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 MPE)

Curriculum

(*2022-2023 admitted students*)

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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 be a leader for academic excellence in the field of electrical, instrumentation and control engineering imparting high quality education and research leading to global competence for the societal and industrial developments.

MISSION STATEMENT OF THE SCHOOL OF ELECTRICAL ENGINEERING

- Impart high quality education and interdisciplinary research by providing conducive teaching learning environment and team spirit resulting in innovation and product development.
- Enhance the core competency of the students to cater to the needs of the industries and society by providing solutions in the field of electrical, electronics, instrumentation and automation engineering.
- Develop analytical skills, leadership quality and team spirit through balanced curriculum.

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.

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

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.

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-22	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	MPED501L	Advanced Semiconductor Devices	3	0	0	3
2	MPED502L	Analysis of Power Converters	3	0	0	3
	MPED502P	Analysis of Power Converters	0	0	2	1
3	MPED503L	Switched Mode Power Supplies	2	0	0	2
4	MPED504L	Generalized Machine Theory	3	1	0	4
5	MPED505L	Industrial Electrical Drives	3	0	0	3
	MPED505P	Industrial Electrical Drives	0	0	2	1
6	MPED506L	Special Machines and Control	3	0	0	3
7	MPED507L	Advanced Processors for Power Converters	3	0	0	3
	MPED507P	Advanced Processors for Power Converters	0	0	2	1
Total Credits						**24**

M. Tech Power Electronics and Drives

Discipline Elective

S. No.	Course Code	Course Title	L	T	P	C
1	MPED601L	Modern Control Theory	3	0	0	3
2	MPED602L	Intelligent Control	3	0	0	3
3	MPED603L	Energy Storage Systems	3	0	0	3
4	MPED604L	Solar Photo Voltaic Systems	3	0	0	3
5	MPED605L	Electric and Hybrid Electric Vehicles	3	0	0	3
6	MPED606L	Wind Energy Conversion Systems	3	0	0	3
7	MPED607L	Microgrid Technologies	3	0	0	3
8	MPED608L	Integrated Circuits for Power Conversion	2	0	0	2
	MPED608P	Integrated Circuits for Power Conversion	0	0	2	1
9	MPED609L	Power Electronics Applications in Power Systems	3	0	0	3

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Curriculum (Semester wise Break up)

Semester-1	Category	L	T	P	C
Advanced Semiconductor Devices	DC-1	3	0	0	3
Analysis of Power Converters	DC-2	3	0	0	3
Analysis of Power Converters Lab	DC-2 L	0	0	2	1
Generalized Machine Theory	DC-3	3	1	0	4
Advanced Processors for Power Converters	DC-4	3	0	0	3
Advanced Processors for Power Converters Lab	DC-4 L	0	0	2	1
Discipline Elective-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)					23.5

Semester-2	Category	L	T	P	C
Switched Mode Power Supplies	DC-5	2	0	0	2
Industrial Electrical Drives	DC-6	3	0	0	3
Industrial Electrical Drives Lab	DC-6 L	0	0	2	1
Special Machines and Control	DC-7	3	0	0	3
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
Open Elective-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)	24.5

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

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

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Discipline Core

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.
2. Understand the various power semiconductor device characteristics and significance of gate drive and protection circuits.

Expected Course Outcome

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

1. Identify and categorize power electronic switches based on its rating
2. Appropriate device selection suitable for application
3. Examine and classify various power semiconductor switching characteristics and summarize the voltage, current controlled devices
4. Analyze the characteristics of new emerging power semiconductor devices.
5. 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-state and switching losses; EMI due to switching		
Module:2	Power Diodes	5 hours
Power diodes: Structure, operating principle, switching characteristics, types, forward and reverse characteristics; device datasheet; simulation of power diode characteristics		
Module:3	Power Thyristors	6 hours
Power Thyristors: 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
Power Transistors: 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 and 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; Heat sink: selection, types and mounting types; simulation of gate drive circuits		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

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	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

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 rectifiers.
2. Understand the working principle and analyse the different types three phase 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; PWM rectifier

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; Multi-quadrant converter; Multi-pulse converter

Module:3	DC-DC CONVERTERS	7 hours

Configurations: Buck, Boost, Buck-Boost; Multi-port and interleaved converters; Synchronous converters; Design and control of DC-DC converter; Multi-quadrant choppers and applications

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; PWM techniques: Sine PWM, space vector 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; Single phase cycloconverters: Types and operating principle

Module:6	**POWER CONVERTERS APPLICATION**	**6 hours**
HVDC applications; Front end rectifier design; Motor control applications; Reactive power compensation; UPS; Induction heating; Power converters in renewable energy and electric vehicles		
Module:7	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Mode of Evaluation: CAT / Assignment / Quiz / FAT		

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.
3.	William Shepherd and Li Zhang, "Power Converter Circuits", Marcel Dekker Inc, New York, 2004.

Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

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.	Losses and thermal estimation of power converters	
3.	Switching characteristics and driver circuits for wide band gap devices	
4.	Performance analysis of Single-phase controlled AC-DC one-pulse converter	
5.	Performance analysis of Single-phase controlled AC-DC two-pulse converter (R, RL-Load)	
6.	Performance analysis of Three-phase controlled AC-DC six-pulse converter (R, RL-Load)	
7.	Performance analysis of AC-AC voltage regulator	
8.	Performance analysis of AC-AC cyclo-converter	
9.	Voltage control of Single-phase inverter- R, RL load	
10.	Implementation of Three-phase inverter- R load	
11.	Duty ratio-controlled DC-DC converters (Buck, Boost, Buck-Boost)	
12.	Implementation of Multi quadrant chopper	
13.	PWM control of DC-AC inverters	
14.	Harmonic mitigations of VSI	
15.	Power factor correction circuit	
	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	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED503L	Switched Mode Power Supplies	2	0	0	2
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

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

Course Outcome

the end of the 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 magnetic components of dc-dc converters
5. 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	Magnetic circuit Design	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		

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 Topics	2 hours

			Total Lecture hours:	**30 hours**
Textbook(s)				
1.	Robert W. Erickson and DraganMaksimovic, “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.			
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test				
Recommended by Board of Studies	09-07-2022			
Approved by Academic Council	No. 67	Date	08-08-2022	

Course code	Course Title	L	T	P	C
MPED504L	Generalized Machine Theory	3	1	0	4
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. Modern techniques and analytical methods for dealing with and solving operational problems in electrical machines.
2. Develop and practise their research skills and find solutions to real problems.

Course Outcome

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

1. Analysis of conversion and utilization of electric energy systems.
2. The transformation of three-phase to two-phase axis model.
3. Comprehend dynamic models of the DC machine, the synchronous machine, induction machine and special machine.
4. Have knowledge about the limitations for a dynamic model of an electrical machine.
5. Have knowledge on the dynamic analysis of Interconnected machines.

Module:1	Principles of Electromagnetic Conversion	7 hours

Single and multiple excited systems; Field energy ,co-energy and mechanical force; Electromechanical energy conversion ;Single and Multiple excited systems : torque and force expression

Module:2	Linear Transformation and Reference Frame Theory	9 hours

Kron's theory ; Transformation from three phase to two phase ; Transformation from rotating axes to stationary axes; Park's transformation ;Physical interpretation;
Reference frame theory ; Transformation between reference frames stationary circuit variable transformation ;Steady state voltage equation

Module:3	DC Machine	8 hours

Analysis of DC machines using the primitive machine equation ; Steady state and transient analysis; Transfer functions of DC generator and motor

Module:4	Modelling of Induction Machine	8 hours

Voltage and torque equations; Machine variables ;Arbitrary reference frame and rotor reference frames ;Steady state operation ;Dynamic model ;Operations of induction motor with non-sinusoidal supply waveforms ;simulation of arbitrary reference frame and linearised model

Module:5	Modelling of Synchronous Machine	9 hours

Reactance of synchronous machine ; Time constants of synchronous machine ;Voltage and torque equation; Machine variables ; Arbitrary reference frame and rotor reference frames; Park's equation ;Dynamic model of synchronous machine ;Effects of magnetic saturation; Simulation of linearised model

Module:6	Modelling of Special Machines	9 hours

Steady-state and dynamic model: Permanent magnet synchronous machine ,BLDC motor; Steady state and dynamic model : Switched reluctance motor

Module:7	**Modelling of Inter connected machines**	**8 hours**
Dynamical Analysis of Interconnected Machines; Machine interconnection matrices; Transformation of voltage and Torque equations using interconnection matrix; Large signal transient analysis using transformed equations		
Module:8	**Contemporary issues**	**2 Hours**
Total Lecture hours:		**60 hours**

Text Book(s)	
1.	Krause PC, Wasynczuk O, Sudhoff SD (2013) Analysis of electrical machinery and drive systems, 3rd edition. IEEE Press
2.	.Bimal K.bose, (2015), Modern Power Electronics and AC Drives, Prentice Hall.
Reference Books	
1.	R. Krishnan, (2015) Electric motor drives, modeling, analysis and control, Pearson.
2.	A. E. Fitzgerald, Charles Kingsley and Stephen D. Umans, (2020), Electric Machinery, Mc Graw Hill , Indian Edition.
3.	Ion Boldea, (2017) Variable speed generators, CRC Press.

