VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ELECTRICAL ENGINEERING

M. Tech Power Electronics and Drives

(M.Tech PED)

Curriculum

(*2024-2025 admitted students*)

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

World class Education: Excellence in education, grounded in ethics and critical thinking, for improvement of life.

Cutting edge Research: An innovation ecosystem to extend knowledge and solve critical problems.

Impactful People: Happy, accountable, caring and effective workforce and students.

Rewarding Co-creations: Active collaboration with national & international industries & universities for productivity and economic development.

Service to Society: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF THE SCHOOL OF ELECTRICAL ENGINEERING

To offer an education that provides strong fundamental knowledge and skills for employability and creates leaders who provide technological solutions to societal and industrial problems.

MISSION STATEMENT OF THE SCHOOL OF ELECTRICAL ENGINEERING

- To prepare students with strong critical thinking and employability skills through personalized experiential learning.
- To create innovators and entrepreneurs by fostering design thinking, creativity and cross-disciplinary research.
- To generate advanced knowledge leading to the solution of societal and industrial problems.

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

M.Tech Power Electronics and Drives

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be engineering practitioners and leaders, who would help solve industry's technological problems.

2. Graduates will be engineering professionals, innovators or entrepreneurs engaged in technology development, technology deployment, or engineering system implementation in industry.

3. Graduates will function in their profession with social awareness and responsibility.

4. Graduates will interact with their peers in other disciplines in industry and society and contribute to the economic growth of the country.

5. Graduates will be successful in pursuing higher studies in engineering or management.

6. Graduates will pursue career paths in teaching or research.

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

M.Tech Power Electronics and Drives

PROGRAMME OUTCOMES (POs)

PO_01: Having an ability to apply mathematics and science in engineering applications

PO_02: Having an ability to design a component or a product applying all the relevant standards and with realistic constraints

PO_03: Having an ability to design and conduct experiments, as well as to analyze and interpret data

PO_04: Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice

PO_05: Having problem solving ability- solving social issues and engineering problems

PO_06: Having adaptive thinking and adaptability

PO_07: Having a clear understanding of professional and ethical responsibility

PO_08: Having a good cognitive load management [discriminate and filter the available data] skills

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

M.Tech Power Electronics and Drives

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Power Electronics and Drives) programme, graduates will be able to

- PSO1: Apply technical knowledge, skills and analytical ability to design, develop and test power electronic converters and drives using modern tools and technologies.

- PSO2: Solve the real world problems in the emerging fields like smart grid, renewable energy interfaces, and electric vehicles and to develop innovative technologies relevant to social, ethical, economic and environmental issues

- PSO3: Solve research gaps and provide solutions to socio-economic, and environmental problems.

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

M.Tech Power Electronics and Drives

CREDIT STRUCTURE

Category-wise Credit distribution

NEW CREDIT STRUCTURE	CREDITS
Core Courses	**24**
Discipline Elective Courses **(3 Credits/Elective Course)**	**12**
Open Elective Courses	3
Skill Enhansement courses 1. Technical report writing-2 2. Qualitative Skills Practice -1.5 3. Quantitative Skills Practice- 1.5	5
Project/ Internship 1. Study oriented project-2 2. Design Project-2 3. Internship/Dissertation I-10 4. Internship/Dissertation II-12	26
Total Graded Credit Requirement	70

M.Tech Power Electronics and Drives
DETAILED CURRICULUM

Discipline Core

S.No.	Course Code	Course Title	L	T	P	C
1	MPED502L	Analysis of Power Converters	3	0	0	3
	MPED502P	Analysis of Power Converters Lab	0	0	2	1
2	MPED508L	Switch Mode Power Conversion	2	0	0	2
3	MPED509L	Electric Drives and Control	3	0	0	3
4	MPED507L	Advanced Processors for Power Converters	3	0	0	3
	MPED507P	Advanced Processors for Power Converters Lab	0	0	2	1
5	MPED505L	Industrial Electrical Drives	3	0	0	3
	MPED505P	Industrial Electrical Drives Lab	0	0	2	1
6	MPED501L	Advanced Semiconductor Devices	3	0	0	3
7	MPED510L	Embedded Systems Design for Power Electronic Applications	3	0	0	3
	MPED510P	Embedded Systems Design for Power Electronic Applications Lab	0	0	2	1
Total Credits						**24**

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Discipline Elective

S.No.	Course Code	Course Title	L	T	P	C
1	MPED622L	Industrial IoT	3	0	0	3
2	MPED623L	Battery Management System	3	0	0	3
3	MPED613L	Intelligent Learning Techniques	3	0	0	3
4	MPED614L	Smart Microgrids	3	0	0	3
5	MPED615L	EMI and EMC in Power Converters	3	0	0	3
6	MPED603L	Energy Storage Systems	3	0	0	3
7	MPED616L	Intelligent and Connected Vehicles	3	0	0	3
8	MPED617L	Solar Photovoltaic Conversion System	3	0	0	0
9	MPED606L	Wind Energy Conversion System	3	0	0	3
10	MPED619L	FPGA for Power Electronic Converters	3	0	0	3
11	MPED618L	Application of Power Electronics to Power System	3	0	0	3
12	MPED620L	Real-Time Interface for Power Converters	2	0	0	2
	MPED620P	Real-Time Interface for Power Converters Lab	0	0	2	1
13	MPED621L	Control System Design	3	0	0	3
14	MPED612L	Hybrid and Electric Vehicles	3	0	0	3

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Curriculum (Semester wise Breakup)

Semester-1	Category	L	T	P	C
Analysis of Power Converters	DC-1	3	0	0	**3**
Analysis of Power Converters Lab	DC-1L	0	0	2	**1**
Advanced Semiconductor Devices	DC-6	3	0	0	**3**
Electric Drives and Control	DC-3	3	0	0	**3**
Advanced Processors for Power Converters	DC-4	3	0	0	**3**
Advanced Processors for Power Converters Lab	DC-4L	0	0	2	**1**
DisciplineElective-1	DE-1	3	0	0	**3**
Technical Report Writing	Core				**2**
Qualitative Skills Practice	Core				**1.5**
Study Oriented Project	Core				**2**
Total Credits (Semester-1)					**22.5**

Semester-2	Category	L	T	P	C
Switch Mode Power Supplies	DC-5	2	0	0	2
Industrial Electric Drives	DC-6	3	0	0	3
Industrial Electric Drives Lab	DC-6 L	0	0	2	1
Embedded Systems Design for Power Electronic Applications	DC-7	3	0	0	3
Embedded Systems Design for Power Electronic Applications Lab	DC-7L	0	0	2	1
Discipline Elective-2	DE-2	3	0	0	3
Discipline Elective-3	DE-3	3	0	0	3
Discipline Elective-4	DE-4	3	0	0	3
OpenElective-1/Discipline Elective-5	OE-1/DE-5	3	0	0	3
Quantitative Skills practice	Core				1.5

Design Project	Core				2
Total Credits (Semester-2)					**25.5**

Semester-3	Category	Credits
Internship-I/Dissertation-I	Project/Internship	**10**

Semester-4	Category	Credits
Internship-II/Dissertation-II	Project/Internship	**12**

Discipline Core

Course code	Course Title		L	T	P	C
MPED502L	**Analysis of Power Converters**		3	0	0	3
Pre-requisite	NIL	**Syllabus version**				
		1.0				

Course Objectives

1. To give a systematic approach for transient and steady state analysis of power electronic converters with passive and active loads.
2. Analyze the advanced converters such as multi-level inverters and compare different PWM techniques for their control.

Expected Course Outcome

On the completion of this course the student will be able to

1. Understand the working principle and analyse the different types single phase controlled rectifiers.
2. Understand the working principle and analyse the different types three phase controlled rectifiers.
3. Analyse and design the different configurations of DC-DC converters.
4. Classify various types of Inverters and Examine the harmonics.
5. Simulate the various types of power electronic converters.

Module:1	Single phase controlled rectifier	7 hours

Single Phase AC to DC controlled converter configurations: Semi-converter and Fully controlled converter with R, RL, RLE load; Continuous and discontinuous conduction mode; Analysis of supply side power factor and power factor improvement techniques; Effect of source inductance; Dual converter

Module:2	Three phase controlled rectifier	8 hours

Three Phase AC to DC controlled converters configurations: Semi-converter and Fully controlled converter with R, RL, RLE load; Continuous and discontinuous conduction mode; Harmonic analysis; Effect of source inductance; Design of converters: Multi-quadrant converter; Multi-pulse converter

Module:3	DC-DC converters	7 hours

Basic Configurations: Type A chopper and Type B chopper; Two quadrant Chopper; Control strategies; Multi-port and interleaved converters; Synchronous converters; Design of DC-DC converter; Multi-quadrant choppers and On-board Chargers

Module:4	DC-AC inverters	9 hours

Single phase Voltage Source Inverter (VSI) and Current Source Inverter (CSI); Three phase VSI and CSI: 120° and 180° modes of operation; Design of Inverters; PWM technique: Sine PWM; Multilevel Inverters: Types, voltage control and applications; Harmonic spectrum: THD analysis and Harmonic mitigation techniques; Filter design; Device selections

Module:5	AC voltage controllers	6 hours

Single phase and three phase voltage regulators; R and RL load, range of control; Design of AC Voltage Controller Circuits; Single phase cycloconverters: Types and operating principle		
Module:6	**Artificial Intelligence to power converters**	**6 hours**
Artificial intelligence and machine learning for power electronics; Power Converter Design using AI, Cybersecurity requirements; Reliability predictions and health monitoring in power converters; Optimization of control loops, and Preventative Maintenance		
Module:7	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Mode of Evaluation: CAT / Assignment / Quiz / FAT		

Text Book(s)

1.	Rashid M.H., "Power Electronics-Circuits, Devices and Applications", Prentice Hall India, New Delhi, 2017.
2.	Ned Mohan, Tore M. Undeland, "Power Electronics – Converters, Applications and Design", John Wiley & Sons, 2008.

Reference Books

1.	Joseph Vithayathil, "Power Electronics – Principles and Applications", Tata McGraw-Hill edition, 2010.
2.	Bin Wu, Mehdi Narimani, "High-Power Converters and AC Drives", John Wiley & Sons, 2017.
3.	William Shepherd and Li Zhang, "Power Converter Circuits", Marcel Dekker Inc, New York, 2004.
4.	S. Zhao, F. Blaabjerg and H. Wang, "An overview of artificial intelligence applications for power electronics", *IEEE Trans. Power Electron.*, vol. 36, no. 4, pp. 4633-4658, Apr. 2021.

