CURRICULUM & SYLLABI

M.Tech. POWER ELECTRONICS & DRIVES

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department
Electrical Engineering

VISION

To excel in education, research and technological services in electrical engineering in tune with societal aspirations.

MISSION

- Impart quality education to produce globally competent electrical engineers capable of extending technological services.
- Engage in research & development in cutting edge and sustainable technologies.
- Nurture scientific temperament, professional ethics and industrial collaboration.

M.Tech. Power Electronics & Drives

Program Educational Objectives

PEO-1	Design and develop independently innovative products and services in the field of Power Electronics & Drives
PEO-2	Adopt and utilize latest technologies and tools in design of products and systems
PEO-3	Communicate effectively to propagate ideas and promote teamwork
PEO-4	Attain intellectual leadership skills to cater to the changing needs of power industry, academia, society and environment

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5
Impart quality education to produce globally competent electrical engineers capable of extending technological services	3	3	3	2	3
Engage in research & development in cutting edge and sustainable technologies	3	3	2	3	3
Nurture scientific temperament, professional ethics and industrial collaboration	3	3	2	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Program Outcomes

PO-1	**Develop** scientific temperament and rational thinking abilities to pursue research and tackle complex problems related to power electronics & drive systems.
PO-2	**Communicate** with technical communities on engineering issues while creating awareness for all sections of society.
PO-3	**Employ** the knowledge of power electronics & drives to contribute towards the development of products / technologies which require a team with multidisciplinary expertise.
PO-4	**Develop** eco-friendly and sustainable technologies using the knowledge of power electronics & drive systems.
PO-5	**Cultivate** an attitude of self-learning to cope with ever changing tools and technologies and be productive throughout his / her career.
PO-6	**Foster** a temperament to manage projects, organizations and entrepreneurial ventures maintaining financial integrity and professional ethics.

CURRICULUM
M.Tech. Power Electronics & Drives

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE16001	Analysis of Power Converters	3-0-0	3
2	EE16003	Electric Drives	3-0-0	3
3	EE16005	Applications of Digital Signal Processors	3-0-0	3
4	EEXXXX	Professional Elective – I	3-0-0	3
5	EEXXXX	Professional Elective – II	3-0-0	3
6	EE16007	Power Electronics Lab	0-1-2	2
7	EE16009	Power Electronic Simulation Lab	0-1-2	2
			Total Credits	**19**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE16002	Advanced Power Electronics	3-0-0	3
2	EE16004	Advanced Electric Drives	3-0-0	3
3	EEXXXX	Professional Elective – III	3-0-0	3
4	EEXXXX	Professional Elective – IV	3-0-0	3
5	EEXXXX	Professional Elective –V	3-0-0	3
6	EE16006	Electric Drives Lab	0-1-2	2
7	EE16008	Advanced DSP Lab	0-1-2	2
8	EE16096	Minor Project	0-0-0	2
			Total Credits	**21**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE16089	Seminar and Technical Writing	0-0-0	2
2	EE16091	Summer Internship/Research Experience	0-0-0	2
3	EE16093	Comprehensive Viva-Voce	0-0-0	2
4	EE16097	Dissertation: Part – A	0-0-0	8
			Total Credits	**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EE16098	Dissertation: Part – B	0-0-0	12
			Total Credits	**12**

Professional Elective Courses

Professional Elective – I		
S.No.	**Code**	**Course Title**
1	EE16021	Wide Band Gap Devices for Power Electronics Applications
2	EE16023	Electromagnetic Interference & Compatibility
3	EE36023	Energy Storage Systems
4	EE46001	Linear Control System

Professional Elective – II		
S.No.	**Code**	**Course Title**
1	EE16025	Electric Vehicles
2	EE16027	Power Quality Improvement Techniques
3	EE46023	Embedded Control Systems
4	MA16063	Numerical Optimization Techniques

Professional Elective – III		
S.No.	**Code**	**Course Title**
1	EE16022	Applications of Power Converters
2	EE16024	Simulation of Power Electronic Converters
3	EE16026	Control & Integration of Renewable Energy Sources
4	EE46024	Digital Control Systems

Professional Elective – IV		
S.No.	**Code**	**Course Title**
1	EE16028	High Power Inverters
2	EE16030	Power Converters for Microgrids
3	EE26030	Evolutionary Algorithms Applications in Power Engineering
4	EE36028	Industrial Internet of Things

Professional Elective – V		
S.No.	**Code**	**Course Title**
1	EE16032	Predictive Control of Power Converters and Drives
2	EE16034	Advanced Control Techniques for Power Converters
3	EE26032	Machine Learning Applications in Power Engineering
4	EE26036	Flexible AC Transmission Systems

The Overall Credit Structure

Credits in Each Semester					
	I Sem	**II Sem**	**III Sem**	**IV Sem**	**Total**
Program Core	13	10	0	0	23
Professional Elective	6	9	0	0	15
Seminar and Technical Writing	0	0	2	0	2
Minor Project	0	2	0	0	2
Summer Internship/Research Experience	0	0	2	0	2
Comprehensive Viva-Voce	0	0	2	0	2
Dissertation: Part-A	0	0	8	0	8
Dissertation: Part-B	0	0	0	12	12
Total credits (Sem. wise)	**19**	**21**	**14**	**12**	**66**

SYLLABI

M.Tech: Power Electronics & Drives

1st Semester

EE16001 **3-0-0 (3)**

Analysis of Power Converters

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify appropriate switching devices for power converters
CO-2	Analyze and design power converter configurations for specific applications
CO-3	Apply suitable control techniques for low and medium-power converters
CO-4	Design power electronic converters to improve power quality

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	1	2	2
CO-2	2	-	3	1	2	2
CO-3	2	-	3	1	2	2
CO-4	2	-	3	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Overview of Switching Power Devices: Static and dynamic characteristics of switching devices: BJT, MOSFET, IGBT, GTO, Wide band gap devices (GaN, SiC) - Design of driver and snubber circuit

DC-DC Converters: Non-isolated DC-DC converters: buck, boost, buck-boost, CUK converters under continuous and discontinuous conduction operation - Isolated DC-DC converters: forward, fly-back, push-pull, half-bridge and full-bridge converters - Relationship between I/P and O/P voltages - design of filter inductor and capacitors

Inverters: Single-phase and three-phase inverters - PWM techniques: single, multiple and sinusoidal PWM techniques - selective harmonic elimination, space vector modulation, current source inverter- High power inverters: Multi-pulse inverters, multi-level inverters - Diode-clamped, cascaded and Flying capacitor types, Carrier and Vector based multi-level modulation schemes -Concept of active power filters- Introduction to Matrix Converters.

Front-End (AC-DC) Converters: Conventional methods of power factor improvements: Semi-converter, extinction angle control, symmetrical angle control – active front-end converters - Single phase: Boost, voltage doubler and PWM rectifiers –voltage and current controlled three-phase PWM rectifiers.

Learning Resources:

Text Books:

1. M. H. Rashid, Power Electronics Handbook, Butterworth-Heinemann Inc, 2024, 5th Edition.
2. N. Mohan, T.M. Undeland, W.P. Robbins, Power Electronics: Converters, Applications and Design, John Wiley & Sons, 2003, 3rd Edition.

Reference Books:

1. L. Umanand, Power Electronics: Essentials and Applications, John Wiley India, 2009, 1st Edition.
2. B. Jayant Baliga, Fundamentals of Power Semiconductor Devices, Springer, 2018, 2nd Edition.
3. Bin Wu, High Power Converters and AC Drives, Wiley-Interscience, 2017, 2nd Edition.
4. Derek A Paice, Power Electronic Converter Harmonics Multipulse Method for Clean Power, IEEE Press, 1995.

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/117/108/117108124/
2. https://onlinecourses.nptel.ac.in/noc20_ee28/preview

EE16003 **3-0-0 (3)**

Electric Drives

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the significance and role of variable speed drives in the present-day industry and the requirement of four-quadrant operation and stability
CO-2	Analyze the basic torque producing mechanisms in electrical machines using the principles of field energy and coenergy
CO-3	Analyze and design Separately Excited DC motor drives in steady state and dynamic conditions
CO-4	Analyze the steady state behavior of induction motor drives with scalar control and its implementation using slip compensation technique

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	1	2	2
CO-2	2	-	2	1	2	2
CO-3	3	-	3	1	2	2
CO-4	3	-	3	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Review of Basic Electrical Drives: Need of variable speed drives, Review of speed control methods in DC and AC drives, role of electrical drives in energy conservation, classification of electrical drives, four-quadrant operation of electrical drives, stability of electrical drives.

Basic Principles for Electrical Machine Analysis: Magnetically coupled circuits: review of basic concepts, magnetizing inductance, modelling linear and nonlinear magnetic circuits, Electromechanical energy conversion: principles of energy flow, concept of field energy and coenergy, Derivation of torque expression for various machines using the principles of energy flow and the principle of coenergy.

Separately Excited DC Motor Drives: Review of the theory of DC machine, State-space model of a Separately Excited DC machine, reduced order model & transfer function of the DC machines, Review of controllers, Speed control of a separately excited DC drive with inner current loop and outer speed loop, Design of current and speed loops.

Induction Motor drives: Review of speed control methods of induction motors, Implementation of scalar control with slip compensation scheme, Limitations of the scalar control method.

Learning Resources:

Text Books:

1. B.K. Bose, Modern Power Electronics & AC Drives, Pearson Education India, 2015, 1st Edition.
2. Rama Krishnan, Electric motor drives: modeling, analysis, and control, Pearson Education India,

2015, 1st Edition.
3. M.B. Patil, V. Ramanarayanan, V.T. Ranganathan, Simulation of Power Electronic Circuits, Narosa, 2013, 1st Edition.

Reference Books:

1. A. E. Fitzgerald, C Kingsley, Stephen D. Umans, Electric Machinery, TMH, 2017, 6th Edition.
2. Rik De Doncker, Duco W. J. Pulle, André Veltman, Advanced Electrical Drives: Analysis, Modeling, Control, Springer, 2011,1st Edition.
3. Paul C. Krause, Oleg W, Scott D. Sudhoff, Analysis of Electric Machinery & Drive systems, IEEE Press, 2013, 3rd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/106/108106023/
2. https://nptel.ac.in/courses/108/108/108108077/

EE16005 **3-0-0 (3)**

Applications of Digital Signal Processors

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop Assembly Language Programs for the Digital Signal Processors
CO-2	Configure and use Digital Input / Output lines and ADCs
CO-3	Configure and use Interrupts and Event Managers for PWM generation
CO-4	Employ DSPs for the real time control of Power Electronic Converters

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	1	3	2
CO-2	3	-	3	1	3	2
CO-3	3	-	3	1	3	2
CO-4	3	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

TMSLF2407 DSP Controller: Brief Introduction to Peripherals - Types of Physical Memory - Software Tools.