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

Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED505L	**Industrial Electrical Drives**	**3**	**0**	**0**	**3**
Pre-requisite	**MPED502L** **MPED504L**	**Syllabus version**			
		1.0			

Course Objectives

1. To introduce basic concepts of load and drive interaction, speed control concepts of ac and dc drives, speed reversal, regenerative braking aspects, design methodology.
2. To analyze EMI and mitigate Harmonics in energy efficient drives.

Expected 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. Summarise EMI and EMC standards and different energy saving schemes.

Module:1	Drive Dynamics and Power Ratings	7 hours

Dynamics of Electric Drives: 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; Selection of power converters: Direct converters, converters with intermediate circuit, Converter rating from motor specification, Factors for drive selection, Overload capacity, Control range, Derating factor, Efficiency

Module:2	Control of DC Motor Drive	6 hours

Factors governing speed and torque of DC motors, Controlled rectifier-based speed control: Single quadrant, Two quadrant and four quadrant-controlled DC motor drive; Chopper fed speed control: Four quadrant operations; Closed loop control

Module:3	Control of Induction Motor Drive	7 hours

Stator side control: Characteristics and equivalent circuit of poly-phase induction motor; Speed control techniques: Stator voltage control, variable frequency control, V/f control; Soft starting methods, braking methods; Rotor side control: static rotor resistance control, Kramer's drive, Scherbius drive, doubly fed induction motor drive

Module:4	Vector Control of Induction Motor Drive	8 hours

Principle of vector control, types of vector control, direct vector control, indirect vector control, rotor flux-oriented control, stator flux-oriented control, air gap flux-oriented control, decoupling circuits-speed sensor less control, Concept of space vectors, DTC control strategy of induction motor

Module:5	Control of Synchronous Machine Drives	7 hours

Steady-state equivalent circuits and dynamic model of synchronous machine; Zero d-axis current control, maximum torque per ampere control, direct torque control, and power factor control

Module:6	Electromagnetic Interference and Harmonics	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

Module:7	**Energy Saving in Electric Drives**	**4 hours**
Classification of energy efficiency, Energy efficient motor starting and control, Load over time, Applications with variable and constant torque, Life cycle costs and system savings using regenerated power		
Module:8	**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.	R. Krishnan, Electric Motor Drives: Modelling, Analysis, and Control, 2015, Second edition, Pearson Education India.		
Reference Books			
1.	Gopal K Dubey, “Fundamentals of Electrical Drives”, CRC Press, Second Edition, 2015.		
2.	Peter vas, Vector control of AC Machines –Oxford university press, 1990.		
3.	R. Raja Singh, Energy Conservation Strategies for Asynchronous Machine Drives, Lap Lambert Academic Publishing, Germany, 2021..		
4.	Danfoss Handbook on VLT Frequency Converters, "Facts Worth Knowing about Frequency Converters", PE-MSMBM Publications, 2014.		
5.	T.J.E Miller, “Brushless Permanent Magnet and Reluctance Motor Drives”, Clarendon Press, Oxford 1989.		
Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED505P	Industrial Electrical Drives Lab	0	0	2	1
Pre-requisite	MPED502L MPED504L	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.	Design and speed control of DC to DC converter fed DC motor drive	
3.	Design and control of DC motor drive under four quadrants	
4.	Design and control AC to AC regulator fed induction motor drive	
5.	Speed control of induction motor drive using V/f control	
6.	Speed control of induction motor drive using VVC+ control	
7.	Speed control of induction motor drive using field-oriented control	
8.	Speed control of induction motor drive using flux sensor less control	
9.	Dynamic braking of induction motor drive	
10.	Automatic motor adaption for machine parameter estimation and formation	
11.	Performance analysis of the induction motor drive with regenerative loading	
12.	Speed control of slip ring induction motor using static rotor resistance control	
13.	Speed control of permanent magnet synchronous motor (PMSM) drive	
14.	Speed control of synchronous drive using PI/PID controller	
15.	Speed control of synchronous reluctance motor (Syn.RM) drive	
16.	Performance analysis of the PMSM drive with regenerative loading	
17.	Performance analysis of the Syn.RM drive with regenerative loading	
18.	Speed control using static Kramer drive and static Scherbius drive	
19.	Performance analysis of doubly fed induction motor	

20.	Drive power and harmonics measurements	
	Total Laboratory Hours:	**30 hours**

Textbook(s)	
1.	Bimal K Bose, "Modern Power Electronics and AC Drives", Pearson Education Asia, 2012.
2.	R. Krishnan, Electric Motor Drives: Modelling, Analysis, and Control, 2015, Second edition, Pearson Education India.
Reference Books	
1.	Gopal K Dubey, "Fundamentals of Electrical Drives", CRC Press, Second Edition, 2015.
2.	Peter vas, Vector control of AC Machines –Oxford university press, 1990.

Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Special Machines and Control	L	T	P	C
MPED506L		3	0	0	3
Pre-requisite	MPED502L	Syllabus version			
		v. 1.0			

Course Objectives:

1. To impart knowledge on special types of electro-mechanical energy conversion machines and their importance.
2. To select the appropriate special machine drive for the specific purpose

Expected Course Outcome:

On the completion of this course the student will be able to:
1. Analyze permanent magnet material property and circuits
2. Interpret the stepper motor with the drive circuits
3. Distinguish switched reluctance motor from synchronous reluctance motor
4. Analyze square wave and sine wave permanent magnet brushless motor drives.
5. Appraise the advanced synchronous motor and develop the linear motors from the conventional motors

Module	Title	Hours
Module:1	**Stepper Motors**	**6 hours**
Constructional and working; Modes of excitation: Drive circuits, Control Aspects; Concept of lead angle		
Module:2	**Switched Reluctance Motors**	**6 hours**
Constructional and working; Power Converters and controllers; Methods of rotor position sensing		
Module:3	**Synchronous Reluctance Motors**	**6 hours**
Constructional and working; Significance of direct and quadrature inductances; Phasor diagram		
Module:4	**Permanent Magnet Brushless DC Motors**	**8 hours**
Permanent Magnet materials, Magnet Characteristics, Permeance coefficient; Magnetic circuit analysis of PMBLDC; EMF and torque equations; Power Converters; Hall-effect sensor; Commutation; closed loop control		
Module:5	**Permanent Magnet Synchronous Motors**	**7hours**
Principle of operation; EMF and Torque equations; Synchronous Reactance; Phasor diagram; Converter Volt-ampere requirements		
Module:6	**Advanced Synchronous Machines**	**5 hours**
Construction and working: Flux Switching and Flux Reversal Machines, Claw Pole Alternators, Axial flux Machine; applications		
Module:7	**Linear Motors**	**5 hours**
Construction and working: Linear DC Motors, Linear Induction Motors, Linear Synchronous Motors, Linear Switched Reluctance Motors; applications		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Mode of Evaluation: CAT / Assignment / Quiz / FAT				
Text Book(s)				
1.	T.J.E Miller, "Brushless Permanent Magnet and Reluctance Motor Drives", Clarendon Press, Oxford 1989.			
2.	R. Krishnan, "Permanent Magnet and Brushless DC Motors Drives", CRC Press, New York, 2010.			
Reference Books				
1.	T. Kenjo and S. Nagamori, "Permanent Magnet and Brushless DC Motor", Clarendon Press, London 1988.			
2.	T. Kenjo, "Stepper Motors and their Microprocessor Controls" , Clarendon Press, London.			
3.	Ion Boldea, "Linear Electric Machines, Drives and MAGLEVs Handbook", CRC Press, London, 2013.			
4.	P. P. Aearnely, "A Guide to Motor Theory and Practice Stepper Motors", Peter Perengrinus, London, 1982.			
5.	T. Kenjo and S. Nagamori, "Permanent Magnet and Brushless DC Motor", Clarendon Press, London 1988.			
Recommended by Board of Studies		09-07-2022		
Approved by Academic Council		No. 67	Date	08-08-2022

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 which will be used to generate pulses.
3. Overview of programming frame work, software building blocks and Interrupt structures, Event manager, and compare unit.

Expected Course Outcome

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

1. Understand the Arm processor architecture
2. Use the Timers and PWM to generate triggering pulses for power electronic circuits.
3. Experiment with the exceptions of ARM processor to vary the triggering pulses for power electronic circuits.
4. Apply digital signal processing in ARM processor.
5. Experiment with the peripherals of DSP processor for power electronics applications.

