Bachelor of Technology

(B Tech)

7th Semester

Detailed Syllabus

2022 Batch

Department of

Electrical Engineering

Seventh Semester (Electrical Engineering)					
Theory					
Sl. No.	**Category**	**Course Code**	**Course Title**	**L-T-P**	**Credit**
1	PCC	22EE7PC01T	PCC-11: Introduction to Advanced Power Electronics	3-0-0	3
2	PCC	22EE7PC02T	PCC-12:Power System Protection	3-0-0	3
3	PEC	**Professional Elective-5:**			
		22EE7PE01T	Energy Audit and Sustainable Management	3-0-0	3
		22EE7PE02T	Electrical Power Quality		
		22EE7PE03T	Smart Grid Technology		
		22EE7PE04T	Artificial Intelligence and Machine Learning		
4	PEC	**Professional Elective-6:**			
		22EE7PE05T	Flexible AC Transmission System	3-0-0	3
		22EE7PE06T	Communication Engineering		
		22EE7PE07T	Energy Storage Systems and Applications		
		22EE7PE08T	Advanced Power Electronics		
5	OEC	**Open Elective-4 (To Other Branch Students)**		3-0-0	3
		22EE7OE01T	Energy Storages		
		22EE7OE02T	Energy Audit and Management		
		Open Elective-4 (To EE Branch Students)			
		22ELC7OE01T	Internet of Things		
		22ME7OE01T	Robotics(Introduction to Kinematics and Dynamics)		
		22ME7OE02T	Numerical Methods for Engineers		
		22BT7OE02T	Biology for Engineers		
		22CS7OE01T	Introduction to Machine Learning		
Total Credit (Theory)					15

Practical					
1	PCC	22EE7PC01L	Introduction to Advanced power Electronics Lab	0-0-2	1
2	PCC	22EE7PC02L	Power System Protection Lab	0-0-2	1
3	PSI	22CM7PS01L	Minor Project	0-0-6	3
4	PSI	22CM7PS02L	Summer Internship/ Training/MOOC Certification	0-0-2	1
5	HSMC	22CM7HS01L	Entrepreneurship Project	0-0-4	2
Total Credit (Practical)					**8**
Total Semester Credit					**23**

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	**Introduction to Advanced Power Electronics**	
Course Type	Theory	
Course Code	22EE7PC01T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	Advanced Power Electronics delves into the design and application of electronic circuits that control and convert electrical power. It builds upon foundational concepts, exploring more complex devices, topologies, and control strategies used in high-power applications like renewable energy, electric vehicles, and industrial systems. The field also encompasses topics such as power quality improvement, FACTS (Flexible AC Transmission Systems), and HVDC (High Voltage Direct Current) transmission.	
Objectives and Outcomes	**Objectives:** 1. To review basic concepts of power electronics in the field of power control and drives 2. To address the underlying concepts and methods behind Advanced Power Electronics	

	3. To impart knowledge of power semiconductor technologies and their advancement in the field of power conversion. 4. To design power electronic converter topologies for a broad range of energy conversion applications.	
	Outcomes: 1. Select and design power electronic converter topologies for a broad range of energy conversion applications. 2. Analyze and simulate the performance of power electronic conversion systems. 3. Ability to model and design controllers for the closed loop operation of power converters. 4. Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and energy conversion, industrial applications, extraction of energy from renewable sources	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	[1] Power Electronics: Circuits, Devices and Applications by M H Rashid, 3rd Edition, Pearson.	

	[2] Power Electronics: Converters, Applications and Design by Mohan, Undeland and Robbin, Wiley India Edition. [3] Modern Power Electronics and AC Drives by Bimal K Bose, Eastern Economy Edition, PHI
Reference Book(s)	[1] Switched Mode Power Supplies: Design and Construction by H W Whittington, B.W Flynn and D E Macpherson, 2nd Edition, Universities Press.&Sons publications.
Digital Learning Resources	Course Name: Advanced power Electronics Course Link: https://nptel.ac.in/courses/108/105/108105101/ Course Instructor: Prof.Sudipt aMukhopadhyay , IIT Kharagpur

CO's Mapping with PO's and PEO's

Course Outcomes	**Course Outcome Statement**	**PO's / PEO's**
CO1	Design dc-dc voltage regulator configurations and analysis a resonant converters	PO1, PO2, PO3, PO4,PO12
CO2	Select appropriate phase shifting converter for a multi-pulse converter	PO1, PO2, PO3, PO4
CO3	Evaluate AC and DC power supplies	PO1,PO2, PO3, PO4,PO5
CO4	Evaluate various multi-level inverter configurations	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	Switching Voltage Regulators	**08hours**
Introduction; Linear power supply (voltage regulators); Switching voltage regulators; Review of basic dc-dc voltage regulator configurations -Buck, Boost, Buck-Boost converters ,C'uk converter.		

