation Projects using software tools (e.g., MATLAB/Simulink) to simulate the behavior of electrical machines under different conditions.
- Industry Visits / Trips to manufacturing plants or power generation facilities to observe the practical applications of electrical machines.

e. Learning Resources

1. Stephen D. Umans, “Fitzgerald & Kingsley’s Electric Machinery”, Tata McGraw Hill, 7th Edition, 2020.
2. Bogdan M. Wilamowski, J. David Irwin, The Industrial Electronics Handbook, Second Edition, Power Electronics and Motor Drives, CRC Press, 2011
3. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven D. Pekarek, “Analysis of Electric Machinery and Drive Systems”, 3rd Edition, Wiley-IEEE Press, 2013.
4. R. Krishnan, Electric Motor & Drives: Modeling, Analysis and Control, Pearson Education, 1st Imprint, 2015.
5. R. Ramanujam, Modeling and Analysis of Electrical Machines, I.K.International Publishing House Pvt. Ltd., 2018

Course Code	Course Name	L	T	P	C
P24PE904	IoT for Smart Systems	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The students will learn how industries strive for increased efficiency, sustainability, and automation, by the integration of IoT technologies into power systems which has become essential. Also, they will understand clearly the infrastructure required for IoT. They will familiarize with the accessories and communication techniques for IoT.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand the concepts of IoT and its present development	K2
CO2	Analyze different IoT technologies	K4
CO3	Apply different platforms and infrastructures available for IoT	K3
CO4	Understand the big data analytics and its importance	K2
CO5	Implement IoT solutions for smart applications	K5
CO6	Choose the embedded processor and sensors required for IoT referring the different platforms and Attributes for IoT	K2

c. Course Syllabus

Total: 45 Hours

INTRODUCTION TO INTERNET OF THINGS 9

Overview, Hardware and software requirements for IOT, Sensor and actuators, Technology drivers, Business drivers, Typical IoT applications, Trends and implications.

IOT ARCHITECTURE 9

IoT reference model and architecture -Node Structure - Sensing, Processing, Communication, Powering, Networking - Topologies, Layer/Stack architecture, IoT standards, Cloud computing for IoT, Bluetooth, Bluetooth Low Energy, beacons.

PROTOCOLS AND WIRELESS TECHNOLOGIES FOR IOT 9

PROTOCOLS: NFC, SCADA and RFID, Zigbee MIPI, M-PHY, UniPro, SPMI, SPI, M-PCIeGSM, CDMA, LTE, GPRS, small cell. Wireless technologies for IoT: WiFi (IEEE 802.11), Bluetooth/Bluetooth Smart, ZigBee/ZigBee Smart, UWB (IEEE 802.15.4), 6LoWPAN, Proprietary systems-Recent trends.

IOT PROCESSORS 9

Services/Attributes: Big-Data Analytics for IOT, Dependability, Interoperability, Security, Maintainability. Embedded processors for IOT: Introduction to Python programming-Building IOT with RASPERRY PI and Arduino.

CASE STUDIES 9

Industrial IoT, Home Automation, smart cities, Smart Grid, connected vehicles, electric vehicle charging, Environment, Agriculture, Productivity Applications, IOT Defense.

d. Activities

- Group discussions on real-world IoT applications (e.g., smart homes, smart cities).
- Guest Lectures by inviting industry Programmes to share real-world insights.
- Field Trips / Visit to companies that implement IoT solutions.

e. Learning Resources

1. Arshdeep Bahga and Vijai Madisetti : A Hands-on Approach “Internet of Things”, Universities Press 2015.
2. Oliver Hersent, David Boswarthick and Omar Elloumi “The Internet of Things”, Wiley, 2016.
3. Samuel Greengard, “ The Internet of Things”, The MIT press, 2015
4. Adrian McEwen and Hakim Cassimally “Designing the Internet of Things “Wiley, 2014.
5. Jean- Philippe Vasseur, Adam Dunkels, “Interconnecting Smart Objects with IP: The Next Internet” Morgan Kuffmann Publishers, 2010.
6. Adrian McEwen and Hakim Cassimally, “Designing the Internet of Things”, John Wiley and sons, 2014.

ELECTIVES GROUP – II

Course Code	Course Name	L	T	P	C
P24PE905	Power Electronics For Renewable Energy Systems	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The students will have a clear understanding about the principles of power electronics in renewable energy systems, designing and analyzing power electronic converters. They will enhance their knowledge in evaluating the impact of technology on sustainable energy solutions.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand different renewable energy systems	K2
CO2	Design and simulate power electronics converters used for interfacing Renewable energy systems	K6
CO3	Design standalone renewable energy system employing embedded energy storage and MPPT strategy	K6
CO4	Design grid connected renewable energy system	K6
CO5	Determine the maximum power that can be extracted using different MPPT algorithms	K5
CO6	Analyze the integration of renewable energy systems (solar/wind) into the grid and evaluate power quality	K4

c. Course Syllabus

Total: 45 Hours

INTRODUCTION 9

Introduction to renewable energy systems, environmental aspects of electric energy conversion, impacts of renewable energy generation on environment, GHG Effect, Qualitative study of different renewable energy resources Ocean, Biomass, Hydrogen energy systems and Fuel cell.

POWER ELECTRONIC CONVERTERS FOR RENEWABLE ENERGY 9

Solar: Block diagram of solar photo voltaic system: line commutated converters (inversion mode) - Boost and buck-boost converters. Wind: three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters.

PHOTO VOLTAIC ENERGY CONVERSION SYSTEMS 9

Introduction, Photo Voltaic (PV) effect, Solar Cell, Types, Equivalent circuit of PV cell, PV cell characteristics (I/V and P/V) for variation of insolation, temperature and shading effect, Stand-alone PV system, Grid connected PV system, Design of PV system-load calculation, array sizing, selection of converter/inverter, battery sizing.

WIND ENERGY CONVERSION SYSTEMS 9

Introduction, Power contained in wind, Efficiency limit in wind, types of wind turbines, Wind control strategies, Power curve and Operating area, Types of wind generators system based on Electrical machines-Induction Generator and Permanent Magnet Synchronous Generator(PMSG), Grid Connected-Single and Double output system, Self-excited operation of Induction Generator and Variable Speed PMSG.

HYBRID RENEWABLE ENERGY SYSTEMS AND MPPT 9

Energy Storage systems, Need for Hybrid Systems, Features of Hybrid Systems, Range and types of Hybrid systems (Wind-Diesel, PV-Diesel and Wind-PV), Case studies of PV- Maximum Power Point Tracking (MPPT) and Wind Energy system

d. Activities

- Design and simulate a solar photovoltaic inverter with MPPT in MATLAB/Simulink.
- Compare different power converter topologies used in wind energy systems and simulate one.
- Analyze the integration of renewable energy systems (solar/wind) into the grid and evaluate power quality.

e. Learning Resources

- 1.S.N.Bhadra, D. Kasta, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009.
2. Rashid .M. H “Power electronics Hand book”, Academic press, 2nd Edition, 2006.
3. Rai. G.D, “Non-conventional energy sources”, Khanna publishers, 2010.
4. Rai. G.D,” Solar energy utilization”, Khanna publishers, 5th Edition, 2008.
5. Gray, L. Johnson, “Wind energy system”, Prentice Hall of India, 1995.
6. B.H.Khan “Non-conventional Energy sources “,Tata McGraw-Hill Publishing Company, New Delhi, 2017.