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 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:6	Digital Signal Processor	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; Interrupts; A/D converter; Event		

Managers (EVA, EVB); PWM signal generation for single phase inverter		
Module:7	**Real Time Digital Signal Processing**	**5 hours**
Sample Based Processing; Frame Based Processing; Basic Buffer Structures; Usage of Buffers in Frame-Based Processing; Overlap Methods for Frame-Based Processing		
Module:8	**Lecture by industry experts**	**2 hours**
	Total Lecture hours:	**45 hours**

Textbook(s)	
1.	Andrew N.Sloss, Dominic Symes, Chris Wright, “ARM System Developer’sGuide 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

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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.	Control signal for obtaining variable duty cycle.	
2.	Obtaining pulse width modulated signal from a saw tooth and DC signal.	
3.	Processor based control of a single phase half-wave controlled converter	
4.	Single phase single quadrant DC-DC converter and its control.	
5.	Control of a single phase single quadrant bridge type AC-DC converter.	
6.	Single phase two quadrant AC-DC converter controlled through ARM processor.	
7.	High power single quadrant bridge type AC-DC converter and its control	
8.	Control of a High power two quadrant bridge type AC-DC converter.	
9.	ARM processor based control of a residential UPS.	
10.	Digital control of high power industrial inverter.	
11.	Control of three phase AC voltage controller	
12.	Single phase step down cycloconverter and its control.	
13.	PWM control of single quadrant DC chopper	
14.	DSP based implementation of PWM techniques to control an inverter.	
15.	Control of single phase half controlled converter using DSP processor	
16.	Control of chopper circuit in TRC and variable frequency method	
	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,

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VIT
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
MPED601L	Modern Control system		3	0	0	3
Pre-requisite	NIL	Syllabus version				
		1.0				

Course Objectives

1. Impart in depth knowledge of linear and nonlinear systems and to analyze the physical systems in state space.
2. Design of controller and observer using state space model.
3. To understand digital control concepts.

Course Outcome

At the end of the 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 state feedback controller and observer
4. Understand various stability notions and stability analysis
5. Apply digital control techniques to dynamic systems

Module:1	Linear Systems	9 hours
Concept of state: state equations for dynamic systems, state diagrams; Time invariance and linearity; Solution of state equations; state transition matrix; Relation between state model and transfer function; Modelling of linear systems; Discrete state variable analysis		
Module:2	**Analysis of Linear Systems**	**7 hours**
Eigen values and eigen vectors; system modes; Controllability; Observability; Canonical forms: Minimal realization; Stabilizability and detectability		
Module:3	**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:4	**Nonlinear Systems**	**7 hours**
Nonlinear dynamics: common nonlinearities, features of nonlinear systems; Modelling of nonlinear systems: equilibrium points, linearization, state space averaging; Nonlinear phenomena in power converters: bifurcation and chaos		
Module:5	**Stability Analysis**	**6 hours**
Stability of LTI Systems: BIBO stability; Nyquist stability criteria; Stability in the sense of Lyapunov; Lyapunov functions: methods of construction; Stability analysis: Lyapunov direct and indirect method		
Module:6	**Nonlinear Control Techniques**	**6 hours**
Lyapunov based control; Control design using feedback linearization: input-state linearization, input-output linearization; Sliding mode control; Design examples		
Module:7	**Contemporary Topics**	**2 hours**
	Total Lecture hours:	**45 hours**

Textbook(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 Tests, Quizzes, Assignment, Final Assessment Test			
Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED602L	Intelligent Control	3	0	0	3
Pre-requisite	NIL	Syllabus version			
		1.0			

Course Objectives

1. Apply neural networks, fuzzy logic and optimization techniques for obtaining desired output.
2. Design multilayer neural networks with proper architecture.
3. Deploy intelligent techniques for real time applications.

Expected Course Outcome

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

1. Understand the mathematical model of a neuron and demonstrate the concepts of feedforward neural networks.
2. Apply the backpropagation training technique and recurrent networks for solving the engineering problems.
3. Estimate the appropriate the fuzzy logic control for real time applications.
4. Analyse the optimisation methods for real time applications.
5. Develop suitable artificial intelligent technique for solving typical task.

Module:1	Artificial Neural Network	6 hours

Mathematical model of a neuron; Neuron models: Single / multi inputs; Activation functions; Network Architecture: single / multiple layers, perceptron network, leaning rule, pattern classification, linear separability limitation

Module:2	Supervised learning	7 hours

Feedforward Neural Network; Learning mechanism: Supervised learning, multilayer perceptron for pattern classification and function approximation; Back propagation algorithm; Drawbacks in Back propagation; Variants of back propagation algorithm; Levenburg Marguardt Algorithm; Other supervised learning methods: supervised Hebb's rule, Widrow Hoff learning rule, Adaline network