C2XX DSP CPU and instruction set: Introduction to the C2xx DSP Core and Code Generation - The Components of the C2xx DSP Core - Mapping External Devices to the C2xx Core and the Peripheral Interface -System Configuration Registers –Memory -Memory Addressing Modes -Assembly Programming Using the C2xx DSP Instruction Set.

Parallel and Serial Data Transfer: Pin Multiplexing (MUX) and General Purpose I/O Overview - Multiplexing and General Purpose I/O Control Registers - Using the General Purpose I/O Ports.

Interrupt system of TMS320LF2407: Introduction to Interrupts - Interrupt Hierarchy - Interrupt Control Registers - Initializing and Servicing Interrupts in Software, real time control with interrupts.

The analog-to-digital converter (ADC): ADC Overview - Operation of the ADC and programming modes.

Event Managers (EVA, EVB): Overview of the Event Manager (EV) - Event Manager Interrupts - General Purpose (GP) Timers- Compare Units - Capture Units and Quadrature Encoded Pulse (QEP) Circuitry - General Event Manager Information - PWM Signal Generation with Event Managers and interrupts, Measurement of speed with Capture Units, Implementation of Space Vector Modulation with DSP TMSLF2407A.

Introduction to TMS320F28069 DSP Controller.

Learning Resources:

Text Books:

1. Hamid A. Tolyat, DSP based Electromechanical Motion Control, CRC press, 2003, 1st Edition.
2. TMS320x2806x Piccolo Technical Reference Manual, Texas Instruments, 2017.

Reference Books:

1. TMS320F/C24x DSP Controllers Reference Guide: CPU and Instruction Set - Literature Number: SPRU160C
2. TMS320F/C24x DSP Controllers Reference Guide: System and Peripherals - Literature Number: SPRU357C

Other Suggested Readings:

1. https://www.ti.com/lit/ug/spru160c/spru160c.pdf
2. https://www.ti.com/lit/ug/spru357c/spru357c.pdf

EE16007 **0-1-2 (2)**

Power Electronics Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine the characteristics of power devices and converters
CO-2	Implement control circuits for power converters
CO-3	Determine the performance of power converters
CO-4	Determine the performance of Z-source and resonant converters

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	2	1	3	2
CO-2	2	-	2	1	3	2
CO-3	3	-	2	1	2	2
CO-4	3	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

List of Experiments

1. Static characteristics of MOSFET and IGBT
2. PV characteristics and Implementation of MPPT
3. Analysis of DC-DC converters (a) Buck converter, (b) Boost converter, and (c) Buck-Boost converter
4. Closed loop control of Buck and Boost converter
5. Quasi-square wave control of a Single-phase Full bridge VSI
6. Unipolar and bipolar PWM techniques for single-phase half-bridge and full-bridge inverters.
7. 120˚ and 180˚ operation of three-phase inverter and selective harmonic elimination for three-phase inverter
8. Sine-PWM techniques for three-phase two-level inverters
9. Space vector modulation for a three-phase VSI
10. Pulse width modulation control of Single-phase AC voltage controller
11. Single phase Five level cascaded H-Bridge inverter
12. Hysteresis current control of a single-phase inverter

13. Control of Front-end active rectifiers/Bidirectional Converters
14. Control of Z-source inverter
15. Control of Resonant DC-DC converters

Learning Resources:

Text Books:

1. M. H. Rashid, Power Electronics Handbook, Butterworth-Heinemann Inc, 2024, 5th Edition.
2. N. Mohan, T.M. Undeland, W.P. Robbins, Power Electronics: Converters, Applications and Design, John Wiley & Sons, 2003, 3rd Edition.

EE16009 **0-1-2 (2)**

Power Electronic Simulation Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Use simulators as a learning aid and gain insight regarding power electronic converters and drive systems
CO-2	Validate the performance of power converters with different PWM schemes
CO-3	Explore the behavior of new circuits for power conversion
CO-4	Explore the dynamic performance of Induction motor and multi-carrier PWM techniques.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	1	3	2
CO-2	3	-	3	1	2	2
CO-3	3	-	3	1	3	2
CO-4	2	-	3	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

List of Experiments

1. Study of the dynamics of second, and higher order systems using SIMULINK
2. Simulation of buck, boost, and buck-boost DC-DC converters in CC & DC modes of operation using SIMULINK
3. Simulation of DC-DC converters with State-space modelling using SIMULINK
4. Study of the dynamic behaviour of the DC-DC converters through numerical integration methods using MATLAB
5. Study on the design of PI controllers and stability analysis for a DC-DC buck Converter using MATLAB
6. Sine-PWM techniques for single-phase half-bridge, full-bridge and three-phase inverters using MATLAB
7. Study of spectral performance of half-bridge, full-bridge and three-phase inverters using Fast Fourier Transforms
8. Space vector modulation (SVM) for three-phase two-level inverters
9. Closed-loop implementation single-phase high power factor rectifiers (Boost rectifier and PWM rectifier).

10. Multicarrier PWM techniques for three-phase diode clamped and cascaded H-bridge multilevel inverters.
11. Study of the performance of a Separately Excited DC Motor Drive
12. Study of the performance of a V/Hz controlled induction motor drive using the *dq0* model.

Learning Resources:

Text Books:

1. N. Mohan, T.M. Undeland, W.P. Robbins, Power Electronics: Converters, Applications and Design, John Wiley & Sons, 2003, 3rd Edition.
2. Rama Krishnan, Electric motor drives: modeling, analysis, and control, Pearson Education India, 2015, 1st Edition.
3. M.B. Patil, V. Ramanarayanan, V.T. Ranganathan, Simulation of Power Electronic Circuits, Narosa, 2013, 1st Edition.

2nd Semester

EE16002 **3-0-0 (3)**

Advanced Power Electronics

Pre-Requisites: **EE16001**

Course Outcomes:

CO-1	Analyze and design resonant converters
CO-2	Develop power converter models under steady-state and small-signal conditions
CO-3	Design feedback control systems for power converters
CO-4	Synthesize and design magnetic components for power converter

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	1	3	2
CO-2	2	-	3	1	3	2
CO-3	2	-	3	1	3	2
CO-4	3	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Resonant Converters: Introduction, Basic resonant circuit concepts, Classification - Load resonant converters, Resonant switch converters, Zero voltage switching(ZVS) clamped voltage converters, Resonant DC link inverters High frequency link integral half cycle converters, Phase modulated resonant converters, Dual active bridge converters, High gain converters.

Modeling of DC-DC Converters: Basic ac modeling approach, State space averaging, Circuit averaging and averaged switch modeling, Canonical circuit modeling, Converter transfer functions for buck, boost and buck-boost topologies.

Current Mode Control: Introduction, types, advantages and disadvantages, Slope compensation, Determination of duty cycle and transfer functions for buck, boost and buck-boost converters.

Design of Closed Loop Control: Controller Design: Introduction, mechanism of loop stabilization, Shaping E/A gains vs frequency characteristics, Conditional stability in feed-back loop, Stabilizing a continuous mode forward and fly-back converter, Feed-back loop stabilization with current mode control, right plane zero.

Design of Power Converters Components: Design of magnetic components - design of transformer, design of inductor and current transformer - Selection of filter capacitors, Selection of ratings for devices, input filter design, Thermal design.

Learning Resources:

Text Books:

1. M.H. Rashid, Power Electronics-Circuits, Devices & Applications, Pearson, 2017, 4th Edition.

2. N. Mohan, T.M. Undeland, W.P. Robbins, Power Electronics: Converters, Applications & Design (An Indian Adaptation), J. Wiley & Sons, 2022, 3rd Edition.

Reference Books:

1. Abraham I. Pressman, Switching Power Supply Design, Keith Billings &Taylor Morey, McGraw Hill International, 2017, 3rd Edition.
2. R.W. Erickson and Dragan Maksimonic, Fundamentals of Power Electronics, Springer, 2020, 3rd Edition
3. Umanand, L, Power Electronics: Essentials and Applications, John Wiley India, 2009, 1st Edition.

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/108/108/108108036/
2. https://archive.nptel.ac.in/courses/117/103/117103148/
3. https://archive.nptel.ac.in/courses/108/105/108105180/

EE16004 **3-0-0 (3)**

Advanced Electric Drives

Pre-Requisites: **EE16003**

Course Outcomes:

CO-1	Apply the theory of transformations to derive the dynamic (*dq0*) model of an induction motor
CO-2	Implement Vector control for induction motor & Permanent Magnet Synchronous Motor (PMSM) drives and the Direct Torque Control for Induction Motor Drives
CO-3	Implement speed control methods for the wound rotor induction motor and analyze 5-Ph induction motor drives
CO-4	Analyze Brushless DC (BLDC) and the Switched Reluctance Motor (SRM) drives

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	2	1	2	2
CO-2	3	-	3	1	3	2
CO-3	3	-	3	1	3	2
CO-4	3	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Theory of Transformations: Concept of space vector, direct and quadrature axis variables, various types of Krause transformation, condition for power invariance, Expression for power with various types of transformation, Transformations between reference frames, Clarke and Park's Transformations, Variables observed from various frames.

Dynamic Model of an induction motor: Inductance matrices of induction motor, Voltage and torque in machine variables, Derivation of *dq0* model for a symmetrical induction machine, Voltage and torque equation in arbitrary reference frame variables.

Induction Motor drives: Principle of vector control of IM, Indirect vector control with feedback, Indirect vector control with feed-forward, Indirect vector control in various frames of reference, Decoupling of vector control with feed forward compensation, Direct Torque Control of IM, control of wound rotor induction machine, introduction and control of five-phase induction motor drives.

Permanent Magnet Drives: Expression for torque, Model of PMSM, Implementation of vector control for PMSM, BLDC drives.

Switched Reluctance Motor Drives: Torque expression, converters for SRM drives, Control of SRM drives.

Learning Resources:

Text Books:

1. Paul C. Krause, Oleg W, Scott D. Sudhoff, Analysis of Electric Machinery & Drive Systems, IEEE Press, 2013, 3rd Edition.