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Course Code	Course Title		L	T	P	C
MPED502P	**Analysis of Power Converters Lab**		0	0	2	1
Pre-requisite	**Nil**	**Syllabus version**				
		1.0				

Course Objectives

1. To acquire knowledge on the design of power converters and implement using simulation and hardware.

Expected Course Outcome

On the completion of this course the student will be able to

1. Ability to simulate the power electronic converter topologies
2. Ability to fabricate the various types of power electronic converters

Indicative Experiments		**hours**
1.	Implementation of driver circuits for power switching devices (SCR/MOSFET/IGBT)	2 hours
2.	Losses and thermal estimation of power converters	2 hours
3.	Switching characteristics and driver circuits for wide band gap devices	2 hours
4.	Performance analysis of Single-phase controlled AC-DC one-pulse converter	2 hours
5.	Performance analysis of Single-phase controlled AC-DC two-pulse converter (R, RL-Load)	2 hours
6.	Performance analysis of Three-phase controlled AC-DC six-pulse converter (R, RL-Load)	2 hours
7.	Performance analysis of AC-AC voltage regulator	2 hours
8.	Performance analysis of AC-AC cyclo-converter	2 hours
9.	Voltage control of Single-phase inverter- R, RL load	2 hours
10.	Implementation of Three-phase inverter- R load	2 hours
11.	Duty ratio-controlled DC-DC converters (Buck, Boost, Buck-Boost)	2 hours
12.	Implementation of Multi quadrant chopper	2 hours
13.	PWM control of DC-AC inverters	2 hours
14.	Harmonic mitigation techniques for VSI	2 hours
15.	Power factor correction circuit	2 hours
	Total Laboratory Hours:	**30 hours**

Textbook(s)

1.	Rashid M.H., “Power Electronics-Circuits, Devices and Applications”, Prentice Hall India, New Delhi, 2017.

2.	Ned Mohan, Tore M. Undeland, "Power Electronics – Converters, Applications and Design", John Wiley & Sons, 2008.
Reference Books	
1.	Joseph Vithayathil, "Power Electronics – Principles and Applications", Tata McGraw-Hill edition, 2010.
2.	Bin Wu, Mehdi Narimani, "High-Power Converters and AC Drives", John Wiley & Sons, 2017.

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023industrial

VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED508L	Switch Mode Power Conversion	2	0	0	2
Pre-requisite	MPED502L, MPED502P	Syllabus version			
		1.0			

Course Objectives

1. To acquire knowledge on switch mode power conversion concepts.
2. Design and develop appropriate switched mode power supplies for particular application.

Expected Course Outcome

On the completion of this course the student will be able to

1. Analyse different non isolated DC-DC converters for steady-state operation.
2. Develop circuit models for different dc –dc converters
3. Compare isolated and non-isolated dc-dc converters
4. Design passive components of dc-dc converters
5. Analyse Resonant converters and its applications
6. Build dynamic and small signal model of switched mode power converters.

Module:1	Non-Isolated DC-DC converters	5 hours

Steady state analysis: ideal Buck, Boost, Buck – Boost and Cuk Converters (CCM and DCM), operating principles, constituent elements, characteristics, comparisons and selection criteria.

Module:2	Modelling and Analysis of Non-Isolated converters	4 hours

Steady state analysis: non-ideal Buck, Boost, Buck–Boost and Cuk Converters, losses and efficiency

Module:3	Isolated converters	4 hours

Significance of isolated converters; Steady State Analysis: Forward Converter, Fly-back Converter, Push pull, Half and full bridge Converter

Module:4	Design of passive components	4 hours

Design of high frequency Inductor, transformer and capacitors for SMPS application; Input filter design

Module:5	Dynamic Analysis and Control of Switching Converters	5 hours

AC equivalent circuit modelling of converters: dynamic equation of buck, boost and buck- boost converters; Small signal model and converter transfer functions; Control of converters; voltage and current mode control; PWM controller Integrated circuits, Sliding Mode Control Implementation: Buck, Boost and Buck-Boost Converters

Module:6	Resonant Converters	3 hours

Classification: Series resonant circuit-parallel resonant circuits; Resonant switches; Zero voltage switching and Zero current switching; Soft switched bidirectional dual active bridge converters.

Module:7	Applications of SMPC	3 hours

Power Factor Correction in Switching Power Supplies: Low Input SMPS for Laptop Computers and

Portable Electronic devices, EV charging systems; Case studies: SMPC simulation using open source tools		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**30 hours**
Mode of Evaluation: CAT / Assignment / Quiz / FAT		

Textbook(s)			
1.	Robert W. Erickson and Dragan Maksimovic, "Fundamentals of Power Electronics", Springer, 3rd edition, 2020.		
2.	Simon Ang, Alejandro Oliva, "Power-Switching Converters", CRC Press, Vol. No., 3rd Edition, 2010.		
Reference Books			
1.	Philip T Krein, "Elements of Power Electronics ", Oxford University Press, 2nd Edition, 2017.		
2.	Ned Mohan, Undeland and Robbin, "Power Electronics 3ed (An Indian Adaptation): converters, Application and design" Wiley India Pvt Ltd, 3rd Edition, 2022.		
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title		L	T	P	C
MPED509L	Electric Drives and Control		3	0	0	3
Pre-requisite	NIL	Syllabus version				
		1.0				

Course Objectives

1. To introduce basic concepts of load and drive interaction, speed control concepts of DC and AC drives, speed reversal, regenerative braking aspects, design methodology

Course Outcome

On the completion of this course the student will be able to:

1. Describe the drives dynamics and identify the suitable power converter ratings
2. Classify the different types of DC drives and construct its controller.
3. Classify the different types of AC drives and construct its controller.
4. Design and Conduct experiments, as well as analyse and interpret data

Module:1	Energy Conversion and Drive Dynamics	6 hours

Electromechanical energy conversion, single and multiple excited systems, torque and force expression. Types of loads, Multi quadrant operation, Moment of inertia, Torque and power for rotational and linear motion loads; Selection of motor power rating: Classes of duty, thermal model-heating and cooling.

Module:2	Selection of Converters	6 hours

Direct Converters, Converters with Intermediate Circuit, Voltage source converters – two-level and three-level, Current source converter. Converter rating from motor specification and load curves. Factors for drive selection: overload capacity, control range, derating factor, efficiency. Selection of DC-DC and DC-AC power converter components: switch, driver circuit, capacitor, inductor, rectifier, heat sink.

Module:3	Control of DC Motor Drive	8 hours

Factors governing speed and torque of DC motors, constant torque and constant power operation, Controlled rectifier fed DC drive, Single phase semi-controlled and fully-controlled converter drives. Three phase semi-controlled and fully-controlled converter drives. Multi-quadrant operation with fully-controlled converter. Chopper controlled DC drive; Series motor and Shunt motor. Chopper fed speed control: Open loop and Closed loop control, four quadrant operations. Soft Starting, braking and regenerative controls of DC drive.

Module:4	Modelling of AC Machines	8 hours

Asynchronous Machine: Equivalent circuit model, dynamic d-q model, axes transformation, synchronously rotating reference frame—dynamic model (Kron equation), stationary frame, dynamic model (Stanley equation), dynamic model state-space equations. Synchronous machine: Equivalent circuit, developed torque, salient pole machine characteristics, dynamic d^e-q^e machine model (Park model)

Module:5	Control of Asynchronous Machine Drives	8 hours

Characteristics and equivalent circuit of poly-phase induction motor, voltage source inverter control, current source inverter control. Stator side speed control: Stator voltage control, variable frequency control, V/f control, open-loop and closed loop control. Soft starting methods, braking -plugging - dynamic braking - regenerative braking. Torque and power limitations. Rotor side speed control: Static

rotor resistance control, Kramer’s drive, Scherbius drive, doubly fed induction motor drive – modes of operation, eddy current drives.		
Module:6	**Control of Synchronous Machine Drives**	**7 hours**
Wound field synchronous and salient pole machine drives –Steady state behaviour, brushed and brush less DC excitation, Separate control mode; Self-Control Mode; Power factor control; Marginal angle control. Open loop V/f control.		
Module:7	**Contemporary Topics**	**2 hours**
	Total Lecture hours:	**45 hours**

Textbook(s)

1.	Gopal K Dubey, “Fundamentals of Electrical Drives”, CRC Press, Second Edition, 2015
2.	Bimal K Bose, “Modern Power Electronics and AC Drives”, Pearson Education Asia, 2012

Reference Books

1.	R. Krishnan, Electric Motor Drives: Modelling, Analysis, and Control, 2015, Second edition, Pearson Education India.
2.	T.A. Lipo, Analysis of Synchronous Machines, CRC Press, 2017
3.	Krause, Paul C., Wasynczuk, Oleg, Sudhoff, Scott D, Analysis of Electric Machinery and Drive Systems (IEEE Press Series on Power Engineering), 3rd Edition - 13 August 2013.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Course code	Course Title	L	T	P	C
MPED507L	Advanced Processors for Power Converters	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. Introducing ARM Processor and DSP controller
2. Overview of resources available in ARM Processor and DSP-controller
3. Overview of programming frame work, software building blocks and Interrupt structures, Event manager, and compare unit

Course Outcome

On the completion of this course the student will be able to:

1. Use the Timers and PWM to generate triggering pulses for power electronic circuits
2. Experiment with the exceptions of ARM processor to vary the triggering pulses for power electronic circuits
3. Apply digital signal processing in ARM processor
4. Experiment with the peripherals of DSP processor for power electronics applications
5. Design and Conduct experiments, as well as analyze and interpret data

Module:1	ARM Processors	5 hours

Arm processor architecture and pipelining; programmer's model; data paths and instruction decoding; Advanced Microcontroller Bus architecture; ARM instruction set; addressing modes; General Purpose Input and Output (GPIO); Analog to Digital Converter; Digital to Analog Converter; Simple programming

Module:2	Timers and PWM	6 hours

Different modes of operation of Timers; Match Registers; Generation of PWM using Compare registers; Capture Control; Single and Double Edge Controlled PWM; programming to generate triggering pulses for power converters.

Module:3	Component Interfacing and Networks	6 hours

System Control; RTC, Watch Dog Timer, USB 2.0 Full-Speed device controller with DMA, Communication interface; UART, I2C Bus Serial Interface, SPI, SSP Serial Interfaces

Module:4	Exception and Interrupt Handling	6 hours

Exception handling overview; Interrupts; Interrupt Handling Schemes; External Interrupt, Timer Interrupt, PWM Interrupt, ADC Interrupt; Utility of interrupts in closed loop control of a real time system; programming.

Module:5	Digital Signal Processer	9 hours

Basic architecture; System configuration registers; Memory addressing mode; Interrupt handling; Instruction set; Programming Concepts; Simple programs. General purpose Input/Output (GPIO) Functionality; Utilization of GPIO in PWM signal generation; PWM signal generation for inverters.