Module:3	Associative and Competitive networks	8 hours

Associative learning; Unsupervised Hebb's rule; In-star learning rule; Out-star rule; Pattern association; Hetero associative, Auto associative and Bi-directional associative memory; Competitive networks; Architecture and algorithm; Kohonen Self-organizing maps, Learning vector quantization

Module:4	Fuzzy Systems	8 hours

Comparison of crisp sets and fuzzy sets; Basic fuzzy set operation and approximate reasoning; Fuzzy relations; Fuzzification methods; Min-Max Composition; Defuzzification Methods; Fuzzy Rule based systems; Predicate logic; Fuzzy Decision Making; Fuzzy based controller design

Module:5	Optimization Algorithms	6 hours

Requirement of optimization algorithms; Single and multi-objective functions; Optimization with and without constraints; Multi-level optimization; Evolutionary algorithms; Optimization tool box; Applications

Module:6	ANN based controllers and estimators	8 hours

Data pre-processing; Convergence; Practical training issues; Neural networks for control task: Direct control, Indirect control, Temperature control; System identification; Online parameter estimation: Neural learning based parameter estimation for high performance drive, impact of estimation speed and accuracy on the drive performance; ANN based maximum power point tracking for solar PV system; Impact of Neural architecture on system performance

Module:7	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Jack M. Zurada, “Introduction to Artificial Neural Systems”,Jaico Publishing House, 2016.
2.	Timothy J. Ross, “Fuzzy Logic with Engineering Application”,McGrw Hill International Editions, 2014.

Reference Books

1.	J.S.R Jang, C.T Sun, E.Mizutani, “Neuro-Fuzzy Soft Computing”, Pearson Education, 2011.
2.	Nguyen, Prasad, Walker, and Walker, "A First Course in Fuzzy and Neural Control", Chapman Hall /CRC Press, 2003.
3.	Orłowska-Kowalska, Teresa, Blaabjerg, Frede, Rodríguez, José ,"Advanced and Intelligent Control in Power Electronics and Drives", Springer, 2014.
4.	Hagan, Martin T., Howard B. Demuth, and Mark Beale. “Neural network design”, PWS Publishing Co., 1997.

Recommended by Board of Studies	**09-07-2022**		
Approved by Academic Council	No.67	Date	08-08-2022

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	Title	Hours
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		09-07-2022		
Approved by Academic Council		No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED604L	Solar Photo Voltaic Systems	3	0	0	3
Pre-requisite	MPED501L	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; 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; 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		09-07-2022		
Approved by Academic Council	No. 67	Date		08-08-2022

Course Code	**Course Title**	**L**	**T**	**P**	**C**
MPED605L	**Electric and Hybrid Electric Vehicles**	**3**	**0**	**0**	**3**
Pre-requisite	**MPED502L**	**Syllabus version**			
		1.0			

Course Objectives

1. Providing knowledge on Electric vehicles and its architectures.
2. Selection of suitable motor drive and battery for Electric vehicles.
3. Charging infrastructure and methods of charging of EVs.

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. Analyse the characteristics of electric motor drives for Electric vehicles
4. Develop battery pack, battery management system and estimate SoC of the battery.

5. Comprehend the various charging strategies of EVs and their constraints		
Module:1	**Vehicle dynamics**	**6 hours**
Review of Conventional Vehicles; Social and environmental impacts of ICE vehicles; Importance of Electric vehicles; Evolution of hybrid electric, Electric and fuel cell vehicles; Vehicle performance and dynamics: Vehicle resistive forces and Tractive effort		
Module:2	**Hybrid Electric vehicle architectures**	**5 hours**
Classification: Micro, Mild, Full HEV; Architectures: Series, Parallel and Series-Parallel; Propulsion systems and components; Hybrid drive train topologies: Power flow control, comparison, design aspects, complete structure of HEV		
Module:3	**Electric vehicle architectures**	**5 hours**
Components of electric vehicle; Electric drivetrain topologies: Power flow control, Comparison, Design aspects; Modern electric drive trains; complete structure of EV		
Module:4	**Electric Motor drives for EVs**	**7 hours**
Configuration and control of DC Motor drives; Three-phase Induction Motor drives; Brushless motor drives; PMSM drives; Switched Reluctance Motor drives; Synchronous reluctance motor drives; Regenerative Braking Characteristics; Hub/In-wheel motors for EVs; Driving Cycles: Types and Indian drive cycles		
Module:5	**Battery and Energy Storage Systems for EVs**	**8 hours**
Li-ion, Li-phosphate, Lithium polymer and Metal oxide batteries; Battery specifications: Modelling, characteristics and selection of batteries for different types of EVs; Packing; protection, degradation; Life cycle estimation, disposal and second use and methods of recycling of batteries; Other energy storage systems: Super capacitor, Fuel Cell and their analysis; Hybridization of different energy storage devices		
Module:6	**Battery Management System**	**6 hours**
Functions, design considerations and various components of BMS; Cell balancing: Types of cell balancing; SoC estimation: Luenberger Observer method, Extended Kalman filter method		
Module:7	**EV charging systems**	**6 hours**
Components of EV charging system; On-board and OFF board chargers; EV charging standards; Wireless EV charging and types		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	James Larminie, John Lowry “Electric Vehicle Technology Explained”, 2nd edition, Wiley publications, 2012.
2	Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay and Ali Emadi, "Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals", CRC Press, 2010.
Reference Books	
1	Iqbal Hussain, "Electric and Hybrid Vehicles-Design Fundamentals", CRC Press, 2nd edition,2011.
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.		
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