2. B.K. Bose, Modern Power Electronics & AC Drives, Pearson Education India, 2015, 1st Edition.
3. R. Krishnan, Electric Motor Drives: Modeling, Analysis and Control, Pearson Education India, 2015, 1st Edition.

Reference Books:

1. Bin-Wu, High-power Converters and AC Drives, Wiley-Blackwell, 2017, 2nd Edition.
2. M.B. Patil, V. Ramanarayanan, V.T. Ranganathan, Simulation of Power Electronic Circuits, Narosa, 2013, 1st ed. edition.

Other Suggested Readings:

1. nptel.ac.in/courses/108/104/108104140/
2. nptel.ac.in/courses/108/104/108104011/

EE16006 **0-1-2 (2)**

Electric Drives Lab

Pre-Requisites: **EE16003 & EE16004**

Course Outcomes:

CO-1	Implement speed control schemes for separately exited DC motor, induction motor
CO-2	Develop control schemes for permanent magnet synchronous motor and Brushless DC motor drives
CO-3	Develop control schemes using analog circuitry and digital control platform
CO-4	Evaluate the closed performance of various electrical drives under different control schemes

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	1	2	2
CO-2	3	-	3	1	3	2
CO-3	3	-	3	1	3	2
CO-4	3	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

List of Experiments:

1. Open-loop control of separately excited DC motor using four-quadrant DC chopper.
2. Speed control of separately excited DC motor using single-phase dual converter.
3. Torque-speed characteristics of a 6-pulse fully controlled rectifier fed Separately Excited DC motor Drive.
4. Symmetrical angle and pulse width modulation control of 1-phase & 3-phase AC motor connected to AC voltage controller.
5. Open-loop speed control of three-phase induction motor using V/f control technique with analog controller.
6. Closed-loop speed control of three-phase induction motor using the slip- compensation technique.
7. Torque-Speed characteristics of a three-phase induction motor using IM-IM drive
8. Speed control of three-phase induction motor drive using three-level Neutral Point Clamped inverter.
9. Torque-Speed characteristics of a three-phase Permanent Magnet Synchronous Motor drive.
10. Implementation of space vector modulation with DSP TMS320LF2407A for V/Hz control of induction motor drive.

11. Speed control of Brushless DC motor drive.
12. Speed control of switched reluctance motor (SRM).

Learning Resources:

Text Books:

1. Paul C. Krause, Oleg W, Scott D. Sudhoff, Analysis of Electric Machinery & Drive Systems, IEEE Press, 2013, 3rd Edition.
2. B.K. Bose, Modern Power Electronics & AC Drives, Pearson Education India, 2015, 1st Edition.
3. R. Krishnan, Electric Motor Drives: Modeling, Analysis and Control, Pearson Education India, 2015, 1st Edition.

EE16008 **0-1-2 (2)**

Advanced DSP Lab

Pre-Requisites: **EE16005**

Course Outcomes:

CO-1	Configure the on-chip peripherals such as ADC, Digital I/O and QEP to suit the control requirements of Power Converters
CO-2	Configure Interrupts and Event manager to implement Pulse Width Modulation
CO-3	Develop Assembly and C-programming Languages for DSP to achieve the real time control of Power Electronic Converters
CO-4	Implement control schemes for different electrical drives

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	1	3	2
CO-2	3	-	3	1	3	2
CO-3	3	-	3	1	3	2
CO-4	3	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

List of Experiments **on TMS320LF2407A Processor (using Assembly Language)**

1. General Programs to get familiarity with addressing modes, instruction set, arithmetic and logical operations such as:
    a. Arithmetic and logical operations
    b. Direct & Indirect Data Transfer
    c. Sorting of Data in Ascending order and Descending order
    d. Square root of positive integer
    e. Maximum and minimum of given set of numbers
2. Study of the phenomenon of Aliasing
3. Study of the on-chip ADC of TMS320LF2407 processor.
4. Study of the GPIO functionality.
5. Waveform generation with on board DAC of EVM TMS320LF2407
6. PWM signal generation using event manager with dead time
7. Study of the interrupts of TMS320LF2407 processor.

8. Space Vector Modulation of a 3-Phase VSI.

List of Experiments on TMS320F2812Processor (using C Programming Language)

9. General Programs to get familiarity with syntax, arithmetic and logical operations (the list is similar to expt.1)
10. Solution of Difference equation
11. Study of interrupts & GPIO
12. Generation of Basic PWM signals
13. Study of Quadrature Encoder Pulse (QEP) Unit
14. Implementation of sine-triangle PWM scheme
15. Implementation of Sine-triangle PWM with Launch XL-F28069M
16. Implementation of SVPWM with Launch XL-F28377S
17. Control of BLDC motor with DRV8301

Learning Resources:

Text Books:

1. Hamid A. Tolyat, DSP based Electromechanical Motion Control, CRC Press, 2003, 1st Edition.
2. TMS320x2806x Piccolo Technical Reference Manual, Texas Instruments, 2017.

Reference Books:

1. TMS320F/C24x DSP Controllers Reference Guide: CPU and Instruction Set - Literature Number: SPRU160C
2. TMS320F/C24x DSP Controllers Reference Guide: System and Peripherals - Literature Number: SPRU357C

EE16096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	2	1	3	1
CO-2	2	1	2	1	3	1
CO-3	2	3	2	1	3	1
CO-4	2	3	2	1	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project.

Learning Resources:

1. Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

3rd Semester

EE16089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	1	1	2	2
CO-2	2	1	1	1	2	2
CO-3	2	1	3	1	2	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Learning Resources:

1. Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE16091 **0-0-0 (2)**

Summer Internship/Research Experience

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	1	2	2	3	2
CO-2	1	1	2	2	3	3
CO-3	1	2	2	2	3	2
CO-4	1	3	2	2	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Every student has to undergo either a Summer Internship / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Learning Resources:

1. Journal and conference papers from reputed publishers such as IEEE, Elsevier, and Wiley.
2. Research Articles / Reports available on Internet.

EE16093 **0-0-0 (2)**

Comprehensive Viva-Voce

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	2	1	1	2	-
CO-2	1	2	1	1	2	-
CO-3	1	3	1	1	2	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

Learning Resources:

1. Reading Material of all the courses.
2. Case Studies/Industrial training reports
3. Mini projects taken up.

EE16097 **0-0-0 (8)**

Dissertation: Part – A

Pre-Requisites: None

Course Outcomes:

CO-1	Identify a topic in advanced areas of Electrical Engineering.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	1	-	3
CO-2	3	2	3	1	-	3
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	10
II	Literature Survey	25
III	Defining the Objectives and Solution Methodology	35
IV	Performance of the Task	30

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	**X**			
II		**X**		
III			**X**	
IV				**X**

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

4th Semester

EE16098 **0-0-0 (12)**

Dissertation: Part – B

Pre-Requisites: None

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code.
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions.
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time.
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	3	2	3
CO-2	2	-	3	3	2	3
CO-3	3	-	3	3	2	3
CO-4	3	3	3	3	3	3
CO-5	3	3	3	-	-	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	Description	Weightages
IV	Performance of the Task	30
V	Dissertation Preparation	20
VI	Review (Presentation & Understanding)	30
VII	Viva-Voce	10
VIII	Publications /Possibility of publication	10

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	**X**	**X**			
V				**X**	
VI			**X**		
VII				**X**	
VIII					**X**

Refer to the M.Tech. – Regulations for any further information regarding mid-term review, end semester evaluation, template for report preparation and plagiarism guidelines etc.

Professional Electives

EE16021 **3-0-0 (3)**

Wide Band Gap Devices in Power Electronics Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Introduce the basic operation of wide band gap devices and their characteristics
CO-2	Ability to do electrical and thermal modeling of wideband devices, as well as EMI filter design for high-frequency power converters
CO-3	Familiar with compact single-layer and multilayer PCB designs according to industrial needs
CO-4	Utilize wide band gap devices for real-time applications through simulation and experimental studies

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	2	3	1	1
CO-2	2	1	2	3	1	1
CO-3	2	1	2	3	1	2
CO-4	2	1	2	3	1	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Wide Band Gap Devices: Introduction to basic power devices, characteristics, and applications - Silicon Power MOSFETs 1976-2010, SiC Planer Power MOSFETs, SiC Trench-Gate Power MOSFETs, Need of GaN device, Basic GaN Transistor structure, GaN Vertical Power HEFTs and Horizontal Power HEFTs, Different types of wide band gap devices, advantages and challenges in designing converters with wide band gap devices.

GaN Transistor Characteristics & Driver Circuits: Turn ON and Turn OFF switching characteristics of GaN devices, Hard switching loss analysis, Gate driver design, Impact of gate resistance, dv/dt and di/dt immunity, etc., Protection design for double pulse test set-up.

Modeling and Measurement of GaN Transistors: Electrical and thermal modeling of GaN transistors, Thermal management, and Reliability.

High-frequency design complexity: The impact of parasitic inductance and capacitance, EMI filter design for high-frequency power converters, and Heat sink design.

PCB Design: Power circuit design, Driver circuit design, Single layer and Multilayer PCBs, separation of the power circuit and driver circuit, High-frequency power loop optimization.

Applications: GaN in AC/DC & DC/AC Power Converters, GaN in Switched Mode Power Amplifiers, Electric Vehicle Applications, and Renewable Applications.

Learning Resources:

Text Books:

1. A. Lidow, J. Strydom, M. D. Rooij, D. Reusch, GaN Transistors for Efficient Power Conversion, Wiley, 2014.
2. G. Meneghesso, M. Meneghini, E. Zanoni, “Gallium Nitride-enabled High Frequency and High-Efficiency Power Conversion,” Springer International Publishing, 2018.
3. Maurizio Di Polo Emilio, GaN and SiC Power Devices, Springer, 2024.