Module:6	Digital Signal Processing with ARM	6 hours

Representing a Digital Signal; Introduction to DSP on the ARM; Industry needs from the digital implementation perspective on the processors.		
Module:7	**DSP Peripherals & Real Time Digital Signal Processing**	**5 hours**
A/D converter; Event Managers (EVA, EVB); Interrupts; Sample Based Processing; Frame Based Processing; Basic Buffer Structures; Usage of Buffers in Frame-Based Processing; Overlap Methods for Frame-Based Processing		
Module:8	**Contemporary issues**	**2 Hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Andrew N.Sloss, Dominic Symes, Chris Wright, "ARM System Developer's Guide Designing and Optimizing System Software" Morgan Kaufmann Publishers, 2011.
2.	Hamid A. Toliyat, Steven Campbell, "DSP based electromechanical motion control", CRC press, New York, Washington Dc, 2012.
Reference Books	
1.	William Hohl, Christopher Hinds "ARM Assembly Language – Fundamentals and Techniques" Second Edition, CRC Press Taylor & Francis Group 2015.
2.	Ata Elahi, Trevor Arjeski "ARM Assembly Language with Hardware Experiments", Springer 2015

Mode of Evaluation**:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test			
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Course Code	Course Title	L	T	P	C
MPED507P	Advanced Processors for Power Converters Lab	0	0	2	1
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. Use the resources available with ARM and DSP controller to generate control signals for power converters

Expected Course Outcome

On the completion of this course the student will be able to

1. Design and Conduct experiments, as well as analyze and interpret data.

Indicative Experiments		hours
1.	Generating Control signal for obtaining variable duty cycle.	2 hours
2.	Obtaining pulse width modulated signal from a saw tooth and DC signal.	2 hours
3.	Processor based control of a single phase half-wave controlled converter	2 hours
4.	Single phase single quadrant DC-DC converter and its control.	2 hours
5.	Control of a single phase single quadrant bridge type AC-DC converter.	2 hours
6.	Single phase two quadrant AC-DC converter controlled through ARM processor.	2 hours
7.	Using ADC of ARM to control the speed of DC motor	2 hours
8.	Using the communication protocol of ARM to remotely control the speed of static drives	2 hours
9.	ARM processor based control of a residential UPS.	2 hours
10.	Digital control of high power industrial inverter.	2 hours
11.	Control of three phase AC voltage controller	2 hours
12.	Single phase step down cyclo-converter and its control.	2 hours
13.	Using exceptions of ARM to have variable voltage and frequency (v/f) drive	2 hours
14.	DSP based implementation of PWM techniques to control an inverter.	2 hours
15.	Control of single phase half controlled converter using DSP processor	2 hours
16.	Control of chopper circuit in TRC and variable frequency method	2 hours
	Total Laboratory Hours:	**30 hours**

Textbook(s)	
1.	Andrew N.Sloss, Dominic Symes, Chris Wright, “ARM System Developer’s Guide Designing and Optimizing System Software” Morgan Kaufmann Publishers, 2011.
2.	Hamid A. Toliyat, Steven Campbell, ”DSP based electromechanical motion control”, CRC press, New York, Washington Dc, 2012.
Reference Books	
1.	William Hohl, Christopher Hinds “ARM Assembly Language – Fundamentals and Techniques” Second Edition, CRC Press Taylor & Francis Group 2015.
2.	Ata Elahi, Trevor Arjeski “ARM Assembly Language with Hardware Experiments”, Springer 2015,

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2024

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED505L	Industrial Electrical Drives	3	0	0	3
Pre-requisite	MPED509L	Syllabus version			
		1.0			

Course Objectives

1. To understand various speed control strategies of industrial AC drives with and without speed sensors.
2. To investigate EMI and harmonics issues on motor drives and to provide solution for mitigating

Expected Course Outcome

On the completion of this course, the student will be able to:

1. Design and develop FOC and DTC for IM and PMSM drives
2. Develop speed sensorless control strategies for IM and PMSM drives
3. Understand the industrial drive features and standards
4. Analyse the effects of EMI and harmonics on the performance of the motor drives
5. Design and conduct experiments, as well as analyze and interpret data

Module:1	Vector Control of Induction Motor Drive	7 hours

Principle of field oriented control (FOC), steady state equivalent circuit, decoupling circuits in rotor-flux oriented reference frame. Direct FOC; flux vector estimation-voltage model and current model. Indirect FOC.

Module:2	Direct Torque and Flux Control of Induction Motor Drive	9 hours

Principle of direct torque and flux control (DTC), torque expression with stator and rotor fluxes, flux and torque hysteresis bands, voltage vector switching tables for DTC, space vector pulse width modulation for DTC.

Module:3	Synchronous Motor Drives	9 hours

Sinusoidal permanent magnet synchronous machine (PMSM) drives; surface permanent magnet and interior permanent magnet machines. FOC constant d-axis current control. FOC flux weakening mode; maximum torque per ampere (MPTA) control, maximum power factor control. Direct torque control for PMSM.

Module:4	Sensorless Control of AC Machines	8 hours

Principle of sensorless FOC and DTC for induction motor and synchronous motor drive. Sensorless startup methods: V/f control, I-f control, high-frequency component injection control. Sensorless speed estimation schemes for IM; slip calculation, model reference adaptive system, flux observer, extended Kalman filter. Sensorless speed estimation schemes for PMSM; terminal voltage and current sensing.

Module:5	Industrial Drive Features and Standards	6 hours

Self commissioning of drives; parameter estimation, automatic motor adaption. Cascaded and multi-motor drive control. Drive DC bus pre-charging, Drive protections; pulse overlap, over current, over voltage, thermal. Drive functional safety features. Drive interfaces; sensors interfacing, human-machine interface (HMI), drive condition monitoring. Communication systems; wired and wireless. Industrial communication protocols and standards.		
Module:6	**Electromagnetic Interference and Harmonics Effects**	**4 hours**
Introduction to EMI and EMC, EMC for power converters, grounding and shielding, EMC classes and standards. Introduction to harmonics, harmonic measurement techniques, reduction methods-mitigation tools, selective harmonic elimination for medium voltage drives - active damping of LCL filters.		
Module:7	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar		

Textbook(s)	
1.	Bimal K Bose, “Modern Power Electronics and AC Drives”, Pearson Education Asia, 2012.
2.	Peter Vas “Sensorless Vector and Direct Torque Control”, Monographs in Electrical and Electronic Engineering, 09 July 1998.
Reference Books	
1.	R. Krishnan, Permanent Magnet Synchronous and Brushless DC Motor Drives, Second edition, Pearson Education India, 2015.
2.	R. Raja Singh, Energy Conservation Strategies for Asynchronous Machine Drives, Lap Lambert Academic Publishing, Germany, 2021..
3.	Danfoss Handbook on VLT Frequency Converters, "Facts Worth Knowing about Frequency Converters", PE-MSMBM Publications, 2014.
4.	Sunit Kumar Sen “Fieldbus and Networking in Process Automation” CRC Press, 2017

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Course Code	Course Title	L	T	P	C
MPED505P	**Industrial Electrical Drives Lab**	0	0	2	1
Pre-requisite	MPED509L	Syllabus version			
		1.0			

Course Objectives

1. To understand the performance of Electrical drives experimentally under various operating conditions.
2. To implement the various speed control strategies for electric drives

Expected Course Outcome

On the completion of this course the student will be able to

1. To design and conduct experiments, as well as analyse and interpret data.

Indicative Experiments		Hours
1.	Design and speed control of AC-to-DC converter fed DC motor drive	2 hours
2.	Design and speed control of DC-to-DC converter fed DC motor drive	2 hours
3.	Design and speed control of DC motor drive with four quadrant operation	2 hours
4.	Design and control AC-to-AC regulator fed induction motor drive	2 hours
5.	Mathematical model development and testing of IM in Matlab	2 hours
6.	Mathematical model development and testing of PMSM in Matlab	2 hours
7.	Closed loop speed control of DC Motor drive using FPGA/ Microcontroller	2 hours
8.	Automatic motor adaption for IM/ PMSM using Danfoss drive	2 hours
9.	V/f based speed control of IM/ PMSM using Danfoss drive	2 hours
10.	VVC+ based speed control of IM/ PMSM using Danfoss drive	2 hours
11.	Field-oriented control of induction motor drive using FPGA/ Microcontroller	2 hours
12.	Speed sensorless control of induction motor drive using FPGA/ Microcontroller	2 hours
13.	Regenerative loading of IM using Danfoss drive	2 hours
14.	Regenerative loading of PMSM using Danfoss drive	2 hours
15.	Speed control of slip ring induction motor using slip power recovery schemes	2 hours
16.	Speed control of PMSM drive using FPGA/ Microcontroller	2 hours

17.	Torque control of PMSM drive using FPGA/ Microcontroller	2 hours
18.	Speed Sensorless control of PMSM or IM using Danfoss drive	2 hours
19.	Performance analysis of DFIM using FPGA/ Microcontroller	2 hours
20.	Analysis of drive power using power quality analyser	2 hours
	Total Laboratory Hours:	**30 hours**

Textbook(s)			
1.	Bimal K Bose, “Modern Power Electronics and AC Drives”, Pearson Education Asia, 2012.		
2.	Peter Vas “Sensorless Vector and Direct Torque Control”, Monographs in Electrical and Electronic Engineering, 09 July 1998.		
Reference Books			
1.	R. Krishnan, Permanent Magnet Synchronous and Brushless DC Motor Drives, 2015, Second edition, Pearson Education India.		
2.	R. Raja Singh, Energy Conservation Strategies for Asynchronous Machine Drives, Lap Lambert Academic Publishing, Germany, 2021.		
3.	Danfoss Handbook on VLT Frequency Converters, "Facts Worth Knowing about Frequency Converters", PE-MSMBM Publications, 2014		
4.	Sunit Kumar Sen “Fieldbus and Networking in Process Automation” CRC Press, 2017		
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED501L	Advanced Semiconductor Devices	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To make the students understand the importance of appropriate devices selection based on the application requirements.
3. Understand the various power semiconductor device characteristics and significance of gate drive and protection circuits

Expected Course Outcome

On the completion of this course the student will be able to

1. Identify and categorize power electronic switches based on its rating and appropriate device selection suitable for application
2. Examine and classify various power semiconductor switching characteristics and summarize the voltage, current controlled devices
3. Analyze the characteristics of new emerging power semiconductor devices.
4. Design appropriate protection circuits to overcome problems associated with power electronic circuits.

Module:1	Semiconductor device selection	6 hours

Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – Safe Operating Area, Device selection strategy – On

Module:2	Power diodes	5 hours

Structure, operating principle, switching characteristics, types, forward and reverse characteristics, device datasheet, simulation of power diode characteristics

Module:3	Thyristors	6 hours

Physics of operation, Two transistor analogy – concept of latching; Gate and switching characteristics; converter grade and inverter grade and other types; series and parallel operation– steady state and dynamic models of Thyristor, simulation of power thyristor characteristics

Module:4	Power Transistors	6 hours

Construction, static characteristics, physics of operation, switching characteristics; Negative temperature co-efficient and secondary breakdown – Power Darlington- Safe operating regions, dynamic models of BJT, comparison of BJT and Thyristor, simulation of power transistor characteristics

Module:5	Power MOSFETs and IGBTs	7 hours

Principle of voltage controlled devices, construction, inversion layer significance, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs, simulation of power MOSFET, IGBT characteristics		
Module:6	**Emerging Power Devices:**	**7 hours**
Smart power devices, Intelligent Power Modules. Silicon Carbide Devices, Wide band gap devices - Vertical and lateral structures - Turn-on and Turn-off characteristics of the device, device datasheet		
Module:7	**Gate Driving and Protection:**	**6 hours**
Isolation circuits, pulse transformer, opto-coupler – Gate drives circuit - semiconductor devices and wide bandgap power devices; Design of snubbers; Thermal management; heat sink – selection, types and mounting types, simulation of gate drive circuits		
Module:8	**Contemporary issues/ Spectrum of applications**	**2 hours**
	Total Lecture hours:	**45 hours**
Mode of Evaluation: CAT / Assignment / Quiz / FAT / Project / Seminar		

Text Book(s)	
1.	Ned Mohan, Tore M. Undeland, “Power Electronics – Converters, Applications and Design”, John Wiley & Sons, 3rd edition 2007.
2.	Rashid M.H., "Power Electronics: Circuits, Devices and Applications ", Pearson Education, 4th edition June 2014.
Reference Books	
1.	F. Wang, Z. Zhang and E. A. Jones, Characterization of Wide Bandgap Power Semiconductor Devices, IET, ISBN-13: 978-1785614910 (2018)
2.	B. J. Baliga, “Gallium Nitride and Silicon Carbide Power Devices,” World Scientific Publishing Company (3 Feb. 2017).