Course Code	Course Name	L	T	P	C
P24PE906	EV Batteries And Charging Systems	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The students will gain a clear idea about the types and characteristics of batteries for EV. They will gain knowledge on the concept of battery modelling and battery management system, and various types of charging infrastructure and chargers

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Describe about the battery characteristics & parameters.	K2
CO2	Discuss about the different types of EV batteries.	K2
CO3	Analyze different types of modelling and battery management system.	K4
CO4	Explain the different types of charging infrastructure.	K2
CO5	Describe different types of battery chargers and connectors.	K2
CO6	Integrate various components to build charging stations	K6

c. Course Syllabus

Total: 45 Hours

BATTERY CHARACTERISTICS AND PARAMETERS 9

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.

CHEMISTRY OF EV BATTERIES 9

Special characteristics, Battery life and maintenance of Lead Acid Batteries – Nickel-based Batteries Nickel cadmium, Nickel metal hydride batteries – Sodium-based Batteries Sodium sulphur batteries, Sodium metal chloride (Zebra) batteries – Lithium Batteries lithium polymer battery, lithium-ion battery – Metal Air Batteries – Aluminium air battery, Zinc air battery.

BATTERY MODELLING AND BATTERY MANAGEMENT SYSTEM

General approach to modelling batteries, simulation model of a rechargeable Li-ion battery, simulation model of a rechargeable NiCd battery, Parameterization of the NiCd battery model, State-of-the-Art of battery State-of-Charge determination – State-of-Charge indication algorithms and methods – Cell equalization problem, Energy & Power estimation, Battery thermal management system

CHARGING INFRASTRUCTURE 9

Domestic Charging Infrastructure, Public Charging Infrastructure, Normal Charging Station, Occasional Charging Station, Fast Charging Station, Battery Swapping Station, Move-and charge zone

BATTERY CHARGERS AND CONNECTORS 9

Battery Chargers: Charge equalization, Conductive charging – Basic charger, Microprocessor based charger – Arrangement of an off-board conductive charger, Standard power levels of conductive chargers, Inductive Principle of inductive charging- Soft switching power converter for inductive charging. Connectors: Different types of EV charging connectors in India – AC and DC Connectors: IEC60309, Type 1 and 2, GB/T, CHAdeMO, CCS1, CCS2, DC Fast Charge EV Plug – Standards

d. Activities

- Battery Pack Design Project for an electric vehicle (EV), considering factors like capacity, weight, and cost. They present their designs with a focus on performance and safety.
- Develop a proposal for an EV charging station, including location analysis, power requirements, and charging technology. Present the business case for the station.
- Simulate different charging profiles (e.g., fast charging vs. standard charging) and analyze their impacts on battery life and performance.
- Use simulation software to model a BMS, analyzing charging/discharging cycles and safety mechanisms. Students report on their findings and optimizations

e. Learning Resources

1. Iqbal Hussain, 'Electric and Hybrid Vehicles: Design Fundamentals', CRC Press, Taylor & Francis Group, Second Edition, 2011.
2. Ali Emadi, Mehrdad Ehsani, John M. Miller, 'Vehicular Electric Power Systems', Special Indian Edition, Marcel Dekker, Inc., 2010.
3. James Larminie, John Lowry, 'Electric Vehicle Technology Explained', John Wiley & Sons Ltd, 2003.
4. C.C Chan, K.T Chau, 'Modern Electric Vehicle Technology', Oxford University Press Inc., New York, 2001.
5. Gregory L. Plett, 'Battery Management Systems: Battery modelling', Artech House, 2015.

Course Code	Course Name	L	T	P	C
P24PE907	Advanced Power Converters	3	0	0	3

Category: Professional Elective Courses

a. Preamble

This course aims to cultivate a new generation of engineers who are not only knowledgeable but also adept at designing and implementing advanced power conversion systems. Students will get in-depth knowledge and will gain a clear commitment to continuous improvements aligned with industry needs, promoting innovation and sustainability in power management.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand the operation and applications of voltage-lift circuits and their role in enhancing the performance of power converters	K2
CO2	Design and analyze super-lift Luo converters for improved voltage gain and efficiency in power conversion systems.	K6
CO3	Evaluate and implement ultra-lift Luo converters and understand their functionality in multiple-quadrant operations.	K6
CO4	Comprehend the working principles and design considerations of bidirectional dual active bridge DC-DC converters for energy storage and regeneration applications.	K2
CO5	Analyze and apply various topologies of impedance source converters, including voltage-fed and current-fed Z-source inverters.	K2
CO6	Develop an understanding of advanced modulation techniques like Sine PWM, SVPWM, and Pulse Width Amplitude Modulation for optimizing power converter performance.	K6

c. Course Syllabus

Total: 45 Hours

VOLTAGE-LIFT CONVERTERS

9

Introduction- Self-lift and reverse self-lift circuits- Cuk converter, Luo converter and SEPIC converters- continuous and discontinuous conduction mode.

SUPER-LIFT LUO-CONVERTERS

9

Main series, -Elementary Circuit, Re-Lift Circuit, Triple-Lift Circuit, Higher-Order Lift Circuit-. Continuous conduction and discontinuous conduction mode.

ULTRA LIFT CONVERTERS AND MULTI – QUADRANT OPERATING

LUO CONVERTERS

9

Ultra-Lift Luo- Converter- Operation - Continuous conduction and discontinuous conduction Mode and of Ultra-Lift Luo-Converter-Instantaneous Values- Multiple quadrant operating Luo Converters- Circuit explanations-modes of operation.

BIDIRECTIONAL DUAL ACTIVE BRIDGE DC–DC CONVERTERS

9

Application of Bidirectional DC–DC Converter-Classification of Bidirectional DC–DC Converter -Working Principle of Hybrid-Bridge-Based Dual active bridge (DAB) converter- Performance- Voltage match control- Principle of Dual-Transformer based DAB converter- Three-Level bidirectional DC–DC converter.