Reference Books:

1. B.J.Baliga, “Gallium Nitride and Silicon Carbide Power Devices,” World Scientific Publishing Company, 2017.
2. F. Wang, Z. Zhang and E. A. Jones, Characterization of Wide Bandgap Power Semiconductor Devices, IET, 2018.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108108377

EE16023 **3-0-0 (3)**

Electromagnetic Interference & Compatibility

Pre-Requisites: **None**

Course Outcomes:

CO-1	Recognize the sources of Conducted and radiated EMI in Power Electronic Converters and consumer appliances and suggest remedial measures to mitigate the problems
CO-2	Assess the insertion loss and design EMI filters to reduce the loss
CO-3	Design EMI filters, common-mode chokes and RC-snubber circuits measures to keep the interference within tolerable limits
CO-4	Develop suitable techniques to mitigate EMI/EMC issues in power converters

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	1	2	2
CO-2	1	-	2	1	2	2
CO-3	2	-	2	1	2	2
CO-4	2	-	2	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Sources of conducted and radiated EMI, EMC standardization and description, measuring instruments, conducted EMI references, EMI in power electronic equipment: EMI from power semiconductors circuits.

Noise suppression in relay systems: AC switching relays, shielded transformers, capacitor filters, EMI generation and reduction at source, influence of layout and control of parasites.

EMI filter elements: Capacitors, choke coils, resistors, EMI filter circuits. Ferrite breeds, feed through filters, bifilar wound choke filter, EMI filters at source, EMI filter at output.

EMI filter design for insertion loss: Worst case insertion loss, design method for mismatched impedance condition and EMI filters with common mode choke-coils, IEC standards on EMI.

EMI in Switch Mode Power Supplies: EMI propagation modes, power line conducted-mode inference, safety regulations (ground return currents), Power line filters, suppressing EMI at sources, Line impedance stabilization network (LISN), line filter design, common-mode line filter inductors- design& example, series –mode inductors and problems, EMI measurements.

Faraday Screens for EMI prevention: As applied to switching devices, transformers faraday screen and safety screens, faraday screens on output components, reducing radiated EMI on gapped transformer cores, metal screens, electrostatic screens in transformers.

Linear Algebra: Linear dependence and independence of vectors; Eigenvalues and eigenvectors of a matrix; Caley-Hamilton theorem and its applications; Reduction to diagonal form; Reduction of a quadratic form to canonical form - orthogonal transformation and congruent transformation.

Differential Calculus: Taylor's theorem with remainders; Taylor's and Maclaurin's expansions; Functions of several variables - partial differentiation; total differentiation; Change of variables - Jacobians; maxima and minima of functions of several variables (2 and 3 variables) - Lagrange's method of multipliers.

Learning Resources:

Text Books:

1. Ficchi, F. Rocco, Practical Design for Electromagnetic Compatibility, Hayden Book Co.,1981.
2. Laszlo Tihanyi, Electromagnetic Compatibility in Power Electronics, IEEE Press, 1995, 1st Edition.
3. Andrzej M. Trzynadlowski, EMI Effects of Power Converters, in Power Electronics Handbook (Fifth Edition), 2024.

Reference Books:

1. Paolo Stefano Crovetti, Electromagnetic Interference and Compatibility, MDPI, 2021.
2. Keith H Billings, Taylor Morey, Handbook on Switch-Mode power supplies, McGraw-Hill Publisher, 2011, 3rd Edition.
3. Abraham I. Pressman, Keith Billings, Taylor Morey, Switching Power Supply Design, McGraw Hill International, 2009, 3rd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/106/108106138/

EE36023 **3-0-0 (3)**

Energy Storage Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the characteristics of energy storage devices
CO-2	Model and simulate the characteristics of energy storage systems
CO-3	Explore the possibilities of deployment of energy storage systems in smart cities and electric vehicles.
CO-4	Evaluate and suggest an efficient storage system in electric transportation.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	–	1	1	3	–
CO-2	3	1	2	3	2	–
CO-3	3	–	3	3	3	3
CO-4	3	2	3	2	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Impacts and requirements of Electrical Energy Storage system, Classification of Energy Storage Systems, Energy costs and load analysis. Grid Applications of Energy Storage systems, Ancillary Services from Energy storage. Economics of energy and power, tied electrical rates and demand response. Role of energy storage system in handling uncertainties with Renewable systems and in microgrids. Mathematical Modelling of various Energy Storage systems.

Battery Energy Storage: Batteries: Introduction to battery storage including lead acid, lithium ion, flow, and emerging battery technologies. Comprehensive analysis of design considerations and application specific needs. Impacts on system cost in terms of life cycle, environmental, and reliability of the end solutions.

Ultra-Capacitors: Introduction to ultra-capacitors including operation, applications, and emerging technologies. Topics include the usage in mobile applications and close proximity to renewable energy sources. Discussion of primary target market usage in today's energy and power sectors.

Super Conducting Magnetic Energy Storage (SMES): Introduction to Super Conducting Magnetic Energy Storage (SMES) operation, theory of usage and emergent research, with focus on large utility scale energy storage facilities.

Mobile and Fixed Energy Storage: Advantages and disadvantages of mobile vs. stationary energy storage, with focus on vehicle to grid applications and opportunities to leverage existing and emergent technology to provide additional grid support functions.

Concept of time-of-day metering for storage planning and management.

Compressed Gas Storage: Compressed gas storage technologies as bulk energy storage. Models for compressed gas capacity, efficiency, and availability, System cost, capacity, conversion efficiency, siting and associated barriers, possible applications in carbon capture and appropriation.

Flywheel Storage: Flywheel energy storage system, Models for flywheel capacity, availability, efficiency, and self-discharge, Applications in transportation, uninterruptible power supply (UPS), pulse power, and bulk storage, Selection and design of flywheels for safety and availability in various applications.

Fuel Cell Based Storage: fuel cell-based energy storage concepts and applications.

Learning Resources:

Text Books:

1. Andrei Ter-Gazarian, Energy Storage for Power Systems, Institution of Engineering and Technology (IET), 2020, 3rd Edition.
2. Ali Keyhani Mohammad Marwali and Min Dai, Integration and Control of Renewable Energy in Electric Power System, John Wiley publishing company, 2010, 2nd Edition.

Reference Books:

1. S. Chowdhury, S. P. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, IET Power Electronics Series, 2012.
2. Zechun Hu, Energy Storage for Power System Planning and Operation, IEEE Press, 2020, 1st Edition.
3. Slobodan Petrovic, Peter Kurzweil, Jürgen Garche, Electrochemical Energy Storage: Batteries, Fuel Cells, and Hydrogen Technologies, McGraw Hill, 2022,1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112106318

EE46001 **3-0-0 (3)**

Linear Control System

Pre-Requisites: **None**

Course Outcomes:

CO-1	Model the dynamical systems using the state-space concept
CO-2	Solve the state space equation and perform the stability analysis
CO-3	Design the control systems using state-space methods
CO-4	Implement the observer based controller concept and optimal control problem

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	2	1	1
CO-2	2	-	3	2	1	1
CO-3	2	-	3	2	1	1
CO-4	2	-	3	2	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Mathematical modelling of LTI control systems - impulse response model, differential equation model, transfer function model, frequency response model, state space model-Introduction to state and state variables – State space - physical systems - Representation using state space approach- Modelling of electrical systems

Control system Analysis in state space: State space representations of transfer functions, Solution of state space equation - State transition matrix -Matrix exponential-Controllability and observability

Control system Design in State space: Pole placement approach to Regulator design-Full order observer- Observer based regulator design

Stability concept: Stability in the sense of Lyapunov - stability of linear systems – Lyapunov equation-Generation of Lyapunov functions-Krasovskii's method Quadratic optimal control-Lyapunov's approach to quadratic optimal regulator design.

Learning Resources:

Text Books:

1. Katsuhiko Ogata, Modern Control Engineering, Pearson Education India, 2020, 5th Edition.
2. M. Gopal, Modern Control Systems Theory, New Age International Publisher, 2023, 5th Edition.

Reference Books:

1. Panos J. Antsaklis, Anthony N. Michel, A Linear Systems Primer, Birkhauser Boston Inc, 2007, 1st Edition.

2. Roy Choudhary, Modern Control Engineering, Prentice Hall India, 2005, 1st Edition.
3. Brogan W. L, Modern Control Theory, Prentice Hall, 2011, 3rd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108106150
2. https://nptel.ac.in/courses/101108057

EE16025 **3-0-0 (3)**

Electric Vehicles

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the concepts of electric vehicles, hybrid electric vehicles and their impact on environment
CO-2	Analyze the drive-train topologies and advanced propulsion techniques
CO-3	Analyze hybrid energy storage methodologies
CO-4	Identify the suitable power converter topologies for motor control and hybrid energy storage

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	3	3	2
CO-2	1	2	2	3	3	2
CO-3	1	2	3	3	3	2
CO-4	2	2	3	3	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Conventional vehicle, basics of vehicle performance, History of electric vehicles, social and environmental importance of electric vehicles, impact of modern drive- trains on energy supplies.

Hybrid Electric Vehicles: Micro hybrid vehicles, mild hybrid vehicles, full hybrid vehicles, configuration of hybrid electric Vehicles -Parallel hybrid, series Hybrid, Series-Parallel Hybrid, Complex Configuration. Power flow diagrams Hybrid electric vehicle configurations for various operating modes. Plug-in Hybrid Vehicles: Operating principle, architectures: series-parallel-series-parallel, challenges related to grid connection. Range-extended Electric Vehicles: Classification and configurations, Fuel Cell Electric Vehicles, Solar electric Vehicles, Electric Bi-cycles and their propulsion systems, Vehicle-to-grid, vehicle-to-home concepts, Electric Hybrid electric vehicles-configurations, Solar powered vehicles.

Electric drive-trains: Basic concept of electric traction, introduction to various electric drive- train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis

Electric propulsion unit: Electric components used in electric vehicles, Configuration and control schemes of DC Motor drives, Induction Motor drives, BLDC motor drives, Permanent Magnet Motor drives, Switch Reluctance Motor drives.

Energy Storage: Storage requirements for Electric Vehicles, Battery energy storage, Fuel Cell based energy storage, Super Capacitor based energy storage and Super Magnetic Energy storage (SMES). Power pack management systems, Active and passive Cell balancing techniques. Hybridization of different energy storage devices, Flywheel based energy storage, compressed air storage systems, super magnetic storage systems.

Converters for Hybrid Energy Storage Systems: Converter configurations for hybrid energy systems based on Battery and Ultra Capacitors-cascaded converter, multiple parallel- connected converter, dual-active-bridge converter, multiple-input converter- multiple modes single converter, interleaved converter,

switched capacitor converter, coupled inductor based configurations.

Fundamentals of Chargers: Charger classifications and standards, selection of AC charging systems, DC charging systems, Converter topologies for charging, wireless chargers.

Learning Resources:

Text Books:

1. Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, 2015.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2021, 3rd Edition.