Recommended by Board of Studies	**30-10-2023**		
Approved by Academic Council	No. 72	Date	**13-12-2023**

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED510L	**Embedded Systems Design for Power Electronic Applications**	**3**	**0**	**0**	**3**
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives

1. Introducing embedded system concepts and to emphasize the significance of the same for power electronics engineer
2. To write Embedded C program to control the power converters
3. Overview of resources available in ARM cortex processor
4. To create a closed loop control of drives using embedded systems

Expected Course Outcome

On the completion of this course the student will be able to

1. Write embedded C programs to generate triggering pulses for the power converters
2. Control the power converter circuits using different on chip peripherals available in ARM processor
3. Explain functional overview of ARM cortex M processor
4. Write program for ARM cortex M processor to control the power electronic circuits using timers
5. Write program for ARM cortex M processor to use the interrupts to vary the real time parameter.

Module:1	Introduction to Embedded System:	5 hours

Embedded system processor; hardware unit; software embedded into a system; Example of an embedded system; Embedded Design life cycle; Layers of Embedded Systems; significance of embedded system in Power Electronic applications.

Module:2	Embedded System Building Process	5 hours

Preprocessing; Compiling, Cross Compiling, Linking; Locating; Compiler Driver; Linker Map Files; Linker Scripts and scatter loading; Loading on the target; Embedded File System, Pre-Processor directives; Structures and Unions; Enumeration Pointers; Scope of Variables; Embedded C programming for power converter applications

Module:3	Communication protocol	6 hours

Overview of BSP; SCI; Ethernet; CAN; LIN; flexray; MOST; SCADA; significance in power applications.

Module:4	Real Time Operating System	7 hours

OS Dependent functionalities – Resource management – RTOS vs General purpose OS. Kernel Architecture and Functionalities (Task management, Process Scheduling, Resource management (Semaphores and Mutex), Task Synchronization. Embedded software development Life cycle. Structure of C compiler, code optimization.

Module:5	**Introduction to ARM Cortex M processor**	**7 hours**
Functional overview of ARM Cortex M; Pinouts and pin description, GPIOs; System configuration controller (SYSCFG), ADC, DAC, Programming		
Module:6	**ARM Cortex M processor: Timers and PWM**	**7 hours**
Basic Timers (TIM6 and TIM7); General Purpose Timers (TIM2 to TIM5); General Purpose Timers (TIM9 to TIM14); Advanced Control Timers (TIM1 and TIM8); Independent Watchdog (IWDG); Window Watchdog (WWDG); Programming to generate triggering pulses with timers and modelling the Pulse Width Modulator (PWM) etc		
Module:7	**ARM Cortex M processor: Interrupts and Events**	**6 hours**
Nested Vectored Interrupt Controller (NVIC); External Interrupt/ Event Controller (EXTI), EXTI Registers; Closed loop control of power converters with interrupt.		
Module:8	**Lecture by industry experts**	**2 hours**
	Total Lecture hours:	**45 hours**

Textbook(s)

1.	Dr. Yifeng Zhu, "Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C" Fourth edition E-Man Press LLC, 2023
2.	Wayne Wolf "Computers as components : Principles of Embedded Computing System Design",The Morgan Kaufmann Series in Computer Architecture and Design,2017

Reference Books

1.	Joseph Yiu, "The Definitive Guide to ARM Cortex M3 and Cortex M4 Processors" Newnes, Elsevier, 2014
2.	Carl Hamacher, Zvonko Vranesic, Safwat Zaky, Naraig Manjikian, "Computer Organization and Embedded Systems", Mc Grawhill International Edition, 2012
3.	Shibu K.V, "Introduction to Embedded Systems", Tata Mc Grawhill, 2014
4.	Vincent Mahout, "Assembly Language Programming ARM Cortex M3" Wiley 2012
5.	Larry D. Pyeatt, "Modern Assembly Language Programming with the ARM Processor", Newnes, Elsevier 2016

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED510P	**Embedded Systems Design for Power Electronic Applications Lab**	**0**	**0**	**2**	**1**
Pre-requisite	**Nil**	**Syllabus version**			
		1.0			

Course Objectives

1. Use the resources available with ARM cortex M microcontroller to generate control signals for power converters
2. Use the external signals to manipulate the control signals

Expected Course Outcome

On the completion of this course the student will be able to

1. Design and Conduct experiments, as well as analyze and interpret data to control the power electronic circuits.

Indicative Experiments		hours
1.	Embedded C programming to control the chopper	2 hours
2.	Embedded C programming for controlling the converters	2 hours
3.	Embedded C programming to generate triggering pulses for inverters	2 hours
4.	Embedded C programming for generating triggering pulses to control AC voltage regulators	2 hours
5.	Embedded C programming to step up and step down the frequency using cycloconverters	2 hours
6.	Embedded C programming which generates PWM pulses for chopper	2 hours
7.	Embedded C programming to use external interrupt to vary the duty ratio of chopper	2 hours
8.	Embedded C programming which uses timer interrupt and external interrupt to generate triggering pulses for variable frequency inverter.	2 hours
9.	Embedded C programming to generate sine PWM using PWM interrupt	2 hours
10.	Embedded C programming for controlling the speed of DC motor using ADC interrupt.	2 hours
11.	Embedded C programming to interface the UART of ARM Processor	2 hours
12.	Embedded C programming for interfacing multiple sensors with ARM processor through I2C protocol	2 hours
13.	Embedded C programming to connect different processors through CAN protocol	2 hours

14.	Embedded C programming for interfacing SPI	2 hours
15.	Embedded C programming which can have a closed loop control of DC motor	2 hours
	Total Laboratory Hours:	**30 hours**

Textbook(s)	
1.	Dr. Yifeng Zhu, “Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C” Fourth edition E-Man Press LLC, 2023
2.	Wayne Wolf “Computers as components : Principles of Embedded Computing System Design”,The Morgan Kaufmann Series in Computer Architecture and Design,2017
Reference Books	
1.	Joseph Yiu, “The Definitive Guide to ARM Cortex M3 and Cortex M4 Processors” Newnes, Elsevier, 2014
2.	Carl Hamacher, Zvonko Vranesic, Safwat Zaky, Naraig Manjikian, “Computer Organization and Embedded Systems”, Mc Grawhill International Edition, 2012
3.	Shibu K.V, “Introduction to Embedded Systems”, Tata Mc Grawhill, 2014
4.	Vincent Mahout, “Assembly Language Programming ARM Cortex M3” Wiley 2012
5.	Larry D. Pyeatt, “Modern Assembly Language Programming with the ARM Processor”, Newnes, Elsevier 2016

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Discipline Electives

Course code	Course Title	L	T	P	C
MPED622L	Industrial IoT	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. Introducing Industrial IoT and its Architectural models
2. Overview of sensors, data analytics along with communication and networking in Industrial IoT
3. Familiarize with the concepts of edge and fog computing, security and various application domains of Industrial IoT

Course Outcome

At the end of the course, the student will be able to

1. Understand the Industry 4.0 details along with Industrial IoT models and layers
2. Comprehend IIoT sensing, processing , communication, networking insights
3. Interpret the edge and fog computing benefits in IIoT applications
4. Identify IoT security and privacy issues, data encryption, access control, and device authentication
5. Analyze the industrial applications and other areas of technology of IIoT use cases.

Module:1	Introduction to Industrial Internet of Things	3 hours

Various industrial revolutions, Role of Industrial Internet of Things in industry, Industry 4.0 revolutions, support system for Industry 4.0

Module:2	Industrial IoT- Models and Layers	3 hours

Industrial IoT models: Business Model and Reference Architecture; Industrial IoT Layers: IIoT Sensing - sensors and actuators, IIoT Processing, IIoT Communication, IIoT Networking

Module:3	Big Data and Advanced Analytics	8 hours

Data collection and management: data collection methods including sensors, gateways, and other devices collecting, storing and managing large amounts of data; **Data preprocessing:** cleaning, transforming, and preparing data for analysis, missing data, outliers, and anomalies handling. **Descriptive analytics:** summarizing and visualizing data, including statistical methods, charts, and graphs. **Predictive analytics:** regression analysis, time-series analysis, and machine learning algorithms. **Prescriptive analytics:** optimization algorithms and decision trees

Module:4	Industrial Communication and Networking	9 hours

IIoT Data Communications protocols: OPC UA, MQTT, CoAP; Data transfer methods: Request/Response, Publish/Subscribe; Industrial **Ethernet Networks** types: PROFINET, EtherNet/IP, Modbus TCP, Ethernet network design and implementation considerations, Ethernet network communication protocols and standards: TCP/IP, UDP, Ethernet/IP; **Wireless Networks**

for IIoT: Wi-Fi, Bluetooth, Zigbee, 5G, Wireless network design and implementation considerations, Wireless network communication protocols and standards: MQTT, CoAP, LoRaWAN		
Module:5	**Edge and Fog computing**	**6 hours**
Edge Computing architectures and components: Edge Devices, Edge Gateways; Edge Computing benefits for IIoT applications, Edge Computing platforms; Fog computing in industrial IoT		
Module:6	**IIoT Security**	**8 hours**
Cybersecurity and the modular architecture in IIoT, **Threats to IIoT Systems**: cyber-attacks, physical attacks, and insider threats**; Security Frameworks**: NIST, ISA-99, and IEC 62443 to secure IIoT systems; Encryption and Authentication, public-key cryptography, digital signatures, and certificate authorities; Security Monitoring and Incident Response, intrusion detection and prevention systems; Physical Security, access control, video surveillance and environmental controls.		
Module:7	**Application domains**	**6 hours**
Power plants, smart grid, healthcare, inventory management and quality control, UAVs in Industries, plant safety and security (AR and VR safety applications), facility management, and smart factories.		
Module:8	**Lecture by industry experts**	**2 hours**
	Total Lecture hours:	**45 hours**

Textbook(s)	
1.	Industry 4.0: The Industrial Internet of Things, Alasdair Gilchrist, Apress Berkeley, CA, 2017.
2.	Industrial Internet of Things: Cybermanufacturing Systems, Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat, Springer, 1st ed. 2017 edition
Reference Books	
1.	Data Analytics in the Era of the Industrial Internet of Things, Aldo Dagnino, Springer Nature Switzerland AG 2021.
2.	Industrial Wireless Sensor Networks: Applications, Protocols, and Standards (Industrial Electronics), Gerhard P. Hancke, V. Cagri Gungoer, CRC Press Inc, 1st edition, 2013.
3.	Edge Computing: Fundamentals, Advances and Applications (Advances in Industry 4.0 and Machine Learning), D. Dharani, G. Sudha Sadasivam, K. Anitha Kumari, M. Niranjanamurthy , Taylor & Francis Ltd; 1st edition, 2022.
4.	A Beginner's Guide to Internet of Things Security Attacks, Applications, Authentication, and Fundamentals, B. B. Gupta, Aakanksha Tewari, Taylor & Francis Group, 2020.

Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test			
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Course code	Course Title	L	T	P	C
MPED623L	Battery Management System	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To introduce learners with the concepts of batteries, its parameters and Battery management system requirements.
2. To impart basic modeling and requirements of batteries
3. To develop classical and intelligent algorithms for BMS

Course Outcome

At the end of the course, the student will be able to

1. Comprehend the various battery terminologies and definitions and to recognize the requirements of Battery Management System
2. Develop the mathematical model of a battery using empirical equations
3. Describe the concepts associated with cell balancing techniques and to calculate the various parameters of battery like SoC and SoH
4. To recognize the requirements of Battery Management System and to understand the various classical control methods deployed in BMS
5. Apply the machine learning concepts to control the BMS

Module:1	Battery storage systems	5 hours

Batteries, Cells, modules; Battery terminologies; Nominal voltage and capacity, C rate, Energy and power; Cells connected in series; Cells connected in parallel; Electrochemical and lithium-ion cells; Rechargeable cell; Charging and Discharging Process; Overcharge and Undercharge; Modes of Charging.