IMPEDANCE SOURCE CONVERTER

9

Voltage-Fed Z-source inverters -Topologies –Steady state and dynamic model- Current fed Z-source inverter -Topology -Modification and operational principles. Modulation Methods- Sine PWM- SVPWM and Pulse width Amplitude Modulation

d. Activities

- Design and simulate a multilevel inverter and analyze its performance in high-power applications.
- Perform a study on the efficiency of different DC-DC converter topologies under varying load conditions.
- Analyze the dynamic performance of advanced power converters and propose optimization techniques.

e. Learning Resources

1. Advanced DC/DC Converters, 2nd Edition, Fang Lin Luo, Hong Ye, CRC Press, 2018.
2. Impedance source power electronic converters, Yushan Liu , Haitham Abu-Rub , Baoming Ge , Dr. Frede Blaabjerg , Omar Ellabban , Poh Chiang Loh, Wiley IEEE Press, 2016.
3. High Frequency Isolated Bidirectional Dual Active Bridge DC–DC Converters with Wide Voltage Gain, Deshang Sha, GuoXu, Springer 2019.
4. Essential DC/DC Converters, 1st Edition, Fang Lin Luo, Hong Ye, CRC, 2005
5. Power Electronics Advanced Conversion Technologies, Second Edition, Fang Lin Luo, Hong Ye, 2018 CRC Press.

Course Code	Course Name	L	T	P	C
P24PE908	Battery Management Systems	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The students will explore key topics such as battery chemistry, system architecture, performance optimization, safety, and environmental considerations. Students will get a clear picture of how to meet the evolving demands of energy storage and management technologies

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Analyze the various performance parameters of battery packs and select a suitable protection scheme for battery management system.	K4
CO2	Apply the standard and optimized procedures to estimate the state of charge for battery pack used in real time applications.	K3
CO3	Analyze the different cell balancing circuits for equal charge distribution in battery packs.	K4
CO4	Analyze the methods of communication	K4
CO5	Analyze thermal management system for BMS.	K4
CO6	Design the battery management systems for electric vehicles applications.	K5

c. Course Syllabus

Total: 45 Hours

BATTERY MANAGEMENT SYSTEM REQUIREMENTS 5

Introduction to Battery management systems - Battery Pack topology - BMS design requirements - Battery Pack Sensing: Voltage, Current, Temperature - Requirements in Charger control - Protection - Estimation requirements: State of charge (SoC), Power, Energy.

BATTERY STATE ESTIMATION 10

Definition of SoC - SoC estimation - Basic approaches to estimate SoC - sequential probabilistic methods - Linear and extended Kalman filter (EKF) - problems associated with EKF - Real world issues pertaining to sensors, initialization.

CELL BALANCING SYSTEM 10

Cause for cell unbalance - Cell balancing - active balancing: Charge Shuttle (Flying Capacitor) Charge Distribution, Inductive Shuttle Charge Distribution - passive balancing: circuits for balancing -Self balancing - Lossless balancing.

COMMUNICATION AND THERMAL MANAGEMENT SYSTEMS 10

Components used for communication - Data bus: RS232, EIA485 connection - I2C bus - CAN bus - LIN bus - PLC systems - Flex Ray bus - SM bus - Thermal effects on batteries - Heat sources and sinks - sensors for temperature measurement.

BMS FOR ELECTRIC VEHICLES 10

Basic data collection from EV battery pack - charge discharge limits - current settings in BMS - Nominal resistance and calculation - Isolation fault detection - busbar compensation - EV Charging interface with BMS.

d. Activities

- Design a battery management system for an electric vehicle, focusing on SOC estimation and balancing.
- Simulate and analyze a thermal management system for batteries under fast charging conditions.
- Develop a simulation model of protection circuits in a BMS to ensure safe operation under various fault conditions.

e. Learning Resources

1. Phillip Weicker, A systems approach to Lithium - ion Battery Management, Artech House Publications, 2014.
2. Gregory L Plett, Battery Management systems - Equivalent circuit methods, Volume 2, Artech House Publications, 2016.
3. Davide Andrea, Battery Management Systems for Large Lithium-ion Battery Packs, Artech House Publications, 2010.
4. Jinchun Jiang, Caiping Zhang, Fundamentals and applications of Lithium Ion batteries in Electric drive vehicles, Willey Publications, 2015.
5. Application Note: Orion BMS 2, EWERT Energy Systems.

ELECTIVES GROUP – III

Course Code	Course Name	L	T	P	C
P24PE909	Energy Storage Technologies	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The students will understand that Energy Storage Technologies play a crucial role in this transition by enabling the efficient capture, storage, and distribution of energy. They will gain knowledge to analyze different battery storage technologies, thermodynamics of Fuel Cell and learn the various applications of energy storage systems

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand the physics of energy storage.	K2
CO2	Model the different energy technologies.	K5
CO3	Recognize the applications of various techniques.	K5
CO4	Design and analyze the energy storage technologies.	K4
CO5	Select and apply the appropriate technique based on the application.	K2
CO6	Compare various alternate energy storage technologies and their applications	K5

c. Course Syllabus

Total: 45 Hours

INTRODUCTION **9**

Necessity of energy storage – types of energy storage – comparison of energy storage technologies – Applications.

THERMAL STORAGE SYSTEM **9**

Thermal storage – Types – Modeling of thermal storage units – Simple water and rock bed storage system – pressurized water storage system – Modelling of phase change storage system – Simple units, packed bed storage units - Modelling using porous medium approach, Use of TRNSYS.

ELECTRICAL ENERGY STORAGE **9**

Fundamental concept of batteries – measuring of battery performance, charging and is charging of a battery, storage density, energy density, and safety issues. Types of batteries – Lead Acid, Nickel-Cadmium, Zinc Manganese dioxide - Mathematical Modelling for Lead Acid Batteries – Flow Batteries.

FUEL CELL **9**

Fuel Cell – History of Fuel cell, Principles of Electrochemical storage – Types – Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, alkaline fuel cell, detailed analysis – advantages and disadvantages –Fuel Cell Thermodynamics

ALTERNATE ENERGY STORAGE TECHNOLOGIES **9**

Flywheel , Super capacitors, Principles & Methods – Applications, Compressed air Energy storage, Concept of Hybrid Storage – Applications, Pumped Hydro Storage – Applications.

d. Activities

- Research and compare various energy storage technologies (batteries, super capacitors, flywheels) in terms of energy density, cost, and application.
- Simulate the integration of energy storage systems with renewable energy sources and evaluate system performance.
- Analyze the role of battery energy storage systems in stabilizing grid operations during peak demand.

e. Learning Resources

1. Ibrahim Dincer and Mark A. Rosen, ‘Thermal Energy Storage Systems and

Applications’, John Wiley & Sons 2002.

2. James Larminie and Andrew Dicks, ‘Fuel cell systems Explained’, Wiley publications, 2003.
3. Lunardini.V.J, ‘Heat Transfer in Cold Climates’, John Wiley and Sons 1981.
4. Ru-shiliu, Leizhang and Xueliang Sun, ‘Electrochemical technologies for energy storage and conversion’, Wiley publications, 2012.
5. Schmidt.F.W. and Willmott A. J., ‘Thermal Storage and Regeneration’, Hemisphere Publishing Corporation, 1981.