Reference Books:

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2023, 3rd Edition.
2. James D. Halderman, Curt Ward, Pear Son, Electric and Hybrid Electric Vehicles, 2023, 1st Edition.
3. Aunpam Singh, Electric Vehicles and the end of ICE Age, 2022, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/106/108106170/
2. https://nptel.ac.in/courses/108/102/108102121/

EE16027 **3-0-0 (3)**

Power Quality Improvement Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify power quality problems in distribution system
CO-2	Evaluate power quality indices in distribution system
CO-3	Develop mitigation techniques for compensating devices to improve power quality in distribution system
CO-4	Suggest compensating devices to improve power quality in distribution system

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	2	2	1	3	2
CO-2	1	2	2	1	3	2
CO-3	3	2	2	1	3	2
CO-4	3	2	2	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Power Quality: Significance of power quality, Power quality terms: Transients, Long- duration voltage variations, Short-duration voltage variations, Voltage imbalance, Waveform distortion, Voltage fluctuation, CBEMA and ITI curves. Devices for Overvoltage Protection: Surge arresters and transient voltage surge suppressors, Isolation transformers and Low-impedance power conditioners.

Waveform Distortion: Introduction, Voltage versus current distortion, Harmonics versus transients, Harmonics indices: Total Harmonics Distortion (THD) and Total Demand distortion (TDD); Harmonic standards; Harmonic analysis; Harmonic phase sequence; Triplen harmonics; Interharmonics.

Harmonic Sources: Introduction; Harmonics generated from electrical machines such as transformers and rotating machines; Arcing devices; Static power conversion: Phase controlled and uncontrolled rectifiers, AC voltage regulators, Pulse width modulated inverters; Converter fed ac and dc drives.

Effects of Harmonic Distortion: Introduction; Resonances; Effects of harmonics on rotating machines; Effect of harmonics on static power plant; Power assessment with distorted waveforms; Effect of harmonics on measuring instruments; Harmonic interference with ripple control systems; Harmonic interference with power system protection; Effect of harmonics on consumer equipment; Interference with communication systems.

Harmonic Elimination: Introduction; Passive power filters: Design, A Shunt active power filters: Configurations, State of the art, Design and control strategies. Three-phase four-wire shunt active power filters

Voltage Quality: Introduction; Sources of Sags, Swell, Unbalance and Flicker; Voltage quality standards; Effects of sags, Swell, Unbalance and Flicker; Voltage sag magnitude due to fault; Voltage sag magnitude calculation based on influence of cross section of conductor, transformer and fault levels; Critical distance for a voltage sag magnitude; Causes of phase-angle jumps in voltage; Classification of voltage sags,

voltage sag transformation due to transformers.

Methods for improving Voltage Quality: Introduction; Dynamic Voltage Restorer (DVR): Operating principle, Configurations, State of the art, Design and control strategies. Three-phase four-wire DVR.

Unified Power Quality Conditioner (UPQC): Introduction; design and control; Three- phase three-wire UPQC and three-phase four-wire UPQC topologies, Multilevel inverters based UPQC topologies, Mitigation of Flicker.

Learning Resources:

Text Books:

1. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad, Power Quality: Problems and Mitigation Techniques, Wiley, 2015.
2. Math H. J. Bollen, Understanding power quality problems, Wiley-IEEE Press, 2000, 1st Edition.
3. Mahesh Kumar Mishra, Power Quality in Power Distribution Systems Concepts and Applications, CRC Press, 2023.

Reference Books:

1. Ghosh Arindam, Ledwich Gerard, Power Quality Enhancement Using Custom Power Devices, Springer, 2009.
2. Hirofumi Akagi, Edson Hirokazu Watanabe, Mauricio Aredes, Instantaneous Power Theory and Applications to Power Conditioning, Wiley-IEEE Press, 2017.
3. Roger C. Dugan, Mark F. McGranaghan, Surya Santoso and H. Wayne Beaty, Electrical Power Systems Quality, McGraw Hill, 2012, 3rd Edition.
4. J. Arrillaga, N.R. Watson, Power System Harmonics, Wiley, 2003, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/107/108107157/
2. https://nptel.ac.in/courses/108/106/108106025/

EE46023 **3-0-0 (3)**

Embedded Control systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Configure and use analog to digital and digital to analog signal conversions
CO-2	Develop the models based on state machine, graph-based methods
CO-3	Program the embedded systems with High level language
CO-4	Design the real time embedded control system using different processors

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	3	2	1	1
CO-2	2	-	3	1	2	1
CO-3	2	-	3	2	2	1
CO-4	2	-	3	2	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

System Design: Definitions, Classifications and brief overview of micro-controllers, microprocessors and Digital Signal Processors. Embedded processor architectural definitions. Typical application scenario of embedded systems.

Data acquisition basics: Introduction to data acquisition on PC, Sampling fundamentals, Input/Output techniques and buses. ADC, DAC, Digital I/O, counters and timers, DMA, Software and hardware installation, Calibration, Resolution, Data acquisition interface requirements, Interface Issues Related to Embedded Systems: A/D, D/A converters, timers, actuators, power, FPGA, ASIC, diagnostic port.

Techniques for Embedded Systems: State Machine and state tables in embedded design, Simulation and Emulation of embedded systems. High-level language descriptions for embedded system, Java embedded system design.

Real time Models, Language and Operating Systems: Event based, process based and graph based models, Petrinet models – Real time languages – The real time kernel, OS tasks, task states, task scheduling, interrupt processing, clocking communication and synchronization, control blocks, memory requirements and control, kernel services.

Software programming: Optimization, concurrent programming. Real time scheduling, I/O Management, Embedded Operating Systems. Developing Embedded Systems, Building Dependable Embedded Systems, Controller Implementation. Case Studies: Discussion of specific examples of complete embedded systems using mc8051, DSP TMS320F28069, PIC series of microcontroller.

Learning Resources:

Text Books:

1. S. Chattopadhyay, Embedded System Design, PHI Learning Pvt. Ltd, 2023, 3rd Edition.
2. Herma K, W. Steiner, Real Time Systems – Design for Distributed Embedded Applications, Springer International Publishing AG, 2022, 3rd Edition.

Reference Books:

1. C.M. Krishna, Kang G. Shin, Real Time Systems, McGraw Hill, 2017, 1st Edition.
2. Tim Wiscott, Applied control for embedded systems, Elsevier Publications, 2011,1st Edition.
3. Jim Ledin, Embedded control systems in C/C++, CRC Press, 2003, 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108102045
2. https://nptel.ac.in/courses/108102169

MA16063 **3-0-0 (3)**

Numerical Optimization Techniques

Pre-Requisites: None

Course Outcomes:

CO-1	Apply concepts of convex sets, convex functions, and optimality conditions
CO-2	Implement one-dimensional optimization methods for searching the optimal solution
CO-3	Classify and execute both direct and indirect unconstrained optimization methods
CO-4	Solve constrained optimization problems using direct methods
CO-5	Utilize indirect methods like the penalty function and augmented Lagrange multiplier methods

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	–	–	–	–
CO-2	2	2	–	3	2	2
CO-3	2	2	2	2	2	2
CO-4	2	–	3	3	2	2
CO-5	–	–	3	2	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Convex Analysis: Convex Sets - Convex Hulls - Closure and Interior of a Set - Weierstrass's Theorem - Separation and Support of Sets - Polyhedral Sets, Extreme Points, and Extreme Directions; Convex Functions - Definitions and Basic Properties - Minima and Maxima of Convex Functions - Generalizations of Convex Functions – Linear Programming - The Fritz John and Karush-Kuhn-Tucker Optimality Conditions.

One-Dimensional Optimization: Introduction - Unimodal Function - Unrestricted Search - Search with Fixed Step Size - Search with Accelerated Step Size - Exhaustive Search - Dichotomous Search - Interval Halving Method - Fibonacci Method - Golden Section Method -Comparison of Elimination Methods.

Unconstrained Optimization: Classification of unconstrained optimization methods - General Approach - Rate of Convergence - Scaling of Design Variables. Direct search methods -Random Search Methods - Grid Search Method - Univariate Method - Pattern Directions - Powell's Method - Simplex Method. Indirect search methods - Gradient of a Function - Steepest Descent (Cauchy) Method - Conjugate Gradient Method – Development of Fletcher-Reeves Method - Newton's Method - Marquardt Method - Quasi-Newton Methods – Davidon, Fletcher, and Powell (DFP) Method – Broyden, Fletcher, Goldfarb, Shanno (BFGS) Method.

Constrained Optimization: Characteristics of a Constrained Problem. Direct methods - Random Search Methods - Sequential Linear Programming - Basic Approach in the Methods of Feasible Directions - Zoutendijk's Method of Feasible Directions -Rosen's Gradient Projection Method - Generalized Reduced Gradient Method - Sequential Quadratic Programming. Indirect search methods - Penalty Function Method

- Parametric Constraints - Augmented Lagrange Multiplier Method - Convergence of Constrained Optimization Problems.

Learning Resources:

Text books:

1. G. N. Vanderplaats, Numerical optimization techniques for engineering design with applications, McGraw–Hill, 2005, 3rd Edition (Reprint).
2. S. S. Rao, Engineering optimization: theory and practice, Wiley, 2019, 5th Edition.

Reference Books:

1. K.Deb, Optimization for Engineering Design: Algorithms and Examples, PHI Learning, 2012, 2nd Edition.
2. M. S. Bazaraa, H. D. Sherali, C. M. Shetty, Nonlinear programming: theory and algorithms, Wiley, 2013, 3rd Edition.

EE16022 **3-0-0 (3)**

Applications of Power Converters

Pre-Requisites: None

Course Outcomes:

CO-1	Identify power converter configurations and improvise the existing control techniques to suit the application
CO-2	Analyze and design inverters for Induction Heating applications
CO-3	Analyze and design converters for lighting, HV systems and Bi-directional converters for charge/discharge applications
CO-4	Analyze HVDC transmission, series and shunt compensation in power systems

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	1	3	2
CO-2	3	-	3	1	3	2
CO-3	3	-	3	1	3	2
CO-4	3	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Inverters for Induction Heating: Inverters for induction cooking, induction hardening, melting, and welding applications.

Power Converters for Lighting, pumping and refrigeration Systems: Electronic ballast, LED power drivers for indoor and outdoor applications. PFC based grid fed LED drivers, PV / battery fed LED drivers. PV fed power supplies for pumping/refrigeration Applications.