Module:2	Mathematical modelling of battery	4 hours

Equivalent circuit models (ECMs); Physics-based models (PBMs); Empirical modelling approach; Battery pack modelling; Life time: Effect of operating temperature on service life, Life cycle, reliability concerns.

Module:3	Battery Management System Requirements:	7 hours

Fundamentals of BMS functionality; Battery pack topology; Sensors interface; High-voltage contactor control; Isolation sensing; Thermal control; Protection- Communication Interface; Range estimation from electric vehicle aspect.

Module:4	Battery Cell balancing Techniques:	8 hours

Cell Balancing; Causes of imbalance; Circuits for balancing; Active and passive cell balancing; Design requirements for balancing circuits; Energy balancing with multiple battery packs.

Module:5	**Battery State of Charge and State of Health Estimation**	**5 hours**
Battery state of charge (SOC) estimation; Voltage-based methods to estimate SOC; Model-based state estimation; Intelligent methods of SoC estimation; Battery Health Estimation; Lithium-ion aging; Beginning of Life and End of Life range estimation; Condition monitoring of health using artificial neural network.		
Module:6	**Classical Control Techniques in Battery Management**	**7 hours**
Control techniques in BMS; Model Predictive Control; Adaptive control; State machine based control; Nonlinear control; Implementation challenges		
Module:7	**Intelligent Control Techniques in Battery Management**	**7 hours**
Rule based control ; Machine learning based supervisory control ;Fuzzy based Control ;Optimization based control ; Energy Efficient control schemes		
Module:8	**Lecture by industry experts**	**2 hours**
	Total Lecture hours:	**45**

Textbook(s)			
1.	Plett, Gregory L. Battery management systems, Volume I: Battery modeling. Artech House, 2015.		
2.	Plett, Gregory L. Battery management systems, Volume II: Equivalent-circuit methods. Artech House, 2015.		
Reference Books			
1.	Davide Andrea,” Battery Management Systems for Large Lithium-ion Battery Packs” Artech House, 2010		
2.	Pop, Valer, et al. Battery management systems: Accurate state-of-charge indication for battery-powered applications. Vol. 9. Springer Science & Business Media, 2008.		
3.	Bergveld, H.J., Kruijt, W.S., Notten, P.H.L “Battery Management Systems -Design by Modelling” Philips Research Book Series 2002.		
Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test			
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Course Code	Course Title		L	T	P	C
MPED613L	Intelligent Learning Techniques		3	0	0	3
Pre-requisite	NIL	Syllabus version				
		1.0				

Course Objectives

1. Overview of intelligent learning techniques intended for power electronic applications
2. Design and development of learning algorithms
3. Develop suitable intelligent algorithms for power electronics and drives

Expected Course Outcome

On the completion of this course the student will be able to:

1. Understand the nuances of machine learning and its implementation procedures
2. Apply supervised and unsupervised learning methods for solving the engineering problems
3. Assess the various machine learning methods and its detailed algorithms
4. Analyse the optimization methods for real time applications
5. Demonstrate intelligent techniques for real time applications pertaining to power electronics and drives

Module: 1	Artificial Neural Network	6 hours

Mathematical model of a neuron; Neuron models: Single / multi-inputs; Activation functions; Network Architecture; Perceptron; Linear separability.

Module: 2	Supervised & Unsupervised learning	6 hours

Multilayer perceptron; Back propagation algorithm; Radial basis function network; Dimensionality reduction: Linear discriminant analysis – Principal component analysis; K means algorithm.

Module: 3	Machine learning	6 hours

Types of machine learning; Supervised learning: Regression – Classification; The machine learning Process; Testing machine learning algorithms; Turning data into probabilities;The Naive Bayes classifier; Basic Statistics and Probability.

Module:4	Probabilistic learning and SVM	6 hours

Gaussian Mixture Models; Nearest Neighbour Methods. Support vector machines: Optimal separation; Kernels; SVM algorithm ; Extensions of SVM.

Module:5	Reinforcement and Evolutionary Learning	8 hours

Reinforcement learning: Overview; Markov decision processes; Values; The difference between SARSA and Q-learning; Uses of reinforcement learning. Evolutionary Learning: Genetic Algorithm; Genetic operators; Genetic programming.

Module: 6	Ensemble learning and learning with trees	5 hours

Ensemble learning: Boosting; Bagging; Random Forests; different ways to combine classifiers. Constructing decision trees; Classification and Regression Trees (CART).			
Module:7	**Intelligent controller design case studies**		**6 hours**
ANN based maximum power point tracking for solar PV system; ANN based harmonic elimination technique in an inverter; Health monitoring and failure analysis of power conditioning systems using machine learning; Machine learning techniques for electrical drives.			
Module:8	**Contemporary issues**		**2 hours**
		Total Lecture hours:	**45 hours**
Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test			
Text Book(s)			
1.	Stephen Marsland, "Machine Learning – An Algorithmic Perspective", 2nd Edition, Chapman and Hall / CRC Machine Learning and pattern Recognition Series, 2014.		
2.	Hagan, Martin T., Howard B. Demuth, and Mark Beale. "Neural network design", PWS Publishing Co., 1997.		
Reference Books			
1.	Tom M. Mitchell, "Machine Learning", 1st Edition, McGraw-Hill Education, India, 2013.		
2.	Shai Shalev-Shwartz and Shai Ben-David, "Understanding Machine Learning: From Theory to Algorithms", 1st Edition, Cambridge University Press, USA, 2014.		
3.	Saikat Dutt, Subramanian Chandramouli, Amit Kumar Das, "Machine Learning",1st edition, Pearson Education, 2019.		
4.	Nguyen, Prasad, Walker, and Walker, "A First Course in Fuzzy and Neural Control", Chapman Hall /CRC Press, 2003.		

Recommended by Board of Studies	**30-10-2023**		
Approved by Academic Council	No.72	Date	**13-12-2023**

Course Code	Course Title		L	T	P	C
MPED614L	Smart Microgrids		3	0	0	3
Pre-requisite	NIL	Syllabus version				
		1.0				

Course Objectives

1. Design modern control technologies for microgrids in islanded and grid connected operation.
2. Understand the concepts for communication in microgrid.
3. To understand the Design, and management of microgrid.
4. To understand the smart microgrid technologies and infrastructural requirements.
5. Model and Analyze the behavior of dynamic microgrids.
6. Evaluate different communication schemes between microgrids.

Expected Course Outcome

On the completion of this course the student will be able to:

1. Understand the concepts of microgrids, and networked microgrids
2. Analyze the influence of smart technologies on microgrids.
3. Understand centralized control and distributed control in microgrids, especially primary, secondary and tertiary control.
4. Understand the key technical threat types, communication protocols, and resilient smart grid architectures.
5. Understand the power quality issues associated with grid integrated microgrids

Module:1	Microgrid Configurations and Smart Grid Introduction	8 hours

Components of Microgrid; CERTS Microgrid Test Bed; Hybrid DC and AC Coupled Microgrid; Grid Connected Mode; Islanded mode; Battery Charging mode; Evolution of Electric Grid, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, National and International Initiatives in Smart Grid

Module:2	Microgrid Control Techniques Processing	7 hours

Mathematical model of microgrid; Impact of load characteristics; Hierarchical control: Primary, secondary and tertiary control; Local control; Centralized Control; Decentralized Control; Distributed control; PQ Control; Droop control methods; Frequency/Voltage Control; Inverter Output Impedance.

Module:3	Smart grid technologies	8 hours

Technology Drivers, Smart energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control, Distribution systems: DMS, Volt/VAR control, Fault Detection, Isolation and service

restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plugin Hybrid Electric Vehicles(PHEV).		
Module:4	**Smart meters and advanced metering infrastructure**	**8 hours**
Introduction ton Smart Meters, Advanced Metering infrastructure(AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit(PMU), Intelligent Electronic Devices(IED)&their application for monitoring & protection.		
Module:5	**Power quality management in smart grid**	**6 hours**
Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.		
Module:6	**High performance computing for smart grid applications**	**6 hours**
Local Area Network(LAN),House Area Network(HAN), Wide Area Network(WAN), Broad band over Power line(BPL),IP based Protocols, Basics of Web Service and CLOUD Computing to make Smart Grids smarter, Cyber Security for Smart Grid.		
Module:7	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test		

Text Book(s)

1.	Hasan Bevrani, Bruno FranÃ§ois and ToshifumiIse,(2017) “Microgrid Dynamics and Control” Wiley Press
2.	J. A. Momoh, “Smart Grid: Fundamentals of Design and Analysis” Wiley India, 1st Edition, 2015

Reference Books

1.	S. Bahrami, and A. Mohammadi. *Smart microgrids*. Springer Nature Switzerland AG: Springer International Publishing, 2019.
2.	B. Singh, A. Chandra, and K. Al-Haddad: Power Quality: Problems and Mitigation Techniques, Wiley, 2015, 1st Edition

Recommended by Board of Studies	**30-10-2023**		
Approved by Academic Council	No.72	Date	**13-12-2023**

Course Code	Course Title	L	T	P	C
MPED615L	EMI and EMC in Power Converters	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To introduce the vital role of EMI/EMC in power electronic circuits
2. To get better clarity of the EMI coupling mechanism and impact on power converters
3. To acquire the knowledge on mitigating the EMI and improve the EMC
4. To produce the power converters as per different EMI standards

Expected Course Outcome

On the completion of this course the student will be able to:

1. Understand the basics of EMI and EMC and its typical environment
2. Get the difference classifications on EMI and EMC
3. Identify the EMI coupling mechanism and its victim
4. Analyze the different EMI standards to be followed when designing power converters for different applications
5. Design the LISN and EMI filter for measuring and mitigating the EMI
6. Apply the soft switching, random switching, and chaotic switching techniques to power converters for improved EMC operation
7. Understand the EMI test setup and measurement methods
8. Apply the concepts in virtual experimentation

Module:1	Fundamentals of EMC/EMI:	6 hours

Introduction to EMI and EMC; Typical EMI environment; Sources and Victims of EMI; Conducted and Radiated EMI emission and Susceptibility; Case Histories; Radiation hazards to humans; EMC Testing categories.

Module:2	EMI coupling principles:	6 hours

Electromagnetic field Coupling paths, coupling via the supply network; Common mode coupling; Differential mode coupling; Impedance coupling; Inductive and Capacitive coupling; Radiative coupling; Ground loop coupling, and Automotive transients.

Module:3	EMI/EMC standards and regulations:	6 hours

Need for Standards; Generic/General Standards for Residential and Industrial environment; National and International EMI Standardizing Organizations: IEC, ANSI, FCC, AS/NZS, CISPR, BSI, CENELEC, ACEC, Military standards-MIL461E/462, Medical standards, and Automotive standards.