Course Code	Course Name	L	T	P	C
P24PE910	Power Quality	3	0	0	3

Category: Professional Elective Courses

a. Preamble

Power quality has become essential for the reliable operation of equipment and the overall efficiency of energy systems. Power quality encompasses a range of factors, including voltage stability, frequency regulation, and harmonic distortion, all of which significantly impact the performance of electrical devices and the satisfaction of end-users.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand Power Quality Phenomena and Standards.	K2
CO2	Understand the Causes and Effects of Voltage Variations	K2
CO3	Understand the Nature and Impact of Electrical Transients	K6
CO4	Understand Harmonic Distortion in Power Systems	K6
CO5	Understand Power Quality Conditioning Equipment	K2
CO6	Understand Techniques for Power Quality Improvement	

c. Course Syllabus

Total: 45 Hours

INTRODUCTION TO POWER QUALITY

6

Overview of Electric Power Quality Phenomena - Definitions and Standards (IEC and IEEE) - Introduction to Power Quality Disturbances - Voltage Fluctuations - Transients, Unbalance - Waveform Distortion - Power Frequency Variations.

VOLTAGE VARIATIONS AND THEIR MITIGATION 9

Voltage Sags and Short Interruptions - Flicker and Long-Duration Voltage Variations - Sources and Impact on Sensitive Circuits - Standards for Voltage Variations - Solutions and Mitigation Techniques - Equipment for Mitigating Voltage Variations.

TRANSIENTS AND THEIR IMPACT 9

Origin and Classification of Transients - Capacitor Switching Transients - Lightning-Induced Transients - Load Switching Transients - Impact of Transients on Users and Systems - Protection Techniques for Transients - Transient Mitigation Strategies

HARMONICS IN POWER SYSTEMS AND POWER QUALITY

CONDITIONERS 12

Sources of Harmonics - Definitions and Standards for Harmonics - Impact of Harmonics on Power Systems - Harmonic Power Flow Analysis - Calculation and Simulation of Harmonics - Mitigation and Control Techniques - Passive and Active Filtering Methods Shunt Compensators - Series Compensators - DStatcom (Distribution Static Compensator) - Dynamic Voltage Restorer (DVR) - Unified Power Quality Conditioners (UPQC) - Application and Case Studies of Power Quality Conditioners

ADVANCED POWER QUALITY IMPROVEMENT TECHNIQUES 9

Advanced Mitigation Techniques for Voltage Variations, Transients, and Harmonics - Integration of Power Quality Conditioners with Smart Grids - Impact of Renewable Energy Sources on Power Quality - Case Studies of Power Quality Improvement in Industrial and Commercial Settings - Future Trends and Emerging Technologies in Power Quality Management

d. Activities

- Perform a power quality audit of a renewable energy system, analyzing harmonics, voltage sag, and flicker.
- Design an active power filter to mitigate harmonics in a renewable energy system.
- Research and present a case study on power quality issues in a renewable energy system.

e. Learning Resources

1. Arindam Ghosh “Power Quality Enhancement Using Custom Power Devices”, Kluwer Academic Publishers, 2002.
2. G.T.Heydt, “Electric Power Quality”, Stars in a Circle Publications, 1994 2nd Edition
3. R.C.Duggan “Electric Power Systems Quality”, Tata McGraw Hill Publishers, Third Edition, 2012.
4. Arrillga “Power System Harmonics”, John Wiley and Sons, 2003
5. Derek A.Paice “Power Electronic Converter Harmonics” IEEE Press, 1995

Course Code	Course Name	L	T	P	C
P24PE911	Machine Learning And Deep Learning	3	0	0	3

Category: Professional Elective Courses

a. Preamble

This course will facilitate the learners to understand the fundamentals of machine learning and Familiarize with basic machine learning algorithms with classification. They will also understand machine learning algorithms with clustering and gain knowledge on the concepts of deep learning.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand fundamentals of machine learning.	K2
CO2	Understand and explore the machine learning algorithms with classification	K2
CO3	Apply machine learning algorithms with clustering and feature extraction.	K3
CO4	Understand the deep networks along with its limitations.	K2
CO5	Apply sequence modeling in practice	K3
CO6	Implement machine learning algorithms to forecast and solve problems	K3

MODELS OF MACHINE LEARNING 9

Components of learning – learning models – geometric models – probabilistic models – logical models – grouping and grading – learning versus design – types of learning – supervised – unsupervised – reinforcement – theory of learning – feasibility of learning – error and noise – training versus testing – theory of generalization – generalization bound – approximation generalization trade off – bias and variance – learning curve.

SUPERVISED LEARNING 9

Perceptron: – multilayer neural networks – back propagation - learning neural networks structures – support vector machines: – soft margin SVM – going beyond linearity – generalization and over fitting – regularization – validation. Decision trees: Training and Visualizing a Decision Tree - Making Predictions - Estimating Class Probabilities - The CART Training Algorithm - Computational Complexity - Gini Impurity or Entropy

UNSUPERVISED LEARNING 9

Introduction - Clustering Algorithms - Mixture densities – K-means clustering – clustering around medoids – silhouettes – hierarchical clustering – k-d trees. Dimensionality Reduction: – Linear Discriminant Analysis – Principal Component Analysis – Factor Analysis – Independent Component Analysis

DEEP NETWORKS 9

Deep Feed-forward networks: Gradient based Learning, Hidden Units, Back propagation and differentiation algorithms, Regularization of Deep Learning: Parameter norm penalties, Dataset augmentation, Multitask learning, Adversarial training, optimization for training deep models.

SEQUENCE MODELING: RECURRENT AND RECURSIVE NETS 9

Recurrent Neural Networks (RNN), Bidirectional RNN, Long Short-Term Memory (LSTM), GRU; Case Study - Language Modelling, Image Captioning using RNNs.

d. Activities

- Develop a machine learning model to predict equipment failures in renewable energy systems, using real-world data.
- Implement a machine learning algorithm to forecast energy production in a solar or wind power system.
- Use machine learning techniques to detect and classify faults in electrical power systems.

e. Learning Resources

1. Probabilistic Machine Learning: An Introduction by Kevin Murphy, MIT Press 2022.
<https://probml.github.io/pml-book/book1.html>
2. Deep Learning by Ian Goodfellow, Yoshua Bengio and Aaron Courville, MIT Press 2016.
3. Dive into Deep Learning by Aston Zhang, Zack C. Lipton, Mu Li and Alex J. Smola
<https://d2l.ai/>
4. Kevin Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012.
5. Ethem Alpaydin, “Introduction to Machine Learning”, Third Edition, Adaptive Computation and Machine Learning Series, MIT Press, 2014.
6. Tom M Mitchell, “Machine Learning”, McGraw Hill Education, 2013.
7. Peter Flach, “Machine Learning: The Art and Science of Algorithms that Make Sense of Data”, First Edition, Cambridge University Press, 2012.
8. Shai Shalev-Shwartz and Shai Ben-David, “Understanding Machine Learning: From Theory to Algorithms”, Cambridge University Press, 2015.
9. Christopher Bishop, “Pattern Recognition and Machine Learning”, Springer, 2007.
10. Hal Daumé III, “A Course in Machine Learning”, 2017 (freely available online).
11. Trevor Hastie, Robert Tibshirani, Jerome Friedman, “The Elements of Statistical Learning”, Springer, Second Edition, 2009. (freely available online).
12. Stephen Marsland, “Machine Learning - An Algorithmic Perspective”, Chapman and Hall/CRC Press, Second Edition, 2014.