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Course Code	Wind Energy Conversion Systems		L	T	P	C
MPED606L			3	0	0	3
Pre-requisite	MPED501L	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

Expected 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.

Module:1	Fundamental 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 and pitch. Generator control; MPPT control schemes, turbine power profile, optimal tip speed ratio, optimal torque control. Braking; electrical and mechanical.

Module:2	Wind Generator Configuration	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. 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	6 hours

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	4 hours

Typical subsystems, turbine technology, transmission network; HVAC and HVDC, and Sea substation impact on power system.		
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. Digital twin technology for WES.		
Module:8	**Contemporary issues:**	**2 hours**
	Total Lecture hours:	**45 hours**
Mode of Evaluation: CAT / Assignment / Quiz / FAT		

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, Grzegorz Iwanski, 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.

Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED607L	Microgrid Technologies	3	0	0	3
Pre-requisite	MPED501L	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.

Course Outcome

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

1. Understand the microgrid types and configurations
2. Analyze the various types of control in microgrid
3. Have enhanced knowledge on control and energy management of islanded and grid connected operation
4. Interpret the power quality problems and incorporation of protection schemes, power quality improvement technologies
5. Identify the application for the various communication protocols in microgrid

Module:1	Microgrid Configurations	5 hours

Components of Microgrid; CERTS Microgrid Test Bed; DC Microgrid; HFAC Microgrid; LFAC Microgrid; Hybrid DC and AC Coupled Microgrid; Grid Connected Mode; Islanded mode; Battery Charging mode; design of power converters for integration

Module:2	Microgrid Control Techniques	6 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	Control and Management in Standalone Microgrid	8 hours

Design of an islanded microgrid; control and optimization techniques; energy storage: energy management; Power sharing; Stability; IEEE standards; Case study

Module:4	Operation and Energy management in Grid Connected Microgrid	8 hours

Design a grid connected microgrid; Grid synchronization; Control and optimization techniques; Energy storage; Energy management; Power sharing; Stability; IEEE and CIGRE standards; Case study

Module:5	Power Quality Assessment & Enhancement	6 hours

Power Quality Issues; Impact of Power Quality on microgrid; Power Quality Improvement technologies; Compensators and controllers for power quality issues; IEEE standards

Module:6	Microgrid Protection	5 hours

Faults in AC & DC microgrid; Challenges in Microgrid Protection; Protection in grid connected and islanded mode

Module:7	Communication in Microgrid	5 hours

Communication Protocols in microgrid; architectures; standards; Local Area Network (LAN); House Area Network (HAN); Wide Area Network (WAN); Basics of Web Service and CLOUD Computing; Cyber Security for Microgrid

Module:8	Contemporary issues	2 hours

		Total Lecture hours:	**45 hours**
Textbook(s)			
1.	Nikos Hatziargyriou,(2014) Microgrids: Architectures and Control, Wiley Press		
2.	Hasan Bevrani, Bruno FranÃ§ois and Toshifumi Ise,(2017) "Microgrid Dynamics and Control" Wiley Press		
Reference Books			
1.	Hasan Bevrani, Bruno FranÃ§ois and Toshifumi Ise,(2017) "Microgrid Dynamics and Control" Wiley Press		
2.	David Wenzhong Gao, (2015) "Energy Storage for Sustainable Microgrid" Academic Press		
3.	Georgios I. Orfanoudakis , Babar Hussain , Suleiman M. Sharkh and Mohammad A. Abu-Sara, (2014) "Power Electronic Converters for Microgrids" IEEE Press		
Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test			
Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Integrated Circuits for Power Conversion	L	T	P	C
MPED608L		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 develop critical design thinking for closed loop and grid synchronization
3. To design PCB schematic and layout