High Voltage Power Supplies - Power supplies for X-ray applications - power supplies for radar applications - power supplies for space applications.

Low Voltage High Current Power Supplies: Power converters for modern microprocessor and computer loads.

Bi-directional DC-DC (BDC) converters: Electric traction, Automotive Electronics, Battery charging converters, UPS and its applications, Line Conditioners and Solar Charge Controllers, Solar PV tracking.

HVDC & FACTS: Introduction, Comparison of DC and AC transmission, modern trends in DC transmission, HVDC with current source converter, converter characteristics, equivalent circuit of HVDC link, p.f. and reactive power of converters, HVDC with voltage source converters, modeling and control of voltage source converters, power exchange between two AC sources.

Power flow in AC systems, basic types of FACTS controllers, shunt and series controllers, overview of power converters used in FACTS controllers, methods of VAR generation, operating principle of STATCOM.

Learning Resources:

Text Books:

1. Abraham I. Pressman, Keith Billings &Taylor Morey, Switching Power Supply Design, McGraw Hill International, 2009, 3rd Edition.
2. Ali Emadi, A. Nasiri, and S. B. Bekiarov, Uninterruptible Power Supplies and Active Filters, CRC Press, 2004, 1st Edition.
3. NarainG.Honorani, Laszlo Gyugyi, Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press, 1999.

Reference Books:

1. Valery Rudnev, Don Loveless, Raymond L. Cook, Hand book of Induction Heating, CRC Press, 2017, 2nd Edition.
2. Steve Winder, Power Supplies for LED Driving, Newnes, 2016, 2nd Edition.
3. William Ribbens, Understanding Automotive Electronics: An Engineering Perspective, Butterworth-Heinemann, 2017, 8th Edition.
4. K.R. Padiyar, HVDC Power Transmission System, New Age Intl. Co, 2017. 3rd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113105102
2. https://archive.nptel.ac.in/courses/108/106/108106170/
3. https://archive.nptel.ac.in/courses/117/108/117108141/
4. https://nptel.ac.in/courses/108107114

EE16024 **3-0-0 (3)**

Simulation of Power Electronic Converters

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply numerical methods to develop simulation software for power electronic systems
CO-2	Carry out transient simulation for power electronic systems
CO-3	Apply switching functions to describe switching states of power converters
CO-4	Develop effective models for power electronic converters

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	1	3	2
CO-2	2	-	3	1	3	2
CO-3	3	-	3	1	3	2
CO-4	2	-	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Computation challenges - Simulation process - mechanics of simulation, Solution techniques for time domain analysis -Equation solvers, circuit-oriented simulators.

Simulation of Power Electronic Converters: MNA and ST Approaches- Nodal Analysis, Modified Nodal Analysis, Spare Tableau Approach, Nonlinear Circuits - Newton-Raphson Method, Computation Time, Convergence Issues, Non-linear Circuit Equations.

Transient Simulation: Introduction, Discretization of Time, Transient Analysis, Accuracy and Stability, Explicit and Implicit Schemes, Methods for Transient Simulation - FE, BE and TRZ, Transient Analysis in Circuit Simulation, Equivalent Circuit Approach: RC Circuit, Buck Converter; Some Practical Aspects: Undamped Oscillations, Ringing, Global Error in Switching Circuits, Round-off Error, Assessment of Accuracy, Singular Matrix Problem, Trapezoidal integration, M & N method for simulating power electronic converters (with buck converter as a representative example).

Switching Function: Introduction, Application of the switching function technique, Properties of the switching function, Voltage-Current relations in switched circuits - Single Switch, Parallel Switch. Pulse Width Modulation Modeling- Unipolar, PWM Signal of a composite function, bipolar square wave modulation, Mathematical Modeling of Buck Converter, Modeling using switching function-Buck converter, Rectifier, 3-phase VSI inverter, matrix converter, m-phase rectifier. PWM rectifier topologies.

Modeling of power electronic converters- PWM rectifier in different frames- abc, alpha-beta and d-q using switching function, Inverters.

Learning Resources:

Text Books:

1. M. B. Patil, V. Ramnarayanan, V.T. Ranganathan, Simulation of Power Electronic Converters, Narosa Publishers, 2010, 1st Edition.
2. P. M. De Russo, R. J. Roy, C. M. Close, Alan A. Desrochers, State Variables For Engineers, John Wiley, New York, 1998, 2nd Edition.

Reference Books:

1. N. Mohan, T.M. Undeland, W.P. Robbins, Power Electronics: Converters, Applications, John Wiley & Sons, 2009, 3rd Edition.
2. J. M. Smith, Mathematical modeling and digital simulation for engineers and scientists, John Wiley, New York, 1987, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/108/108108034/

EE16026 **3-0-0 (3)**

Control & Integration of Renewable Energy Sources

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand different renewable energy sources and storage devices
CO-2	Model and simulate renewable energy sources
CO-3	Analyze and simulate control strategies for grid-connected and off-grid systems
CO-4	Develop converters to comply with grid standards to obtain grid integration

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	2	3	3	2
CO-2	3	3	3	3	3	2
CO-3	3	3	3	3	3	2
CO-4	3	3	3	3	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Electric grid, Utility ideal features, Supply guarantee, power quality, Stability and cost; Importance & Effects of Renewable Energy penetration into the grid, Boundaries of the actual grid configuration, Consumption models and patterns.

Dynamic Energy Conversion Technologies: Introduction, types of conventional and nonconventional dynamic generation technologies, principle of operation and analysis of reciprocating engines, gas and micro turbines, hydro and wind-based generation technologies.

Static Energy Conversion Technologies: Introduction, types of conventional and nonconventional static generation technologies; Principle of operation and analysis of fuel cell, photovoltaic systems and wind generation technologies; MPPT techniques and its classifications, principle of operation and partial shading effects; Storage Technologies -batteries, fly wheels, super capacitors and ultra-capacitors.

Control Issues and Challenges: Linear and nonlinear controllers, predictive controllers and adaptive controllers, Load frequency and Voltage Control, PLL, Modulation Techniques, Control of Diesel, PV, wind and fuel cell-based generators, Dimensioning of filters, Fault-ride through Capabilities.

Integration of Energy Conversion Technologies: Introduction & importance, sizing, Optimized integrated systems, Interfacing requirements, Distributed versus Centralized Control, Grid connected Photovoltaic systems –classifications, operation, merits & demerits; Islanding Operations, stability and protection issues, load sharing, operation & control of hybrid energy systems, Solar Photovoltaic applications. IEEE & IEC codes and standards for renewable energy grid integrations.

Learning Resources:

Text Books:

1. G. Masters, Renewable and Efficient Electric Power Systems, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 2nd Edition.
2. A. Mahaboob Subahani, G. R. Kanagachidambaresan, M. Kathiresh, Integration of Renewable Energy Sources with Smart Grid, Willey 2021.
3. Felix A. Farret, M. Godoy Simoes, Integration of Renewable Sources of Energy, Wiley, 2017, 2nd Edition.

Reference Books:

1. Chetan Singh Solanki, Fundamentals, Technologies & Applications, Solar Photovoltaic, PHI Publishers, 2019, 3rd Edition.
2. Quing-Chang Zhong, Control of Power Inverters in Renewable Energy and Smart Grid Integration, IEEE-John Wiley and Sons Ltd. Publishers, 2013, 1st Edition.
3. Bin Wu, Yongqiang Lang, Navid Zargari, Power Conversion and Control of Wind Energy Systems, IEEE- John Wiley and Sons Ltd. Publishers, 2011, 1st Edition.
4. S. Chowdhury, S. P. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, IET Power Electronics Series, 2012.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/102/108102145/
2. https://nptel.ac.in/courses/103/103/103103206/

EE46024 **3-0-0 (3)**

Digital Control Systems

Pre-Requisites: **EE46001**

Course Outcomes:

CO-1	Model the discrete time (DT) system in state space form
CO-2	Perform the stability analysis for DT dynamical system
CO-3	Design the state feedback control for DT system
CO-4	Formulate and solve the DT optimal control problems

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	2	2	2	1
CO-2	2	-	3	2	2	1
CO-3	2	-	3	2	2	1
CO-4	2	-	3	2	2	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Continuous and Discrete time system-Digital control systems - Quantizing and quantization error, Sampling theorem.

Z-Transform: Z-transforms of elementary functions, important properties and theorems, Inverse Z-transform, Z-transform method of solving difference equations.

Z-Plane Analysis of Discrete-Time Control Systems: Impulse sampling and data hold, Pulse transfer function, Realization of digital controllers and digital filters, Mapping between s-plane and z-plane, Stability analysis of closed loop systems in z-plane, Transient and steady state analyses.

State Space Analysis of digital control systems: Solution of discrete time state space equations, Discretization of continuous time state space equations, Lyapunov stability analysis for Discrete linear system, Controllability, Observability, Pole Placement and Observer Design.

Discrete Optimal Control Systems: Linear Quadratic Regulator (LQR) Design via pole placement, Steady state quadratic optimal control.

Learning Resources:

Text Books:

1. K. Ogata, Discrete time control systems, Pearson Education India, 2015, 2nd Edition.
2. M. Gopal, Digital Control and State Variable Methods, McGraw Hill Education, 2017, 4th Edition.

Reference Books:

1. C.L. Phillips, H.T. Nagle, A. Chakrabortty, Digital Control System Analysis and Design, Pearson, 2014, 4th Edition.
2. B.C. Kuo, Digital Control Systems, Oxford University Press, 2012, 2nd Edition.
3. C.A. Rabbath, N. Lechevin, Discrete-Time Control System Design with Applications, Springer-Verlag New York Inc, 2014, 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108105186
2. https://nptel.ac.in/courses/108103008

EE16028 **3-0-0 (3)**

High Power Inverters

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze the Weighted THD and implement SVM based on instantaneous phase reference voltages
CO-2	Implement level-shifted, phase-shifted, hybrid and Space Vector PWM schemes for Cascaded H-Bridge Multilevel Inverters
CO-3	Develop PWM schemes to balance the neutral point, eliminate common mode voltage and reduce the switching power loss in diode clamped multilevel inverter
CO-4	Develop reduced switch count MLIs and PWM current source inverters

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	3	1	3	2
CO-2	3	-	3	1	3	2
CO-3	3	1	3	1	3	2
CO-4	3	1	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Review of two-level inverters and their PWM schemes. Effect of dead-time and compensation in two-level inverters. Limitations of two-level inverters and introduction to multilevel inverters. Conventional multilevel inverter topologies.