Module:4	**EMI in power converters:**	**5 hours**
EMI phenomena in power switching devices; conducted EMI in power semiconductors; EMI in rectifier circuits; EMI in fast switching converters; EMI in inverter circuits; EMI in power supplies; EMI in motor drives; Broad band noise; Narrow band noise; Radiation from PCB boards.		
Module:5	**EMI measurement and testing:**	**8 hours**
EMI test shielded chamber and shielded ferrite lined anechoic chamber; Line Impedance Stabilization Networks (LISN); Conducted emission test setup; EMI receiver, and Spectrum analyzer; Pre-compliance immunity Test; Conducted emission test; Radiated emission test.		
Module:6	**EMI mitigation techniques:**	**6 hours**
EM Shielding; Grounding: Filters; Soft switching; Random modulation and Chaotic PWM technique.		
Module:7	**EMI modeling and simulation:**	**6 hours**
EMC/EMI Modelling Techniques and Applications; Virtual EMC Lab; EMI mitigation algorithm and Programming.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**
Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test		

Text Book(s)

1.	David A.weston "Electromagnetic compatibility", CRC press, Third edition, 2017.
2.	Henry W. Ott, "Electromagnetic Compatibility Engineering", John Wiley & Sons Inc, New York, 2009.
3.	Bogdan Adamczyk "Foundation of Electromagnetic Compatibility with practical applications", John wiley& sons, First edition,2017

Reference Books

1.	Laszio Tihanyi "Electromagnetic Compatibility in Power Electronics", IEEE Press 1995.
2.	V. Prasad Kodali, Engineering Electromagnetic Compatibility: Principles, Measurements, Technologies, and Computer Models, 2nd Edition, Wiley-IEEE Press, 2001.
3.	Dr Kenneth L Kaiser, "The Electromagnetic Compatibility Handbook", CRC Press 2005.
4.	Paul, C.R., "Introduction to Electromagnetic Compatibility", 2nd ed., Wiley (2010).
5.	Hong Li, ZhongLi,Bo Zhang, Wallace K.S. Tang and Wolfgang A. Halang "Suppressing Electromagnetic interference in Direct current converters" IEEE circuits and system Magazine, 2009.

Recommended by Board of Studies	**30-10-2023**		
Approved by Academic Council	No.72	Date	**13-12-2023**

Course code	Course Title	L	T	P	C
MPED603L	**Energy Storage Systems**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To understand different types of Energy Storages.
2. To describe basic physics, chemistry, and engineering issues of energy storage devices, such as batteries, thermoelectric converters, fuel cells, supercapacitors.
3. To design energy storage systems for different applications.

Course Outcome

the end of the course the student will be able to

1. Identify different energy storage techniques and recent trends.
2. Compare different battery technologies and its characteristics.
3. Analyze fuel cells, supercapacitors and its applications.
4. Discuss the applications of energy storage in PV.

Module:1	Energy Storage	7 hours

Mechanical, electrical and chemical energy storage systems and its applications; Available energy; Energy analysis: Second law efficiency; Helmholtz & Gibb's function; Recent trends in energy storage systems; Energy market policy

Module:2	Classical Battery	7 hours

Basic concepts; Battery performance: charging and discharging, storage density, energy density and safety issues; Modelling of batteries

Module:3	Modern batteries	7 hours

Zinc-air, Nickel hydride, Lithium battery; State of charge; Technology challenges

Module:4	Super capacitors	7 hours

Super capacitors; Types of electrodes and electrolytes; Electrode materials: high surface area activated carbons, metal oxide and conducting polymers; Electrolyte: aqueous or organic, disadvantages and advantages of super capacitors; Modelling of super capacitors; Application of super capacitors

Module:5	Fuel cells	8 hours

Fuel cells; Direct energy conversion; Modelling of Fuel Cells, maximum intrinsic efficiency of an

electrochemical converter; Physical interpretation; Carnot efficiency factor in electrochemical energy converters; Types of fuel cells: hydrogen oxygen cells, hydrogen air cell, alkaline fuel cell and phosphoric fuel cell		
Module:6	**Energy Storage Applications**	**7 hours**
Application of Power Electronics Converters in Energy Storage Systems; Standalone photovoltaic systems; Grid connected systems; Power smoothing, grid ancillary services, energy management case studies and simulation		
Module:7	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Yves Brunet, “Energy Storage", Wiley-ISTE, 1st Edition, 2010.
2.	Robert A. Huggins, “Energy Storage”, Springer, 2nd Edition, 2015.

Reference Books

1.	Andrei G. Ter-Gazarian, "Energy storage systems for Power systems", 2nd edition, IET 2011.
2.	R M. Dell, D.A.J. Rand, "Understanding Batteries" RSC Publications, 1st edition, 2012.
3.	Tetsuya Osaka, Madhav Datta, “Energy Storage Systems in Electronics-New Trends in Electrochemical Technology”, CRC Press, 2000.

Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023

Course Code	Course Title		L	T	P	C
MPED616L	Intelligent and Connected Vehicles		3	0	0	3
Pre-requisite	MPED612L	Syllabus version				
		2.0				

Course Objectives

1. To provide knowledge on autonomous and connected vehicle technology
2. To create awareness about self-driving and remote controlled vehicles

Course Outcome

On the completion of this course the student will be able to:

1. Understand the requirements for connected vehicles
2. Describe the sensor and wireless sensor systems for connected and autonomous vehicles
3. Develop intelligent vehicle systems for path planning and motion control
4. Evaluate advanced driver assistance systems for self-driving cars
5. Comprehend safety and security standards for autonomous and connected vehicles

Module:1	Connected cars	8 hours

Manual and Automatic Transmission, Regulations, IoV Standards, Short and long range connectivity technology, Communication Architectures, Connectivity technology: Deployment challenges, Potential benefits- Connectivity Fundamentals, Navigation and Other Applications, Vehicle-to-Vehicle (V2V), Vehicle-to-Roadside (V2R), Vehicle-to-Infrastructure (V2

Module:2	Sensor systems	8 hours

Principles and Characteristics of Sensor Hardware: Cameras, RADAR, LIDAR, Ultrasonic SONAR, Sensor Suites : Overview and Functionality, Actuation and Propulsion Hardware, Sensor Fusion: Model, Architecture, Sensor Interactions, Applications

Module:3	Vehicle Intelligence and Control	7 hours

Digital Twin Technology, Electronic Control Unit (ECU), Collaborative Adaptive Cruise Control (CACC), Intelligent Traffic Signals, Automotive Open System Architecture (AutoSAR), Reliability

Module:4	Path Planning and Motion Control	6 hours

Path Planning Objectives, Structured Environments, Unstructured Environments, Behavioral Decision-Making, Trajectory Planning, Motion Control, End-to-End Automated Driving

Module:5	Safety and Security Standards	6 hours

Verification and Validation, Design and Development methods, Test and Validation methodology, Operational safety metrics , Evaluation criteria			
Module:6	**Advanced Driver Assistance Systems**		**4 Hours**
Basic System Operation, Applications – Legacy, New, & Future, Integration into Vehicle Electronics, System Examples , Role of Data Fusion , Model Construction – Point Cloud, Failure Modes and Self Calibration			
Module:7	**Self driving cars**		**4 hours**
Driverless Vehicle Technology, Artificial Intelligence and Deep Learning techniques, Implementation Issues			
Module:8	**Contemporary Topics**		**2 hours**
	Total Lecture hours:		**45 hours**
Text Book(s)			
1	Jeffrey Wishart; Yan Chen; Steven Como; Narayanan Kidambi; Duo Lu; Yezhou Yang, "Fundamentals of Connected and Automated Vehicles," SAE Internatinal, 2022.		
2	Nicu Bizon Lucian Dascalescu and Naser Mahdavi Tabatabaei, "Autonomous Vehicles: Intelligent Transport Systems and Smart Technologies', Nova publishers, New York 2012,		
Reference Books			
1	Dimitrakopoulos, Aggelos Tsakanikas, Elias Panagiotopoulos, George "Autonomous Vehicles: Technologies, Regulations, and Societal Impacts" , 1st Edition – April 14, 2021, Elsevier.		
2.	Hod Lipson , Melba Kurmanr, "Driverless: Intelligent Cars and the Road Ahead (MIT Press) 1St Edition, September 23, 2016		
3.	Herrmann, Walter Brenner, Andreas, Rupert Stadler, "Autonomous Driving: How the Driverless Revolution will Change the World", Emerald Publishing Limited, 26 March 2018		
Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test			
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED617L	Solar Photo Voltaic Conversion Systems	3	0	0	3
Pre-requisite	MPED502L, MPED502P	Syllabus version			
		1.0			

Course Objectives

1. To understand the importance and applications of Solar Energy
2. To make them acquainted with power electronic interface circuits for Solar Energy

Course Outcome

the end of the course the student will be able to

1. Apply new techniques for estimation of solar PV cell parameters
2. Develop new tracking techniques and reconfiguration methods for improved power extraction from solar PV systems
3. Design a photovoltaic system and its interfacing circuits for stand-alone, grid connect system.
4. Compute the cost analysis and payback period of solar PV installations and categorize various environmental impacts of PV.
5. Understand the different standards and communication system used in solar PV systems.

Module:1	Solar PV cell fundamentals	5 hours

Principle of direct solar energy conversion; Solar cell: types, material properties and construction methods;I-V characteristics of a PV module; New materials for PV cell; solar PV modelling and equations: modelling techniques; performance parameters: cell efficiency ,fill factor

Module:2	Maximum power extraction methods	6 hours

Formation of PV modules and arrays: series and parallel combination, effect of shading, use of bypass and blocking diodes; Need for Maximum power tracking: effects of irradiation and temperature on PV characteristics; DC-DC converters; Tracking techniques and array reconfiguration methods for maximum power extraction

Module:3	Standalone PV Systems	7 hours

Standalone PV system: design, schematics, array and battery sizing; Charge controllers; Off-grid inverters; Balance of system (BOS) for power plant: Supporting structures, mounting and installation, cables, maintenance and monitoring; Typical applications: design of Home lighting system, and water pumping

Module:4	**Grid Connected PV Systems**	**8 hours**
Interfacing with the power grid: Schematics, Interface Components, Types of grid interface, Balance of system; Buildings integrated PV systems: analysis and performance; Grid interactive inverters; PV SYST; preparing DPR including financial evaluation		
Module:5	**Energy Storage**	**6 hours**
Energy storage devices: Structure, Different types, and Materials for Energy Storage; Materials for Low and High Temperature Storage Applications; Measurement of battery performance, charge-discharge cycle of a battery; Estimation techniques		
Module:6	**Cost Analysis and Environmental Issues**	**6 hours**
Cost analysis and pay back calculations: Different types of solar panels and collectors; installation and operating costs; Environmental and safety issues; protection systems; Performance monitoring; Techno-economic analysis of solar PV power plants: Environmental considerations, Site selection and land requirements		
Module:7	**Standards and communication**	**5 hours**
IEEE Standard 1547; Elements of communication and networking: architectures, standards, PLC, Zigbee, GSM, BPL, Local Area Network (LAN); House Area Network (HAN) ;Wide Area Network (WAN)		
Module:8	**Contemporary Topics**	**2 hours**
	Total Lecture hours:	**45 hours**

	Textbook(s)
1.	Michael Boxwell, "Solar Electricity Handbook - 2021 Edition: A simple, practical guide to solar energy - designing and installing solar photovoltaic systems", Greenstream Publishing, UK, 2021
2.	Chetan Singh Solanki "Solar PV technology and system", PHI learning private limited, 2015
	Reference Books
1.	Ali Keyhani, "Design of Smart Power Grid Renewable Energy Systems", 3rd Edition John Wiley & Sons, 2019.
2.	D. Yogi Goswami , "Principles of Solar Engineering" 3rd Edition, , CRC Press, 2015
3.	Sukhatme S.P., "Solar Energy", Tata McGraw Hills P Co., 3rd Edition, 2008
4.	Roger Messenger, Amir Abtahi, "Photovoltaic Systems Engineering", 4th edition, CRC Press, 2017
5.	Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, 'Communication Networks for Smart Grids', Springer, 2014

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No. 72	Date	13-12-2023

Course Code	Course Title	L	T	P	C
MPED606L	Wind Energy Conversion Systems	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To study different types of generators and appropriate power electronic controllers for onshore and offshore wind energy systems
2. To understand the grid integration and power quality issues with their standards

Course Outcome

On the completion of this course the student will be able to:

1. Outline the basic concepts of wind turbines and their characteristics and discuss the control methods of wind turbines.
2. Explain the various generator configurations, power converters and their control techniques.
3. Understand the grid integration, power quality issues and recommend the standards.
4. Summaries the offshore wind power generation.
5. Design a component or a product applying all the relevant standards with realistic constraints

Module:1	Principles and Control of Wind Energy Generation System	7 hours

Aerodynamic Principles: design, Betz limit and Power limitations, Components and types of wind turbines, Operating characteristics of wind turbine, Wind turbine safety, Aerodynamic power controls: flap power control, yaw control, stall control and pitch control, Generator control: MPPT control schemes, Turbine power profile, Optimal tip speed ratio, Optimal torque control. Braking: electrical and mechanical.