Course Outcome

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

1. Compare and choose suitable carrier wave generation techniques for power converters
2. Interface sensors, ADC and DAC for closed loop power converters
3. Formulate suitable circuits for grid synchronization
4. Prepare Schematic and PCB Layout

Module:1	Switching pulse generation for power converters	6 hours
Op-Amp: Linear and Non-Linear applications; Trailing edge, leading edge, and double edge carrier wave generation; 555 Timer based application circuits; Pulse width modulation techniques: Power converters; inverters		
Module:2	**Sensor interfaces**	**4 hours**
Hall effect sensor: AC/DC Voltage and current sensors, signal gain design; 8 bit ADC and DACs		
Module:3	**Closed loop control**	**4 hours**
Power converters: Voltage regulation using analog and digital Integrated circuits, Design and tuning of PID controller parameters; Real time interface: Rapid control prototyping		
Module:4	**Grid synchronization**	**5 hours**
Voltage controlled oscillator: frequency control; grid synchronization: phase locked loop (PLL), Hardware-in-the-loop		
Module:5	**Power Supply ICs**	**5 hours**
Regulated power supply ICs: Fixed and adjustable regulators, protection schemes; Biasing circuits: analog and digital ICs; Switching regulator ICs; Opto-driver circuits; Pulse transformer: driver circuits, Multiple isolated grounds		
Module:6	**PCB Schematic and Layout Design**	**4 hours**
PCB design, Schematic design, PCB Layout, 3D Visualization; Sample PCB design for power converters		
Module:7	**Contemporary Topics**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)

1.	Robert F. Coughlin and Frederick F. Driscoll, “Operational Amplifiers and Linear Integrated Circuits”, PHI Learning Private Limited, Sixth Edition, 2015.

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.		
3.	PCB Design with Proteus – Udemy online course		
4.	Datasheets: Devices and IC’s		
Mode of Evaluation**:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test			
Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED608P	Integrated Circuits for Power Conversion 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 and asymmetric carrier waves	
2.	Switching pulse generation for non-isolated DC to DC converter	
3.	Variable frequency pulse generation using VCO	
4.	Pulse width modulation using 555 timer	
5.	PWM controlled rectifier with grid synchronization	
6.	Switching pulse generation for single phase inverter	
7.	Implementation of dual linear regulated power supply	
8.	Generation of phase shifted switching pulses	
9.	Generation of gate pulses with dead-band	
10.	Generation of overlapping gate pulses	
11.	Switching pulse generation for three phase inverter	
12.	Gate pulse generation for multilevel inverter	
13.	Preparation of schematic and PCB Layout	
	Total Laboratory Hours:	**30 hours**

Text Book(s)

Robert F. Coughlin and Frederick F. Driscoll, "Operational Amplifiers and Linear Integrated Circuits", PHI Learning Private Limited, Sixth Edition, 2015.

Reference Books

Robert L. Boylestad and Louis Nashelsky, "Electronic Devices and Circuit Theory", Prentice Hall, Eleventh Edition, 2015.

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

Recommended by Board of Studies	09-07-2022		
Approved by Academic Council	No. 67	Date	08-08-2022

Course Code	Course Title	L	T	P	C
MPED609L	Power Electronics Application in Power Systems	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

the end of the 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
Power Flow in AC Systems : importance of controllable parameters, stability Limits; Theory of static shunt and series compensation		

Module:2	SVC and STATCOM	6 hours
Objectives of shunt compensation ;SVC : Comparison of different SVC , Voltage control; STATCOM :VI Characteristics ,Dynamic compensation		

Module:3	TCSC and SSSC	6 hours
Need for variable series compensation ; TCSC: modelling of TCSC, operating control scheme,sub synchronous characteristics; SSSC: control range and VA rating		

Module:4	Phase angle Regulator	6 hours
Objectives of voltage and phase angle regulator : Thyristor controlled voltage and phase angle regulators ; Switching converter based voltage and phase angle regulator		

Module:5	Unified Power flow controller	6 hours
Operating Principle : control structure, Performance analysis		

Module:6	Application of FACTS Devices	6 hours
Sub-synchronous resonance, Damping oscillations, Transient stability and voltage stability; Coordination of FACTS		

Module:7	High Voltage DC Transmission	7 hours
Analysis of HVDC Converter: Line commutated converters and Modular Multi level converters		
Module:8	Contemporary Topics	2 hours
	Total Lecture hours:	45 hours

Textbook(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 disribution ”, 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	09-07-2022		
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