Diode clamped multilevel inverter (DCMLI): 3, 4 and 5 level DCMLIs, level-shifted PWM, Neutral point voltage balance, SVM and discontinuous SVM, Elimination of common mode voltage, Active Neutral Point Clamped Inverter (ANPCI).

Cascade H-bridge (CHB) multilevel inverter (MLI): Symmetrical and asymmetrical topologies, level-shifted PWM, phase-shifted PWM, hybrid PWM and SVM. Concept of coupling transformer-less grid connected applications, Topologies of modular multilevel inverters (MMI).

Reduced switch count MLIs: Introduction, classification, operation of T-type, multilevel dc link, switched series parallel source and other topologies.

PWM current source inverters: Trapezoidal modulation, selective harmonic elimination and SVM, Load-commutated inverters (LCI).

Learning Resources:

Text Books:

1. Bin Wu, High Power Converters and AC Drives, Wiley-Inter science, 2017, 2nd Edition.

2. D. Grahame Holmes, Thomas A. Lipo, Pulse Width Modulation for Power Converters: Principles and Practice, Wiley-IEEE Press, 2003.

Reference Books:

1. Research Publications.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/102/108102157/

EE16030 **3-0-0 (3)**

Power Converters for Microgrids

Pre-Requisites: **None**

Course Outcomes:

CO-1	Compare types of microgrid architectures and their standards.
CO-2	Modeling of power electronic converters in microgrid applications.
CO-3	Develop power converters and control techniques for micro grid applications.
CO-4	Evaluate dynamics and stability of microgrids.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	2	1	2	1
CO-2	1	1	3	1	3	2
CO-3	1	1	3	1	3	2
CO-4	1	1	3	1	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Micro-Grid: Power system resilience, The concept of micro-grids, Types of micro-grids, Autonomous and non- autonomous grids, Sizing of micro-grids, Microgrid Modeling & Analysis, Micro-grids with multiple DGs. Standards and regulation issues associated with AC & DC microgrids, Comparison between AC and DC Microgrids.

Microgrid Control: Centralized control, Hierarchical principle: Primary, secondary and tertiary control – Distributed control, Protection issues and Communication based techniques.

Modeling of Power Electronic Converters in Microgrid application: Modeling of voltage source PWM rectifier, modeling of voltage source inverter in current controlled mode and voltage controlled mode, modeling of boost DC-DC converter and its control, modeling of isolated bidirectional DC-DC converter and its control.

Microgrid Dynamics: Modeling of AC & DC microgrid and its dynamic studies.

Control of grid connected inverter in AC Microgrid: Basics of Voltage-frequency control and P-Q control in AC microgrid, control of grid-forming inverter, control of grid-feeding inverter, control of grid-supporting power inverter, synchronization of inverters in ac microgrids.

Control of DC-DC converter in DC Microgrid: Voltage control and power control in DC microgrid, control of parallel DC-DC converters in a DC microgrid.

Linear and nonlinear Stability system in AC & DC Microgrid: System models and stability analysis of AC & DC Microgrid, stabilization strategies-impedance and admittance stability criteria, stabilization using nonlinear techniques-feedback linearization and sliding mode control, intelligent control of microgrids-fuzzy logic control and ANN control. Future Perspectives.

Learning Resources:

Text Books:

1. Fusheng Li, Ruisheng Li, Fengquan Zhou, Microgrid Technology and Engineering Application, Elsevier, 2015.
2. Nikos Hatziargyriou, Microgrids Architectures and Control, John Wiley Sons, 2014.
3. Hassan Bevrani, BrunoFrançois, Toshifumi Ise, Microgrid Dynamics and Control, John Wiley Sons, 2017.

Reference Books:

1. Manuela Sechilariu, Fabrice Locment, Urban DC Microgrid: Intelligent Control and Power Flow Optimization, Butterworth-Heinemann, 2016.
2. Gevork B. Gharehpetian, S. Mohammad Mousavi Agah, Distributed Generation Systems: Design, Operation and Grid Integration, Butterworth Heinemann, 2017.
3. S. Chowdhury, P. Crossley, Microgrids and Active Distribution Networks, Institution of Engineering and Technology, 2009.
4. IEEE Transactions.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/107/108107143/

EE26030 **3-0-0 (3)**

Evolutionary Algorithms Application in Power Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discriminate the capabilities of bio-inspired system and conventional methods in solving optimization problems
CO-2	Examine the importance of exploration and exploitation of evolutionary algorithm to attain near global optimal solution
CO-3	Distinguish the functioning of various evolutionary algorithms
CO-4	Employ various bio-inspired algorithms for Power Engineering applications

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	1	1	1
CO-2	3	1	3	1	1	1
CO-3	3	1	3	1	2	1
CO-4	3	1	3	3	2	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Fundamentals Of Soft Computing Techniques- Definition-Classification of optimization problems- Unconstrained and Constrained optimization Optimality conditions- Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Single solution based and population based algorithms – Exploitation and exploration in population based algorithms - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems.

Genetic Algorithm and Particle Swarm Optimization-Genetic algorithms- Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators -Bird flocking and Fish Schooling – anatomy of a particle- equations based on velocity and positions -PSO topologies - control parameters – GA and PSO algorithms for solving ELD problem.

Artificial Bee Colony Algorithm and Differential Evolution - Artificial bee colony (ABC) algorithms-binary ABC algorithms – ACO and ABC algorithms for solving Economic Dispatch of thermal units. The Motivation for Differential Evolution (DE), Introduction to Parameter Optimization, Single-Point, Derivative-Based Optimization, Local Versus Global Optimization, Differential Mutation, Recombination, Selection, Benchmarking Differential Evolution, DE Versus Other Optimizers, DE on Parallel Processors.

Shuffled Frog-Leaping Algorithm and Bat Optimization Algorithm- Bat Algorithm- Echolocation of bats- Behaviour of microbats- Acoustics of Echolocation- Movement of Virtual Bats- Loudness and Pulse Emission- Shuffled frog algorithm-virtual population of frogs-comparison of memes and genes -memeplex formation- memeple updation- BA and SFLA algorithms for solving ELD and optimal placement and sizing

of the DG problem.

Multi Objective Optimization- Multi-Objective optimization Introduction- Concept of Pareto optimality - Non-dominant sorting technique-Pareto fronts-best compromise solution- min-max method-NSGA-II algorithm and applications – Control of Power Converters.

Learning Resources:

Text Books:

1. Xin-She Yang, Recent Advances in Swarm Intelligence and Evolutionary Computation, Springer International Publishing, Switzerland, 2015, 1st Edition.
2. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, John Wiley & Sons, 2001, 1st Edition.
3. Altaf Q. H. Badar, Evolutionary Optimization Algorithms, CRC Press, 2022.

Reference Books:

1. James Kennedy, Russel E Eberheart, Swarm Intelligence, The Morgan Kaufmann Series in Evolutionary Computation, 2001.
2. N P Padhy, Artificial Intelligence and Intelligent Systems, Oxford University Press, 2005.

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/112/103/112103301/

EE36028 **3-0-0 (3)**

Industrial Internet of Things

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand and evaluate the characteristics of Domestic & Industrial appliances
CO-2	Understand the behaviour of Industrial IoT and their applications
CO-3	Manage smart communication systems with multiple sensors and protocols
CO-4	Design and simulate smart homes and smart cities with IoTs and cloud computing

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	–	1	–	2	–
CO-2	3	1	2	–	1	–
CO-3	3	–	3	3	2	2
CO-4	3	2	3	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

IoT Communication Technologies: Introduction to IoT, Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications. Interoperability in IoT.

IoT Control Technologies and Programming: Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Internet of Things Open-Source Systems. Introduction to Python programming, Introduction to Raspberry. Implementation of IoT with Raspberry Pi, Smart Grid Hardware Security.

Domestic & Industrial Appliances: Solid State Lamps: Introduction - Review of Light sources - white light generation techniques-Characterization of LEDs for illumination application. Power LEDs- High brightness LEDs-Electrical and optical properties. LED driver considerations-Power management topologies -color issues of white LEDs- Dimming of LED sources, BLDC motors for pumping and domestic fan appliances, inverter technology-based home appliances, Smart devices and equipment. Industrial IoT applications- Factories and Assembly Line- Power Plants, Plant Safety and Security (Including AR and VR safety applications)- Oil and chemical Industry- Applications of UAVs in Industries.

IoT Cloud Computation and Applications: Introduction to SDN. SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor- Cloud. Fog Computing, Smart Cities and Smart Homes, Electric Vehicles, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring, Role of ML and AI in IoT.

Learning Resources:

Text Books:

1. Sudip Misra, Chandana Roy, Anandarup Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0, CRC press, 2021.
2. Kostas Siozios, Dimitrios Anagnostos, Dimitrios Soudris, Elias Kosmatopoulos, IoT for Smart Grids: Design Challenges and Paradigms, Springer publishers, 2019.

3. Vinod Kumar Khanna, Fundamentals of Solid-State Lighting: LEDs, OLEDs, and Their Applications in Illumination and Displays, CRC press, 2014, 1st Edition.

Reference Books:

1. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress Publishers, 2016.
2. Craig Di Louie, Advanced Lighting Controls: Energy Savings, Productivity, Technology and Applications, River publishers, 2006, e-book, 2021,1st Edition.
3. Chang-liang Xia, Permanent Magnet Brushless DC Motor Drives and Controls, John Wiley & Sons Singapore Pte. Ltd., 2012, 1st Edition.

Other Suggested Readings:

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

EE16032 **3-0-0 (3)**

Predictive Control of Power Converters and Drives

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop the mathematical models of predictive control for power converters and drives
CO-2	Design the predictive controller scheme for power converters and drives
CO-3	Optimize the cost function through analysis and simulation of power converters and drives
CO-4	Implement model predictive control schemes for electric drive systems

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	3	1	3	2
CO-2	2	1	3	1	3	2
CO-3	2	1	3	1	3	2
CO-4	2	1	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction and Classical Control Methods for Power Converters and Drives: Power converter control in the past, power converter control today, control requirements and challenges, digital control platforms, why predictive control is particularly suited for power electronics.

Model Predictive Control: Predictive control methods for power converters and drives, basic principles of model predictive control, model predictive control for power electronics and drives, controller design, implementation, general control scheme.