Module:2	Generators for Wind Energy Conversions	5 hours

Fixed speed generators; soft starters, two speed variations, Variable speed generators; reduced capacity converters, full capacity converters, Generator types; synchronous generators, asynchronous generators, high voltage generator, switched reluctance generator, and transverse flux generator.

Module:3	**Power Electronic Interface and Control**	**8 hours**
Converter configurations; AC voltage controllers, interleaved boost converters, voltage source converters, current source converters, and back-to-back power converters, Grid Connected WECS, Standalone WECS, Grid side converter control and Machine side converter control: voltage-oriented control, decoupled controller, real and reactive power control.		
Module:4	**Grid Integration and Grid Codes**	**7 hours**
Wind interconnection requirements and grid codes; Steady state operation, Dynamic operation, Fault ride through, Series dynamic braking resistor, Crowbar, DC link chopper, Dynamic voltage restorer, Ramp rate limitations, Ancillary services for frequency and voltage control, and synchronization methods.		
Module:5	**Power Quality Issues and Standards**	**6hours**
Power quality affecting factors and issues; voltage variations, frequency variations, unbalance, and harmonics. Standards and regulations, mitigation techniques and control.		
Module:6	**Offshore Wind Energy**	**4hours**
Typical subsystems, Turbine technology, Transmission network; HVAC and HVDC, and Sea substation impact on power systems.		
Module:7	**Digital Monitoring and Control of Wind Energy Systems**	**6 hours**
Components of SCADA control systems; remote terminal unit, intelligent electronic devices and interfaces, SCADA communication; requirements, topologies and protocols. Energy management systems for WES; challenges, data flow time frames, and forecasting. IoT and Edge computing technologies for WECS, Digital twin technology approach for WECS.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Bin Wu, Yongqiang Lang, Navid Zargari, Samir Kouro, “Power Conversion and Control of Wind Energy Systems”, John Wiley & Sons, 2011.
2	Siegfried Heier, “Grid Integration of Wind Energy Conversion Systems”, Wiley, 2009.
Reference Books	
1	Thomas Ackkermann, “Wind Power in Power Systems”, John Wiley & Sons, Ltd, 2012.
2.	Gonzalo Abad, Jesus Lopez, Miguel Rodriguez, Luis Marroyo, GrzegorzIwanski, Doubly Fed Induction Machine: Modeling and Control for Wind Energy Generation, October 2011, Wiley-IEEE Press
3.	Olimpo Anaya-Lara, David Campos-Gaona, Edgar Moreno-Goytia, Grain Adam, “Offshore Wind Energy Generation: Control, Protection, and Integration to Electrical Systems”, John Wiley & Sons, 2014.
4	Mini S. Thomas, John D. McDonald, “Power System SCADA and smart grids”, CRC Press, Taylor and Francis, April 2015.
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test	

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023

Course Code	Course Title		L	T	P	C
MPED619L	**FPGA for Power Electronic Converters**		**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**				
		1.0				

Course Objectives

1. Introducing FPGA concepts and to emphasize the significance of the same for power electronics engineer
2. To acquire knowledge on verilog HDL and VHDL program to control the power converters
3. Utilizing FPGA to generate triggering pulses for different power electronic circuits
4. To create a closed loop control of drives using FPGA

Course Outcome

On the completion of this course the student will be able to:

1. Control the power converter circuits using different peripherals that can be designed in the FPGA board.
2. Understand the functioning of FPGA board to utilize it for the control of power converters
3. Understand the verilog HDL and VHDL program for FPGA board to control the power electronic circuits using different peripherals like timers, PWM etc.
4. Design verilog HDL and VHDL program for FPGA board to have a closed loop control of power converter based drives.
5. Use verilog HDL and VHDL code to generate triggering pulses for the power converters in Hardware-in-loop for Power converters.

Module:1	**FPGA**	**7 hours**

Introduction to Field Programmable Gate Arrays – CPLD Vs FPGA, Development and evolution of digital devices - design and verification tools, Abstraction levels of digital system design - Configurable logic Blocks (CLB), Input/Output Block (IOB) – Programmable Interconnect Point (PIP) – Xilinx 4000 series - overview of Spartan and Virtex FPGA boards. Significance of FPGA in Power Electronics

Module:2	**Verilog HDL and VHDL**	**7 hours**

Introduction to Verilog HDL and VHDL; simulation using Xilinx Webpack - Modeling styles: Behavioral, Dataflow, and Structural Modeling, gate delays, switch-level Modeling, Hierarchal structural modeling.

Module:3	**Programming for Combinational Logic Circuits**	**7 hours**

Verilog HDL and VHDL program for combinational logic circuits – Adder/subtractor – Multiplexers – Demultiplexers – Encoders – Priority Encoder - Decoders – Comparators, generating triggering pulses for power converters.

Module:4	**Programming for Sequential Logic Circuits**	**6 hours**

Verilog HDL and VHDL program for sequential logic circuits - Flip-Flops, Shift Registers, Counters, Clock divider circuit – Generation of multi-phase clock - Finite State Machine Modelling.

Module:5	**Verification of Design Codes**	**6 hours**
Verification of design files - Functional verification, simulation types, Test Bench design, value change dump (VCD) files. Coding to control power converters.		
Module:6	**Interfacing Peripherals with FPGA Board**	**6 hours**
Fixed point implementation using Verilog HDL and VHDL (P, PI, PID, etc.) – Modelling phase locked loop using VHDL. Interface ADC and DAC blocks with FPGA – closed loop control of power converters.		
Module:7	**FPGA Applications to Power Electronic System**	**6 hours**
Gate Pulse generation for DC-AC converter, AC-DC converter, PWM generation for Buck Converter, SPWM generation. DC motor control, Induction Motor Control		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Samir Palnitkar, “Verilog HDL: A Guide to Digital Design and Synthesis” Pearson, Second Edition, 2009.
2	Wayne Wolf, “FPGA-Based System Design”, Prentice Hall India Pvt. Ltd., 2005.
Reference Books	
1	Ming-Bo Lin., Digital System Designs and Practices Using Verilog HDL and FPGAs. Wiley, 2008.
2.	Woods, R., McAllister, J., Yi, Y. and Lightbody, G. FPGA-based implementation of signal processing systems. John Wiley & Sons, 2017.
3.	M. H. Rashid, “Power Electronics: Circuits, Devices and Applications. Pearson 3rd edition, 2013.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED618L	**Application of Power Electronics to Power System**	**3**	**0**	**0**	**3**
Pre-requisite	**NIL**	**Syllabus version**			
		1.0			

Course Objectives

1. To impart in-depth knowledge of reactive power control, application of FACTS controllers.
2. To bring out the importance of flexible AC transmission systems and controllers.

Course Outcome

On the completion of this course the student will be able to:

1. Apply the concept of load compensation and reactive power control to AC power system
2. Operation, modelling and performance analysis of shunt and Series FACTS devices
3. Operating principle, modeling and control structure of Phase angle regulator and Unified power flow controller
4. Application of FACTS controllers in transmission system
5. Comprehensive knowledge of line commutated and modular multilevel converters in HVDC systems

Module:1	**Transmission System Compensation**	**6 hours**

Concept of reactive power compensation, Review of Power Flow methods and series-shunt compensation, Review of voltage and current sourced converters, Concepts of transient stability and voltage stability. Need for FACTS controllers- types of FACTS controllers.

Module:2	**Shunt Compensation**	**6 hours**

Objectives of shunt compensation; SVC: Comparison of different SVC, Voltage control; STATCOM: VI Characteristics, Dynamic compensation

Module:3	**Series Compensation**	**6 hours**

Need for variable series compensation ;TCSC: modelling of TCSC, operating control scheme, SSSC: control range and VA rating

Module:4	**Shunt-Series Controller**	**6 hours**

Unified Power flow controller: principle, control structure, Performance analysis

Module:5	**Application of FACTS Devices**	**6 hours**

Sub-synchronous resonance, Damping oscillations, Transient stability and voltage stability; Coordination of FACTS

Module:6	**High Voltage DC Transmission**	**6 hours**

Introduction, various possible HVDC configurations, components of HVDC system, operation of 6-pulse and 12-pulse converter.

Module:7	**Analysis of HVDC Converter**	**7 hours**

Analysis of HVDC Converter: Line commutated converters and Modular Multi level converters

Module:8	**Contemporary issues:**		**2 hours**
		Total Lecture hours:	**45 hours**
Text Book(s)			
1.	Narain Hingorani & Lazzlo Gyugi “Understanding FACTS. Concepts & Technology of FACTS”, Standard publishers & distributors, 2011		
2	Mohan Mathur, Rajiv. K. Varma, “Thyristor Based FACTS Controllers for Electrical Transmission systems” John Wiley and Sons, 2001		
Reference Books			
1	T.J.E Miller “Reactive Power Control in Electric system” John Wiley & Sons, NY, 2010.		
2.	Enrique Acha, Claudio R. Fuerte-Esquivel, Hugo Ambriz-Pérez, “FACTS: Modelling and Simulation in Power Networks”, John Wiley, 2011		
3.	K.R. Padiyar, “FACTS controllers in Power transmission and distribution`”, New Academic Science, 2011		
4.	Dragan Jovcic, “High Voltage Direct Current Transmission: Converters, Systems and DC Grids”, 2019, Wiley Publications		
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED620L	Real-Time Interface for Power Converters	2	0	0	2
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. To understand and analyze PWM techniques for power converters
2. To understand Hardware-in-the-loop and Rapid control prototyping for power converters
3. To design Opto-driver circuit with isolated ground for the power converters

Course Outcome

On the completion of this course the student will be able to:

1. Compare and choose suitable carrier wave generation techniques for power converter circuits
2. Interface sensors, ADC and DAC for closed loop power converters
3. Formulate suitable circuits for power conversion using Hardware-in-the-loop and Rapid Control Prototyping
4. Prepare Opto-driver circuit for power converters

Module:1	Switching pulse generation for power converters using analog IC's	5 hours

Symmetric and asymmetric carrier wave generation; Trailing edge, leading edge, and double edge; control of power switching devices: Duty cycle generation using multiplier IC; Pulse width modulation techniques: Non-isolated and isolated converters; single phase and three phase inverters

Module:2	Sensor interfaces for power converters	4 hours

Hall effect sensor: AC/DC Voltage and current sensors; temperature and humidity sensor, speed sensors, signal gain design;4 bit and 8 bit Analog to digital converter(ADC) and Digital to analog converters (DAC)

Module:3	Hardware-in-the-loop using Real time interface controller	6 hours

Hardware-in-the-loop: Simulink Model of the power converters; Real time interface controller Architecture; Front panel, Rear panel; Specifications; Real time controller Target Support; PWM pulses: Digital IN; Digital OUT, Accessing analog signals: ADC and DAC ports; measurement of small-signal transfer functions; closed loop control of power converter; thermal resistance of heat sink; thermal modeling