Course Code	Course Name	L	T	P	C
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P24PE912	Electrical Energy Conservation And Management	3	0	0	3
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Category: Professional Elective Courses

a. Preamble

The students will realize the necessity for effective electrical energy conservation and management has never been more critical. Efficient energy use not only reduces costs and environmental impacts but also enhances the reliability of electrical systems. Instilling a deep understanding of energy conservation principles, strategies, and technologies. Students will explore the fundamental concepts of electrical energy efficiency, sustainable practices, and innovative management techniques.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Analyze the various energy conservation schemes and apply energy conservation act for electrical systems.	K4
CO2	Analyze the factors affecting the performance of electrical systems and improve the performance using energy conservation techniques.	K4
CO3	Apply the suitable energy audit technique and tools to maximize the efficacy of electrical system.	K3
CO4	Analyze the different financial management techniques in energy management system for system optimization.	K4
CO5	Evaluate the demand side management and barriers in electrical system for cost reduction.	K5
CO6	Demonstrate comprehensive energy audits to identify energy consumption patterns and potential areas for savings.	K2

c. Course Syllabus

Total: 45 Hours

Energy Scenario- Role of energy Managers in Industries- Energy monitoring, auditing and targeting- Economics of various energy conservation schemes -Total energy systems-Energy conservation and its importance- Energy conservation Act 2001 and its features

ELECTRICAL ENERGY CONSERVATION 10

Energy Efficiency Improvement in Electrical Systems- -Electrical load management, maximum demand control- Power factor correction- Electric Motors efficiency, factors affecting motor performance- energy efficient motors- Transformers- lighting-case studies

ENERGY MANAGEMENT 10

Definition, energy audit, need, types of energy audit. Energy management (audit) approaches- understanding energy costs- Benchmarking, energy performance, matching energy use to requirement, maximizing system efficiencies, fuel and energy substitution, energy audit instruments and metering.

FINANCIAL MANAGEMENT 10

Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation- risk and sensitivity analysis

ENERGY EFFICIENCY AND DEMAND SIDE MANAGEMENT 10

Basic concepts -Importance of demand side managements- Efficiency gains - Estimation of energy efficiency potential -Cost effectiveness- Barriers for energy efficiency and Demand Side Management.

d. Activities

- Conduct an energy audit for a residential or commercial building, identifying conservation opportunities.
- Design an energy management system that integrates renewable energy sources and storage for optimal energy usage.
- Simulate a demand-side energy management strategy for reducing peak loads in power systems.

e. Learning Resources

1. Thomas Johansson, A K N Reddy, Robert Williams, "Energy for a Sustainable world", Wiley Eastern, 2000.
2. Albert Thumann, Terry Niehus, Handbook of Energy Audits, 2012.
3. Charles E Brown, World Energy Resources, Springer, 2012.
4. Amlan Chakrabarti, Energy Engineering and Management, Prentice hall India, 2011.
5. BEE reference book, 1/2/3/4.

ELECTIVES GROUP - IV

Course Code	Course Name	L	T	P	C
P24PE913	Optimization Techniques	3	0	0	3

Category: Professional Elective Courses

a. Preamble

This course will facilitate the learners to understand the classification of optimization, linear programming models and solution techniques. Also, they will apply different non-linear programming problem solution techniques with clear understanding of the concept of dynamic programming.

a. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Compare different classifications of optimization problems and techniques.	K2
CO2	Solve problems on linear programming concepts	K2
CO3	Understand the application of non-linear programming in optimization techniques	K2
CO4	Understand the fundamental concepts of dynamic programming	K2
CO5	Apply knowledge about Genetic algorithm and understand its application to power system optimization.	K3
CO6	Apply optimization techniques to improve the performance of power converters	K3

c. Course Syllabus

Total: 45 Hours

INTRODUCTION 9

Definition, Classification of optimization problems, Classical Optimization Techniques, Single and Multiple Optimization with and without inequality constraints.

LINEAR PROGRAMMING (LP) 9

Simplex method of solving LPP, revised simplex method, duality, Constrained optimization, Theorems and procedure, Linear programming, mathematical model, solution technique, duality.

NON LINEAR PROGRAMMING 9

Steepest descent method, conjugates gradient method, Newton's Method, Sequential quadratic programming, Penalty function method, augmented Lagrange multiplier method.

DYNAMIC PROGRAMMING (DP) 9

Multistage decision processes, concept of sub-optimization and principle of optimality, Recursive relations, Integer Linear programming, Branch and bound algorithm

GENETIC ALGORITHM 9

Introduction to genetic Algorithm, working principle, coding of variables, fitness function, GA operators; Similarities and differences between Gas and traditional methods; Unconstrained and constrained optimization using genetic Algorithm, real coded gas, Advanced Gas, global optimization using GA, Applications to power system.

d. Activities

- Use optimization algorithms to improve the efficiency of renewable energy systems (solar/wind) under varying conditions.
- Develop an optimization model to balance supply and demand in a microgrid that integrates renewable energy sources.
- Apply optimization techniques to improve the performance of power converters in terms of efficiency and cost.

e. Learning Resources

1. S.S. Rao, "Engineering Optimization – Theory and Practice", John Wiley & Sons, Inc., 2009.
2. Hamdy A. Taha, Operations Research: An Introduction, 10th Edition, Pearson, 2016.
3. David G. Luenberger, "Introduction to Linear and Nonlinear Programming", Addison- Wesley, 1973.
4. E. Polak, "Computational methods in Optimization", Academic Press, 1971.
5. Pierre D.A., "Optimization Theory with Applications", Wiley Publications, 1969.

Course Code	Course Name	L	T	P	C
P24PE914	Smart Grid	3	0	0	3

Category: Programme Elective Courses

a. Preamble

The students will appreciate the transition to a Smart Grid represents a pivotal shift in how generation, distribution, and consumption of electricity. This advanced infrastructure harnesses technology to enhance the efficiency, reliability, and sustainability of power systems. Integration of cutting-edge technologies, such as smart meters, renewable energy sources, and advanced communication systems, enabling students to understand the complexities and benefits of Smart Grid systems.

a. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand concept of smart grid and its advantages over conventional grid	K2
CO2	Understand smart metering techniques	K2
CO3	Understand wide area measurement techniques	K2
CO4	Understanding the problems associated with integration of distributed generation & its solution through smart grid.	K2
CO5	Understanding the applications of smart grid	K2
CO6	Find innovative solutions to real-world problems in smart grid deployment and management.	K2

c. Course Syllabus**Total: 45 Hours****INTRODUCTION TO SMART GRID 9**

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

SMART GRID TECHNOLOGIES 9

Smart energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection control, Distribution systems: DMS, Volt/VAR control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV).