Module No. 2	Resonant Converters	**08hours**
Introduction, Need of resonant converters, Classification of resonant converters, Load resonant converters, Resonant switch converters, zerovoltage switching dc-dc converters, zero current switching dc-dc converters		

Module No. 3	**Multipulse Converters**	**07 Hours**
Concept of multi-pulse, Configurations for m-pulse (m=12,18,24 ….) converters, Different phase shifting transformer (Y-Δ1, Y-Δ2, Y-Z1 and Y-Z2) configurations for multi-pulse converters, Applications		

Module No. 4	POWER SUPPLIES	**08 hrs**
Introduction, DC power supplies: fly back converter, forward converter, push-pull converter, half bridge converter, full bridge converter, AC power supplies: switched mode ac power supplies, resonant ac power supplies, bidirectional ac power supplies		

Module No. 5	**Multilevel inverters**	**07hrs**
Diode Clamped MLI, Flying Capacitor MLI, Cascaded H-Bridge topology: operation with equal and unequal DC voltages, Carrier modulation schemes of multilevel inverter, SVPWM of Multilevel inverter, Neutral Point Balancing schemes		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Power System Protection	
Course Type	Theory	
Course Code	22EE7PC02T	
Category	PCC (Professional Core Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	Basic understanding of Power System	
Subject Description	Power system protection is the science and practice of detecting and isolating faults (like short circuits) in electrical power grids to prevent damage and maintain system stability. It ensures safety and reliability by quickly disconnecting faulty components while minimizing disruption to the rest of the system.	
Objectives and Outcomes	1. To understand the need of protection of electric equipment and their protection schemes. 2. Introduce students to power system protection and switchgear. 3. To understand operations & characteristics of various electromagnetic and static relays. 4. To understand the operations of various types of circuit breakers and their ratings. 5. To understand the unit protection and over voltage protection of different	

	apparatus in power system. 6. To understand the unit protection and over voltage protection of different apparatus in power system. 7. Develop in students an ability and skill to design the feasible protection systems needed for each main part of a power system.	
	1. Understand the fundamental need for power system protection and identify the key components and principles involved in protective systems. 2. Analyze symmetrical and unsymmetrical faults in power systems using sequence components and fault calculation techniques. 3. Evaluate the operation and characteristics of different types of relays and protection schemes used for feeders and transmission lines. 4. Apply protection schemes for major power system apparatus and examine the working and testing of various types of circuit breakers.	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Power System Protection and Switchgear – B.Ravindranath & M.Chander– New Age International Publishers (Second Edition). 2. John J Grainger, W. D. Stevenson, “Power System Analysis”, TMH Publication. 3. Van C Warrington, “Protective Relays”, Vol.-I & II.	

<table>
<tr><td></td><td>4. Power System Protection and Switchgear - Badri Ram, Vishwakarma, Tata McGraw hill.

5. Fundamentals of Power System Protection – Y.G.Paithankar and S.R.Bhide, PHI 7th Semester REL6D001 Electric Power System</td></tr>
<tr><td>Reference Book(s)</td><td>1. Electrical Power System - C.L.Wadhwa New Age International Publishers. (Sixth Edition).

2. Protection and Switchgear - B.Bhalja, R.P.Maheshwari, N.G. Chothani, OXFORD University Press.

3. Switchgear and Protection – Sunil S Rao , Khanna Publishers, New Delhi.

4. Power System relaying by Horwitz, Phadke, Research Press</td></tr>
<tr><td>Digital Learning Resources</td><td>
<table>
<tr><td>Course Name</td><td>Power System Protection</td></tr>
<tr><td>Course Link</td><td>https://nptel.ac.in/courses/108/105/108105167/</td></tr>
<tr><td>Course Instructor</td><td>Prof. Ashok Kumar Pradhan, IIT Kharagpur</td></tr>
<tr><td>Course Name</td><td>Power System Protection and Switchgear</td></tr>
<tr><td>Course Link</td><td>https://nptel.ac.in/courses/108/107/108107167</td></tr>
<tr><td>Course Instructor</td><td>Prof. Bhaveshkumar R. Bhalja, IIT Roorkee</td></tr>
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CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Understand the fundamental need for power system protection and identify the key components and principles involved in protective systems	PO1, PO2,PO10
CO2	Analyze symmetrical and unsymmetrical faults in power systems using sequence components and fault calculation techniques	PO1, PO2, PO3, PO4, PO5, P12
CO3	Evaluate the operation and characteristics of different types of relays and protection schemes used for feeders and transmission lines.	PO1,PO2, PO3, PO4,PO5, PO10, PO12
CO4	Apply protection schemes for major power system apparatus and examine the working and testing of various types of circuit breakers	PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO11, PO12