Module:4	Rapid control prototyping using Real time interface controller	5 hours

Real time interface: Rapid control prototyping; PWM generation; Digital OUT Ports; Non-isolated and isolated converters; single phase and three phase inverters; Sensor signal Interface: output voltage feedback with ADC Ports; tuning of PID controllers

Module:5	Linear Power Supply ICs for analog and digital ICs	4 hours

Linear power supply ICs: Positive, Negative and Dual fixed voltage regulators, adjustable dual regulators, head room voltage, protection schemes; Practical biasing circuits: analog and digital Ics; Switching regulator Ics

Module:6	Design of Opto-driver circuits for controlled power switches	4 hours

Opto-driver circuits; Single bias circuit, Dual bias circuits; unequal ON and OFF time resistors; Isolated transformer: Generation of multiple isolated grounds for driver circuits; Practical circuits

Module:7	**Contemporary issues:**		**2 hours**
		Total Lecture hours:	**30 hours**
Text Book(s)			
1.	Robert W. Erickson, Dragan Maksimovic, "Fundamentals of Power Electronics", Springer, Third Edition, 2020.		
2	Robert F. Coughlin and Frederick F. Driscoll, "Operational Amplifiers and Linear Integrated Circuits", PHI Learning Private Limited, Sixth Edition, 2015.		
Reference Books			
1	L. Umanand, "Power Electronics: Essentials & Applications", Wiley, 2009.		
2.	Daniel W. Hart, "Power Electronics", Mc Graw Hill, 2010.		
3.	Robert L. Boylestad and Louis Nashelsky, "Electronic Devices and Circuit Theory", Prentice Hall, Eleventh Edition, 2015.		
4.	Bob Dobkin, Jim Williams, "Analog Circuit Design: A Tutorial Guide to Applications and Solutions", Elsevier Inc, First Edition, 2011.		
5.	Datasheets: Devices, IC's and Sensors		
6.	Real time interface controller user Manual		
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test			

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED620P	Real-Time Interface for Power Converters Lab	0	0	2	1
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To simulate and fabricate PWM circuits for power converters
2. To design and validate the controller parameters

Expected Course Outcome

On the completion of this course the student will be able to

1. Experimentally analysing various PWM techniques for power conversion

Indicative Experiments		Hours
1.	Generation of symmetric carrier wave	2 hours
2.	Generation of asymmetric carrier waves	2 hours
3.	Switching pulse generation for non-isolated DC to DC converter	2 hours
4.	Switching pulse generation for single phase inverter	2 hours
5.	Implementation of dual linear power supply	2 hours
6.	Hardware-in-the-loop testing with DC to DC buck converter with CCM operation	2 hours
7.	Hardware-in-the-loop testing with closed loop control of boost converter	2 hours
8.	Hardware-in-the-loop testing with DC to AC Inverter	2 hours
9.	Hardware-in-the-loop testing with three phase Inverter	2 hours
10.	Design of Opto-driver circuit for controlled power switches	2 hours
11.	Hands-on exercises: soldering and de-soldering practice	2 hours
12.	Rapid control prototyping with DC to DC buck converter with CCM operation	2 hours
13.	Rapid control prototyping with DC to DC boost converter with CCM operation	2 hours
14.	Rapid control prototyping with DC to AC Inverter	2 hours
15.	Rapid control prototyping with three phase Inverter	2 hours
16.	Thermal resistance of heat sink	2 hours
17.	Toroid inductor design and fabrication	2 hours
	Total Laboratory Hours:	**30 hours**

1.	Robert W. Erickson, Dragan Maksimovic, “Fundamentals of Power Electronics”, Springer, Third Edition, 2020.
Reference Books	
1.	Robert L. Boylestad and Louis Nashelsky, “Electronic Devices and Circuit Theory”, Prentice

	Hall, Eleventh Edition, 2015.
2.	Bob Dobkin, Jim Williams, "Analog Circuit Design: A Tutorial Guide to Applications and Solutions", Elsevier Inc, First Edition, 2011.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023

Course Code	Course Title	L	T	P	C
MPED621L	Control System Design	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. Impart in depth knowledge on continuous system and discrete system and effect of sampling
2. impart knowledge on design of controllers using root-locus, frequency domain and state space techniques.
3. To understand nonlinear control concepts.

Course Outcome

On the completion of this course the student will be able to:

1. Analyze linear and nonlinear systems
2. Obtain state space model of linear and nonlinear systems
3. Design controller using Root-locus and Frequency Domain technique
4. Design state feedback controller and observer
5. Apply nonlinear control techniques to dynamic systems

Module:1	Linear and Nonlinear Systems	9 hours

Review of continuous systems- Need for discretization-comparison between discrete and analog system. Sample and Hold devices - Effect of sampling on transfer function and state space analysis. Modelling of nonlinear systems: equilibrium points, linearization, state space averaging; Nonlinear phenomena in power converters: bifurcation and chaos

Module:2	Root Locus Design	6 hours

Design specifications-In Continuous domain - Limitations- Controller structure- Multiple degrees of freedom- PID controllers and Lag-lead compensators- Root locus design- Discretization & Direct discrete design

Module:3	Frequency Response Based Design	6 hours

Lag-lead compensators – Design using Bode plots- use of Nicholsss's chart and Routh-hurwitz Criterion-Jury's stability test- Digital design

Module:4	State Feedback Control and Observer Design	8 hours

Design of state feedback control: Regulation and tracking; Design of full order and reduced order observer; Extended state observer; Discrete pole placement and observer design; Simulation tools and case studies

Module:5	LQR And LQG Design	6 hours

Formulation of LQR problem- Pontryagin's minimum principle and Hamiltonian solutions- Ricatti's equation – Optimal estimation- Kalman filter –solution to continuous and discrete systems - Design examples

Module:6	Nonlinear Control Design Techniques	8 hours

Lyapunov based control; Control design using feedback linearization: input-state linearization, input-output linearization; Sliding mode control; Design examples

Module:7	Contemporary issues:	2 hours

			Total Lecture hours:	**45 hours**
Text Book(s)				
1.	Ogata, K. (2010). Modern control engineering (Vol. 5). Upper Saddle River, NJ: Prentice hall.			
2	Slotine, J. J. E., & Li, W. (1991). Applied nonlinear control (Vol. 199, No. 1, p. 705). Englewood Cliffs, NJ: Prentice hall.			
Reference Books				
1	Chi-Tsong Chen, 'Linear System Theory and Design', Oxford University Press,1984			
2.	Khalil, H. K. (2015). Nonlinear control (Vol. 406). New York: Pearson.			
3.	Sira-Ramirez, H. J., & Silva-Ortigoza, R. (2006). Control design techniques in power electronics devices. Springer Science & Business Media.			
4.	Banerjee, S., & Verghese, G. C. (Eds.). (2001). Nonlinear phenomena in power electronics: Bifurcations, chaos, control, and applications. Wiley-IEEE Press.			
5.	Tymerski R, Chuinard A, Rytkonen F. Applied classical and modern control system design. Lecture Notes, ECE451, Portland State University.			
6.	Donald, E. (2016). Optimal control theory: an introduction. Dover Publications.			
7.	G. F. Franklin, J. D. Powell and M Workman, 'Digital Control of Dynamic Systems', PHI (Pearson), 2008.			
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test				
Recommended by Board of Studies	30-10-2023			
Approved by Academic Council	No.72	Date	13-12-2023	

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course Code	Course Title	L	T	P	C
MPED612L	Hybrid and Electric Vehicles	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. Impart knowledge on Electric vehicles and its architectures
2. Design suitable motor drive with appropriate control for Electric vehicles
3. Recognize the requirements for battery management and charging systems

Course Outcome

On the completion of this course the student will be able to:

1. Understand the environmental issues of conventional vehicles and need of Electric vehicles
2. Describe the different architectures of Hybrid Electric and Electric vehicles
3. Know fuel cell and Solar powered Electric vehicles
4. Develop AUTOSAR architectures for various electric vehicles
5. Comprehend battery management and charging system of EVs and their constraints.

Module:1	Vehicle dynamics	6 hours

Review of Conventional Vehicle; Social and environmental impacts of ICE vehicles; Importance of Electric vehicle; Evolution of hybrid electric, Electric and fuel cell vehicles; Vehicle performance and dynamics: Vehicle resistive forces and Tractive effort

Module:2	Hybrid Electric Power Trains	5 hours

Hybrid Electric Powertrains: Series hybrid, Parallel hybrid and Power split hybrid-operating modes; Hybrid Powertrain Components: Regenerative Braking Systems, Hybrid Powertrain Controls: engine OFF/ON decisions, engine operating point optimization, and Regenerating braking control.

Module:3	Hybrid Electric Vehicles	5 hours

Fuel economy improvement in HEVs, effect of driving cycles on fuel economy enhancement and emission reduction, driving cycles and road conditions on fuel economy; HEV TECHNOLOGIES: Micro, Hybrid, Mild and Full hybrid; Plug in HEV, case studies of HEV.

Module:4	Electric Vehicle Power Trains	7 hours

Components of electric vehicle; Electric drivetrain topologies, Comparison, Design aspects; Modern electric drive trains; Complete structure of EV, in wheel motors, design of in wheel motors. Components of e-axle and Design of e-axle system, case studies.

Module:5	Fuel cell and Solar Electric Vehicles	8 hours

Fuel cell introduction, Fuel cell electric vehicle powertrain, Fuel cell combined with other energy storage systems. Solar electric vehicle powertrains: conventional solar-powered powertrain, solar-powered powertrain with maximum power point tracking, and solar-powered in-wheeldrive with MPPT and regenerative braking.

Module:6	AUTOSAR Architecture	6 hours

Introduction to AUTOSAR, architectures and layers, base software layers and interfaces, Application software- components, types, ports, interfaces, compositions and connectors, Run time environments, AUTOSAR methodology.

Module:7	Battery Management and EV Charging Systems	6 hours
BMS Functions, design considerations and various components of BMS; Cell balancing, SoC estimation, SoH estimation. EV charging system: On-board and OFF board chargers; EV charging standards; Wireless EV charging and types-inductive wireless charging, capacitive wireless charging, resonant wireless charging system, dynamic wireless charging system. Solar-powered Charging Station.		
Module:8	**Contemporary Topics**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Ali Emadi, “Advanced Electric drives vehicles” , CRC Press, 2015
2	Iqbal Hussain, "Electric and Hybrid Vehicles-Design Fundamentals", CRC Press, 2nd edition,2011.

Reference Books

1	Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay and Ali Emadi, "Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals", CRC Press, 2010.
2.	Chris Mi, MA Masrur, and D W Gao, "Hybrid Electric Vehicles- Principles and Applications with Practical Perspectives", Wiley, 2011.
3.	Davide Andrea, "Battery management Systems for Large Lithium-Ion Battery Packs", Artech House, 2010.
4.	Ottorino Veneri “Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles”, Springer publishers, 2017.
5.	James Larminie, John Lowry “Electric Vehicle Technology Explained”, 2nd edition, Wiley publications, 2012.
6.	Chitra A., S. Padmanaban, Jens Bo Holm-Nielsen, S. Himavathi, “Artificial Intelligent Techniques for Electric and Hybrid Electric Vehicles”, Wiley Publisher, July, 2020.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test

Recommended by Board of Studies	30-10-2023		
Approved by Academic Council	No.72	Date	13-12-2023