Predictive Control of a Three-Phase Inverter: Introduction, predictive current control, cost function converter model, load model, discrete-time model for prediction, working principle, implementation of the predictive control strategy, comparison to a classical control scheme, predictive control simulation of three-phase inverter

Predictive Control of a Three-Phase Neutral-Point Clamped Inverter: Introduction, system model, predictive current control method, implementation, reduction of the switching frequency, capacitor voltage balance.

Control of an Active Front-End Rectifier: Introduction, rectifier model, space vector model, discrete-time model, predictive current control in an active front-end, cost function, predictive power control, cost function and control scheme, predictive control of an ac – dc – ac, control of the inverter side, control of the rectifier side, control scheme.

Predictive Control of Induction Machines: Introduction, dynamic model of an induction machine, predictive torque control of an induction machine fed by a voltage source inverter, comparison to a classical control scheme, predictive control simulation – torque control of an induction machine fed by a two-level voltage source inverter.

Predictive Control of Permanent Magnet Synchronous Motors: Introduction, machine equations, discrete-time model of field-oriented control using predictive current control, and discrete-time model of predictive speed control, predictive control simulation – torque control of PMSM fed by a two-level voltage source inverter.

Design and Implementation issues of Model Predictive Control: Cost function selection, weighting factor design, cost function classification, weighting factors adjustment and examples.

Learning Resources:

Text Books:

1. Jose Rodriguez, Patricio Cortes, Predictive Control of Power Converters and Electrical Drives, Wiley-IEEE Press, 2012, 1st Edition.
2. Tobias Geyer, Model Predictive Control of High Power Converters and Industrial Drives, Wiley, 2016, 1st Edition.

Reference Books:

1. Adel Merabet, Advanced Control Systems for Electric Drives, Mdpi AG, 2020.
2. Yugeng Xi, Dewei Li, Predictive Control: Fundamentals and Developments, Wiley, 2019, 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/127/106/127106225/
2. https://onlinecourses.nptel.ac.in/noc21_ge01/preview

EE16034 **3-0-0 (3)**

Advanced Control Techniques for Power Converters

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand and analyze the different types of converter model and its usage
CO-2	Design the advanced PID controller with its fractional version and resonant controller for converters
CO-3	Design the robust controller for converter using the loop-shaping methods and the Sliding mode control
CO-4	Design the controller using fuzzy logic and AI techniques for converters and drives

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	2	1	3	2
CO-2	3	1	3	1	3	2
CO-3	2	1	3	1	3	2
CO-4	2	1	3	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Modeling of Power converters: Types of Models- Linearized Averaged models- Large signal and Small signal models- Switched models- Relation between various model types- Control goals in converter operation- Review of classical control methods.

Advanced PID controller: PID controller-Tuning methods of PID controller- Set point weighting- Integrator Windup- Controller degrees of freedom- Model based Design methods: Direct Synthesis (DS) method, Internal Model Control (IMC) method- Fractional Control System (FOS) -Design of Fractional PID controller- Case Study: PID controller design for DC-DC boost converter.

Resonant Controller: Necessity of resonant controller- Principle of Proportional Resonant (PR) control- Design methods of PR controller- Example of PR controller design for DC-DC boost converter.

Loop-shaping design: Concept of Loop shaping- Robust controller design using the loop shaping methods: H∞ Control, Quantitative feedback theory (QFT)- Case Study: Loop shaping methods to design the robust controller for DC-DC converter.

Sliding mode controller (SMC): Nonlinear control preliminaries-Types of Uncertainty-Sliding surface design- Stability of SMC- Equivalent control concept- Integral Sliding Mode Control (ISMC) design- Case study: Application of SMC to design the robust controller for DC-DC converter.

Fuzzy logic control and artificial Intelligence (AI) techniques: Introduction to fuzzy logic and AI techniques, application of fuzzy logic to power converters and electric drives, hardware system description, application of AI techniques to electric machines and drives.

Learning Resources:

Text Books:

1. S. Bacha, I. Munteanu, A.I. Bratcu, Power Electronic Converters Modeling and Control with Case Studies, Springer- Verlag London, 2014, 1st Edition.
2. L. Wang, S. Chai, D. Yoo, L. Gan, K. Ng, PID and Predictive Control of Electrical Drives and Power Converters using MATLAB/Simulink Wiley Press, 2015, 1st Edition.
3. A. Mehta, B. Naik, Sliding Mode Controllers for Power Electronic Converters, Springer Nature, 2019.

Reference Books:

1. C. Olalla, Ramon Leyva, I. Queinnec, Robust Linear Control of DC-DC Converters: A Practical Approach to the Synthesis of Robust Controllers, VDM Verlag- Dr. Muller, 2010, 1st Edition.
2. S-C. Tan, Y-M. Lai, C.K. Tse, Sliding Mode Control of Switching Power Converters: Techniques and Implementation, CRC Press, 2012, 1st Edition.
3. Freede Blaabjerg, Control of Power Electronic Converters and Systems, Academic Press, 2018. 1st Edition.
4. Q- C. Zhong,T. Hornik, Control of Power Inverters in Renewable Energy and Smart Grid Integration, Wiley Press, 2013, 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/103/108103007/
2. https://nptel.ac.in/courses/101/108/101108047/
3. http://web.mit.edu/nsl/www/videos/lectures.html
4. https://people.ee.ethz.ch/~apnoco/

EE26032 **3-0-0 (3)**

Machine Learning Applications in Power Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand basic concepts of Machine Learning Techniques
CO-2	Distinguish between supervised learning, unsupervised learning and reinforced learning
CO-3	Develop the skills in using machine learning software for solving practical problems
CO-4	Apply Machine Learning Algorithms for Electrical Engineering problems

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	1	1	1
CO-2	3	1	3	1	1	1
CO-3	3	1	3	3	2	1
CO-4	3	1	3	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Neural Networks: Introduction to Neural Networks, Models of Neuron Network, Architectures – Knowledge representation, Artificial Intelligence and Neural Networks – Learning Process, Error Correction Learning, Multi-layer perceptron using Back Propagation Algorithm (BPA)

Learning Theory: Introduction to Machine Learning: What is Learning – Learning Objectives – Data needed – Bayesian inference and Learning – Bayes theorem – inference – naïve Bayes – Regularization – Bias-Variance Decomposition and Trade-off – Concentration Inequalities – Generalization and Uniform Convergence – VC –dimension- Types of Learning- Supervised Learning – Unsupervised Learning and Reinforcement Learning.

Supervised Learning: Simple linear Regression – Multiple Linear Regression- Logistic Regression – Exponential Family and Generalized Linear Models- Generative Models: Gaussian Discriminate Analysis, Naïve Bayes – Kernal Method: Support Vector Machine (SVM) – Kernal function – Kernal SVM - Gaussian Process – Tree Ensembles: Decision Trees- Random Forests – Boosting and Gradient Boosting

Unsupervised Learning (Clustering): K –means Clustering Algorithm – Gaussian Mixture Model (GMM) – Expectation Maximization (EM) – Variational Auto Encoder (VAE) – Factor Analysis – Principle Components Analysis (PCA) – Independent Component Analysis (ICA)

Reinforcement Learning: Markov Decision Processes (MDP) – Bellman's Equations- Value Iteration and Policy Iteration - Value Function Approximation – Q – Learning

Applications of ML: Load Forecasting – Energy Market forecasting – Fault identification and localization – Renewable energy forecasting, Fault identification and localization – Renewable Uncertainty estimation. ML for solar power MPPT, False data injection attack detection, and Control of Power Converters.

Learning Resources:

Text Books:

1. Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2011.

2. E. Alpaydin, Machine Learning, MIT Press, 2010.
3. Anuradha Srinivasaraghavan, Vincy Joseph, Machine Learning, Wiley 2019, 1st Edition.

Reference Books:

1. Giuseppe Bonaccorso, Machine Learning Algorithms, Packt Publishing, 2018, 2nd Edition.
2. Tom M. Mitchell, Machine Learning, McGraw Hill International Edition, 1997.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc22_cs24
2. https://nptel.ac.in/courses/106106198

EE26036 **3-0-0 (3)**

Flexible AC Transmission Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the need for control of Real and Reactive power flows
CO-2	Identify the objectives of series and shunt compensation of power systems
CO-3	Analyse the performance of Series, Shunt and combined FACTS controllers
CO-4	Evaluate the performance and stability of power systems with FACTS controllers

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	-	1	1
CO-2	3	1	3	-	1	1
CO-3	3	3	3	-	1	1
CO-4	3	3	3	-	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Need for power system interconnections, Evolution of AC and DC transmission systems, Comparison of HVDC and HVAC Transmission systems, Power flow in AC systems, Relative importance of controllable parameters, Basic types of FACTS controllers, shunt and series controllers. Overview of power converters used in FACTS controllers.

Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, FC-TCR configurations, STATCOM, basic operating principle, control approaches and characteristics.

Objectives of series compensator, variable impedance type of series compensators, switching converter type compensators, TCSC, TSSC- operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating.

Static Phase Angle Regulators – power flow control by phase angle regulator and improvement of transient stability.

Introduction to Unified Power Flow Controller, Basic operating principles, Conventional control capabilities, Control structure of UPFC, Interline power flow controller.

Virtual and Synthetic Inertia: Introduction to virtual Synchronous machine, Virtual and synthetic Inertia. Estimating the inertia of traditional and RES power systems. Modeling of virtual and synthetic inertia for frequency control. Effects of fast acting storage units on fast frequency control of micro-grid.

Learning Resources:

Text Books:

1. Suman Bhowmick, Flexible AC Transmission Systems (FACTS), CRC Press, 2023, 1st Edition.
2. Yong Hua Song, Allan T Johns, Flexible AC Transmission Systems (FACTS), IEE power and energy series, 2008.
3. Narain G.Honorani, Laszlo Gyugyi, Understanding FACTS – Concepts and Technology of Flexible AC Transmission Systems, Wiley-IEEE Press, 1999.

Reference Books:

1. K.R. Padiyar, FACTS Controllers in Power Transmission and Distribution, New Age International Publishers, 2016.
2. R. Mohan Mathur, Rajiv K. Varma, Thyristor- Based FACTS controllers for electrical transmission systems, IEEE Press, 2002.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/107/108107114/
2. Prachal Jadeja, Vijay K Sood, “Synthetic/virtual Inertia in RES Grid, A Review”, IEEE explore, 2023.