SMART METERS AND ADVANCED METERING INFRASTRUCTURE 9

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

POWER QUALITY MANAGEMENT IN SMART GRID 9

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

HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS 9

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

d. Activities

- Design a smart grid architecture that integrates renewable energy sources, storage, and demand response.
- Simulate the operation of a smart grid with real-time monitoring and control using MATLAB/Simulink.
- Research and present on cybersecurity challenges and solutions in smart grid technology.

e. Learning Resources

1. Smart Grid: Technology and Applications Janaka B. Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, Wiley April 2012
2. Stuart Borlase “Smart Grid Infrastructure, Technology and Solutions”, CRC Press2012.
3. Yang Xiao, Communication and Networking in Smart Grids, CRC press, 2012
4. Nouredine Hadjsaïd and Jean-Claude Sabonnadière Smart, SmartGrids, ISTE Ltd. 2012.

Course Code	Course Name	L	T	P	C
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P24PE915	HVDC Transmission	3	0	0	3
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Category: Professional Elective Courses

a. Preamble

High Voltage Direct Current (HVDC) transmission technology that is revolutionizing the way electricity is transmitted over long distances, enhancing efficiency and stability in power systems. As the global demand for energy grows, integrating renewable sources and managing grid interconnections become imperative.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand the basics of power transmission networks and need for HVDC	K2
CO2	Analyze the operation, control and application of thyristor based FACTS controllers.	K4
CO3	Explain the concept of multi terminal DC (MTDC) systems.	K2
CO4	Analyze the power flow in AC/DC Systems.	K4
CO5	Illustrate the faults in converters and associated protection	K2
CO6	Understanding and Application of Multi-Terminal DC Systems	K2

c. Course Syllabus

Total: 45 Hours

DC POWER TRANSMISSION TECHNOLOGY 9

Comparison of AC and DC transmission - Application of DC transmission - Description of DC transmission system-Planning for HVDC transmission-Modern trends in DC transmission.

CONVERTER AND HVDC SYSTEM CONTROL 9

Simplified analysis of Graetz circuit-twelve pulse converter-detailed analysis of converters- General principles of DC link control - Converter control characteristics - System control hierarchy-Firing angle control-Current and extinction angle control-starting and stopping of DC link - power control - Generation of harmonics and filtering.

MULTI TERMINAL DC SYSTEMS 9

Introduction - Potential applications of MTDC systems-Types of MTDC systems -Control And protection of MTDC systems- Multi-infeed DC systems.

POWER FLOW ANALYSIS IN AC/DC SYSTEMS 9

Overview of power flow analysis-DC system model-per unit system-solution procedure -influence of AC system strength on AC/DC interaction.

CONVERTER FAULTS AND PROTECTION 9

Converter faults-commutation failure-arc through-misfire-current extinction-short Circuit in a bridge-protection against over current-protection against over voltages.

d. Activities

- Simulate an HVDC system for long-distance power transmission from a renewable energy source.
- Design a converter station for an HVDC system and evaluate its efficiency.
- Research and present a case study on a large-scale HVDC project, focusing on the power electronics used.

e. Learning Resources

1. P. Kundur, "Power System Stability and Control", McGraw-Hill, 2006.
2. K.R.Padiyar, "HVDC Power Transmission Systems", New Age International (P)Ltd., New Delhi, 2002.
3. Mohan Mathur, R., Rajiv. K. Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley& Sons, Inc.
4. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International (P) Ltd., Publishers, New Delhi, Reprint 2008.
5. J.Arrillaga, "High Voltage Direct Current Transmission", Peter Pregrinus, London, 1983.
6. Erich Uhlmann, "Power Transmission by Direct Current", BS Publications, 2004.

Course Code	Course Name	L	T	P	C
P24PE916	Renewable Energy Technology	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The students enrolled in this course will realize the challenges of climate change and dwindling fossil fuel resources, harnessing renewable energy sources—such as solar, wind, hydro, and bioenergy. This course emphasizes practical, real-world applications, enabling students to engage deeply with the principles of renewable energy systems while fostering critical thinking and innovation.

a. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Understand the fundamentals of renewable energy sources and their potential in power generation.	K2
CO2	Analyse the principles, design, and applications of solar energy systems, including both thermal and photovoltaic technologies	K4
CO3	Understand the mechanics of wind energy systems and their components, along with the factors affecting their performance.	K2
CO4	Evaluate biomass and biogas energy conversion processes, their technologies, and applications	K5
CO5	Explore the potential and utilization of various hybrid energy systems integrating multiple renewable resources.	K3
CO6	Analyze the principles and applications of other renewable energy sources, such as hydrogen, geothermal, OTEC, tidal, and wave energy.	K4

c. Course Syllabus

Total: 45 Hours

INTRODUCTION

9

Primary energy sources, renewable vs. non-renewable primary energy sources, renewable energy resources in India, Current usage of renewable energy sources in India, future potential of renewable energy in power production and development of renewable energy technologies

SOLAR ENERGY

9

Solar Radiation and its measurements, Solar Thermal Energy Conversion from plate Solar Collectors, Concentrating Collectors and its Types , Efficiency and performance of collectors, Applications of Solar Thermal Energy use of low and medium, high temperature and recent advances in industry and buildings. Direct Solar Electricity Conversion from Photovoltaic, types of solar cells and its application of battery charger, domestic lighting, street lighting, and water pumping, power generation schemes. Recent Advances in PV Applications: Building Integrated PV, Grid Connected PV Systems, Hybrid Systems and Solar Cars, Solar Energy Storage system and their economic aspects

WIND ENERGY

9

Wind energy principles, wind site and its resource assessment, wind assessment, Factors influencing wind, wind turbine components, wind energy conversion systems (WECS), Classification of WECS devices, wind electric generating and control systems, characteristics and applications. Hybrid systems - safety and environmental aspects, economic aspects.

BIO-ENERGY

9

Energy from biomass, Principle of biomass conversion technologies/process and their classification, Bio gas generation, types of biogas plants, selection of site for biogas plant, classification of biogas plants, Advantage and disadvantages of biogas generation, thermal gasification of biomass, biomass gasifies, Application of biomass and biogas plants and their economics

OTHER TYPES OF ENERGY

9

Energy conversion from Hydrogen and Fuel cells, Geo thermal energy Resources, types of wells, methods of harnessing the energy, potential in India. OTEC, Principles utilization, setting of OTEC plants, thermodynamic cycles. Tidal and wave energy: Potential and conversion techniques, mini- hydel power plants and their economics

d. Activities

- Research and present on emerging renewable energy technologies, such as floating solar farms or tidal energy.
- Perform an efficiency analysis of different renewable energy technologies, comparing wind, solar, and hydro.
- Design and simulate a renewable energy system (solar or wind) for a specific application (e.g., rural electrification).

e. Learning Resources

1. Twidell & Wier, “Renewable Energy Resources” CRC Press(Taylor & Francis).
2. Tiwari and Ghosal/ Narosa, ‘Renewable energy resources’.
3. D.P.Kothari, K.C.Singhal, “Renewable energy sources and emerging technologies’, P.H.I.
4. D.S.Chauhan, S.K. Srivastava, ‘Non – Conventional Energy Resources’, New Age Publishers, 2006.
5. B.H.Khan, ‘Non – Conventional Energy Resources’, Tata Mc Graw Hill, 2006.

Course Code	Course Name	L	T	P	C
P24PE917	Distributed Generation And Micro Grid	3	0	0	3

Category: Professional Elective Courses

a. Preamble

The shift towards decentralized energy systems is reshaping the way electricity generated, distributed, and consumed. The students will clearly understand distributed generation and microgrids play a pivotal role in enhancing energy resilience, promoting sustainability, and integrating renewable resources into the grid. As communities and industries seek to harness local energy solutions, understanding these systems becomes essential for the next generation of energy Programmes.

a. Course Outcomes

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

CO s	Course Outcomes	Knowledge Level
CO1	Understand the fundamental concepts of Distributed Generation and Microgrids.	K2
CO2	Explain about various Distributed Generation (DG) resources and their characteristics.	K2
CO3	Identify planning and protection schemes of Distributed Generation systems	K3
CO4	Interpret the concept of Microgrid and its mode of operation	K2
CO5	Illustrate the technical and economic impacts of Microgrids on the power system.	K2
CO6	Analyze the challenges, management, and economic issues associated with Microgrid integration.	K4

INTRODUCTION TO DISTRIBUTED GENERATION 9

DG definition - Reasons for distributed generation-Benefits of integration - Distributed generation and the distribution system - Technical, Environmental and Economic impacts of distributed generation on the distribution system - Impact of distributed generation on the transmission system-Impact of distributed generation on central generation

DISTRIBUTED ENERGY RESOURCES 9

Combined heat and power (CHP) systems-Wind energy conversion systems (WECS)- Solar photovoltaic (PV) systems-Small-scale hydroelectric power generation-Other renewable energy sources-Storage devices-Inverter interfaces

DG PLANNING AND PROTECTION 9

Generation capacity adequacy in conventional thermal generation systems-Impact of distributed generation-Impact of distributed generation on network design-Protection of distributed generation- Protection of generation equipment from internal Faults-Protection of the faulted distribution network from fault currents supplied by the distributed generator-Impact of distributed generation on existing distribution system protection.

CONCEPT OF MICROGRID 9

Microgrid Definition-A typical Microgrid configuration- Functions of Micro source controller and central controller- Energy Management Module (EMM) and Protection Co-ordination Module (PCM) - Modes of Operation - Grid connected and islanded modes- Modelling of Microgrid- Microturbine Model- PV Solar Cell Model- Wind Turbine Model-Role of Microgrid in power market competition.

IMPACTS OF MICROGRID 9

Technical and economic advantages of Microgrid-Challenges and disadvantages of Microgrid development-Management and operational issues of a Microgrid- Impact on heat utilization-Impact on process optimization-Impact on market-Impact on environment-Impact on distribution system-Impact on communication standards and protocols.Microgrid economics-Main issues of Microgrid economics-Microgrids and traditional power system economics- Economic issues between Microgrids and bulk power systems-benefits of Microgrid economics.

d. Activities

- Design a microgrid integrating solar, wind, and battery storage, focusing on power flow management and stability.
- Simulate the operation of a microgrid with renewable energy sources and evaluate system performance under varying load conditions.
- Analyze a real-world case of distributed generation and microgrid implementation, discussing the challenges and benefits.

e. Learning Resources

1. Nick Jenkins, Janaka Ekanayake , Goran Strbac , “Distributed Generation”, Institution of Engineering and Technology, London, UK, 2010.
2. S. Chowdhury, S.P. Chowdhury and P. Crossley, “Microgrids and Active Distribution Networks”, The Institution of Engineering and Technology, London, United Kingdom, 2009.
3. Math H. Bollen , Fainan Hassan, “Integration of Distributed Generation in the Power System”, John Wiley & Sons, New Jersey, 2011.
4. Magdi S. Mahmoud, Fouad M. AL-Sunni, “Control and Optimization of Distributed Generation Systems”, Springer International Publishing, Switzerland, 2015.
5. Nadarajah Mithulananthan, Duong Quoc Hung, Kwang Y. Lee, “Intelligent Network Integration of Distributed Renewable Generation”, Springer International Publishing, Switzerland, 2017.
6. Ali K., M.N. Marwali, Min Dai, “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley and sons, New Jersey, 2010.

Course Code	Course Name	L	T	P	C
P24PE918	Power Electronics For Wind And Solar Energy Systems	3	0	0	3

Category: Professional Elective Courses

a. Preamble

Students will gain insights into the design and operation of power electronic converters, control systems, and integration strategies specific to renewable energy applications. They will understand that these technologies are crucial for converting, controlling, and managing the energy harvested from natural sources, ensuring efficiency and reliability in energy delivery.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Analyse the impacts of renewable energy generation on environment	K4
CO2	Understand the importance and qualitative analysis of solar and wind energy sources.	K2
CO3	Apply the principle of operation of electrical machines for wind energy conversion and their performance characteristics	K3
CO4	Design suitable power converters for solar PV and wind energy systems	K6
CO5	Understand MPPT and install Hybrid Renewable Energy Systems	K2
CO6	Analyze appropriate plants based on Wind-PV-Maximum Power Point Tracking (MPPT).	K4

c. Course Syllabus

Total: 45 Hours

INTRODUCTION

9

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) -Qualitative study of different renewable energy resources ocean, Biomass, Hydrogen energy systems : operating principles and characteristics of: Solar PV, Fuel cells, wind electrical systems-control strategy, operating area

ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION

9

Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG

POWER ELECTRONICS FOR SOLAR

9

Block diagram of solar photo voltaic system : line commutated converters (inversion-mode) - Boost and buck-boost converters-selection of inverter, battery sizing, array sizing- standalone PV systems - Grid tied and grid interactive inverters-grid connection issues

POWER ELECTRONICS FOR WIND

9

Three phase AC voltage controllers-AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, matrix converters- Standalone operation of fixed and variable speed wind energy conversion systems- Grid connection Issues -Grid integrated PMSG and SCIG Based WECS

HYBRID RENEWABLE ENERGY SYSTEMS

9

Need for Hybrid Systems -Range and type of Hybrid systems-Case studies of Wind-PV- Maximum Power Point Tracking (MPPT).

d. Activities

- Performance study using MATLAB/Simulink.
- Design and simulate a power converter for a wind energy system, focusing on grid integration.
- Analyze the performance of power electronics in a hybrid solar and wind energy system under varying environmental conditions.

e. Learning Resources

1. S.N.Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009.
2. Rashid .M. H “power electronics Hand book”, Academic press, 2001.
3. Rai. G.D, “Non-conventional energy sources”, Khanna Publishers, 1993.
4. Rai. G.D,” Solar energy utilization”, Khanna publishes, 1993.
5. Gray, L. Johnson, “Wind energy system”, prentice hall linc, 1995.
6. B.H.Khan, “Non-conventional Energy sources", Tata McGraw-Hill Publishing Company.
7. P.S.Bimbhra,“Power Electronics”, Khanna Publishers, 3rd Edition,2003.
8. Fang Lin Luo Hong Ye, “Renewable Energy systems", Taylor & Francis Group,2013.
9. R.Seyezhai and R.Ramaprabha, “Power Electronics for Renewable Energy Systems”, Scitech Publications, 2015.

Course Code	Course Name	L	T	P	C
P24PE919	Industry 4.0 And Industrial Internet Of Things (IIoT)	3	0	0	3

Category: Professional Elective Courses

a. Preamble

This course will facilitate the learners to know and understand Industry 4.0 and IIOT as well as understand the application of Industry 4.0 and IIOT.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Knowledge of theory and practice related to Industry 4.0	K2
CO2	Understand Industrial 4.0 applications	K2
CO3	Understand the theory and practice related to Industrial IoT Systems.	K2
CO4	Identify, formulate and solve engineering problems by using Industrial IoT	K2
CO5	Implement real field problem by gained knowledge of Industrial applications with IoT capability	K3
CO6	Design and prototype IoT devices using platforms like Arduino or Raspberry Pi.	K6

c. Course Syllabus

Total: 45 Hours

INTRODUCTION TO INDUSTRY 4.0 **9**

Digitalization and the Networked Economy - Introduction to Industry 4.0 - Comparison of Industry 4.0 Factory and Today's Factory - Internet of Things (IoT) - Sensing & actuation, Communication, Cyber Physical Systems- Industrial Internet of Things (IIoT) - Smart Devices and Products

CONCEPTUAL FRAMEWORK AND APPLICATION OF INDUSTRY 4.0 **9**

Smart Logistics - Support System for Industry 4.0 - Architecture of Industry 4.0 - Cloud computing, Machine learning, Big Data and Data science for IIOT - Industry 4.0 integration with manufacturing systems, Application domains- Smart Factories. Case studies on IoT cloud system in manufacturing and other domains.

INTRODUCTION TO INDUSTRIAL IOT (IIOT) SYSTEMS **9**

The Various Industrial Revolutions, Role of Internet of Things (IoT) & Industrial Internet of Things (IIoT) in Industry, Industry 4.0 revolutions, Industrial IoT-Layers, IIoT Reference Architecture- Support System for Industry 4.0

IMPLEMENTATION SYSTEMS FOR IIOT **9**

Sensors and Actuators for Industrial Processes, Sensor networks, Process automation and Data Acquisitions on IoT Platform, Microcontrollers and Embedded PC roles in IIoT, Wireless Sensor nodes with Bluetooth, WiFi, and LoRa Protocols and IoT Hub systems IoT Gate way, cloud and IoT Edge Systems.

INDUSTRIAL IOT- APPLICATIONS **9**

Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Industrial Automation, IIOT application in Healthcare, Power Plants, Smart grid, Manufacturing, Inventory Management & Quality Control, Plant Safety and Security, Facility Management-Case studies

d. Activities

- Arrange factory visits/ tours of smart factories to observe IIoT technologies in action.
- Attend industry events/ Tech Conferences to expose students to the latest trends and technologies.
- Analyze successful IIoT implementations in various sectors (e.g., automotive, pharmaceuticals) and present findings.

e. Learning Resources

1. Alasdair Gilchrist, 'Industry 4.0: The Industrial Internet of Things', A Press, 2016.
2. Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat, 'Industrial Internet of Things Cyber manufacturing Systems', Springer, 2017.
3. Christoph Jan Bartodziej, 'The Concept Industry 4.0, An Empirical Analysis of Technologies and Applications in Production Logistics', Springer, 2017.
4. Rajkamal, 'Embedded System: Architecture, Programming and Design', TMH3, 2017.
5. Ovidiu Vermesan, Peter Friess, 'Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems', River Publishers, 2016.
6. Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stamatis Karnouskos, Stefan Aves and David Boyle, 'From Machine-to-Machine to the Internet of Things – Introduction to a New Age of Intelligence', Elsevier, 2014.

Course Code	Course Name	L	T	P	C
P24PE920	Digital Control In Power Electronics	3	0	0	3

Category: Professional Elective Courses

a. Preamble

Students will understand that rapid advancement of digital technologies is transforming the landscape of power electronics, enhancing system efficiency, reliability, and functionality. As industries increasingly adopt sophisticated control methods, the integration of digital control in power electronics has become essential for optimizing performance across a range of applications—from renewable energy systems to electric vehicles and smart grids.

b. Course Outcomes

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

COs	Course Outcomes	Knowledge Level
CO1	Model and analyse various rectifier configurations.	K4
CO2	Elaborate on modelling choppers and cyclo-converters.	K2
CO3	Design single phase and three phase inverters for various control techniques.	K6
CO4	Model and simulate the various dc and ac motors	K6
CO5	Understand the modeling of matrix converter and explore various PWM control techniques for rectifiers.	K2
CO6	Simulate real-time digital control system for a power electronic converter	K6

c. Course Syllabus

Total: 45 Hours

SIMULATION OF RECTIFIERS 9

Basic Terms & Definitions - Power Electronic Switches- Uncontrolled rectifiers and Controlled Rectifiers- Half wave rectifiers- Full wave rectifiers- Analysis of rectifiers for various loads-dual converters.

SIMULATION OF CHOPPERS & CYCLOCONVERTERS 9

Basic chopper - operation & control techniques-step- down & up choppers- buck-Boost chopper-Types of choppers-Chopper commutation techniques-step-up cycloconverter - step down cycloconverter.

SIMULATION OF SINGLE PHASE & THREE PHASE INVERTERS 9

Single-phase Inverters-Half-wave Inverter-Full- wave Inverter-Full wave Inverter with R-L Load-Current Source Inverter-Three-phase Inverters- Three-phase 180° Conduction mode Inverter-Three phase 120 degrees Conduction Mode Inverter PWM Inverter.

SIMULATION DC & AC MACHINES 9

DC machines- Separately Excited DC Machines-DC Series Motor- DC Shunt Motor-AC Motors- Three-phase Induction Motor-Three-phase Synchronous Motor.

SIMULATION OF MATRIX CONVERTERS 9

Introduction to Matrix Converter-Basics of Matrix Converter-Bi- directional switches, Commutation problem-Modulation techniques-Programming and simulation of Matrix Converters- Introduction to PWM rectifier-Control Techniques.

d. Activities

- Design a digital control system for a DC-DC converter and implement it using microcontrollers or FPGAs.
- Simulate the application of digital control techniques (e.g., PID, sliding mode control) in power converters.
- Implement a real-time digital control system for a power electronic converter and test its performance under dynamic conditions.

e. Learning Resources

TEXT BOOKS:

1. M. B. Patil, V. Ramanarayanan, V.T.Ranganathan, M.C.Chandorkar”
Simulation of PowerConverters”,1st edition, Narosa Publishers,2010.
2. V. Rajagopalan, “ Modeling& Simulation of PE systems”, Marcel Dekkar Inc.