DETAILED SYLLABUS:

Module No. 1	**Introduction:**	**06 hours**
Need for protective schemes, Nature and causes of faults, Zones of protection, Primary and back-up protection, Essential qualities of protection, Basic principle of operation of protective system, Components of Protection System		

Module No. 2	**Sequence Components and Fault Analysis:**	**06 Hours**
Significance of positive, negative and zero sequence ,sequence impedance, fault calculations, sequence network equations, Single line to ground fault, Line to ground fault with Zf, Faults in Power systems, and Concept of short circuit capacity of a Bus		

Module No. 3	**Operating Principles and Relay Construction:**	**08 Hours**
Relay Classification, Types of Electromagnetic Relays, Relay design and construction, Theory of Induction relay torque, General Equations of Comparators and Electromagnetic Relays, Over Current relays, Directional relays, Distance relays, Differential relays. Feeder Protection: Over current, Distance and. Static Relays: Basis for static relay development, Basic elements of a static relay, Over Current Relays, Differential Protection, Static distance Protection..		

Module No. 4	**Apparatus Protection:**	**08Hours**
Transformer Protection, Generator Protection, Motor Protection, Bus bar protection schemes. Numerical relays: Block Diagram of Numerical Relay, Signal Sampling & Processing, Numerical Over-current protection, Numerical Transformer differential Protection, Numerical distance Protection of Transmission Line		

Module No. 5	Switchgears: Auto reclosing:	07 Hours
Theory of Circuit interruption, Circuit constants in relation to Circuit breaking, Re-striking voltage transient, characteristics of Re-striking Voltage, Interaction between breaker and circuit, Current chopping. Circuit Breakers: Types of circuit breakers (air blast, air break, oil, vacuum, SF6, DC circuit breaker), advantages and testing of circuit breaker		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Energy Auditing and Sustainable Management	
Course Type	Theory	
Course Code	22EE7PE01T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	Energy auditing and sustainable management are processes focused on improving energy efficiency and reducing environmental impact. Energy auditing identifies where and how energy is used, while sustainable management implements strategies to reduce consumption and optimize resource use. Together, they help organizations minimize energy cost and reduce the carbon footprint.	
Objectives	1. To facilitate the students to achieve a clear conceptual understanding of technical and commercial aspects of energy conservation and energy auditing. 2. To enable the students to develop managerial skills to assess feasibility of alternative approaches and drive strategies regarding energy conservation and	

and	energy auditing	
Outcomes	1. Conceptual knowledge of the technology, economics and regulation related issues associated with energy conservation and energy auditing 2. Ability to analyze the viability of energy conservation projects 3. Capability to integrate various options and assess the business and policy environment regarding energy conservation and energy auditing 4. Advocacy of strategic and policy recommendations on energy conservation and energy auditing.	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1.Energy Management: W. R. Murphy, G. Mckay (Butterworths). 2.Energy Management Principles: C. B. Smith (Pergamon Press). 3.Efficient Use of Energy : I. G. C. Dryden (Butterworth Scientific) 4.Energy Economics - A. V. Desai (Wiley Eastern) 5.Industrial Energy Conservation : D. A. Reay (Pergammon Press) 6.Energy Management Handbook – W. C. Turner (John Wiley and Sons, A Wiley Interscience Publication)	
Reference Book(s)	1. Industrial Energy Management and Utilization – L. C. Witte, P. S. Schmidt, D. R. Brown (Hemisphere Publication, Washington) 2. Industrial Energy Conservation Manuals, MIT Press, Mass, 1982	

	3. Energy Conservation guide book Patrick/Patrick/Fardo (Prentice Hall)
Digital Learning Resources	Course Name: Energy management System Course Link: https://nptel.ac.in/courses/108106022 Course Instructor: Dr. K. Shanti Swarup, IIT Madras

CO's Mapping with PO's and PEO's

Course Outcomes	**Course Outcome Statement**	**PO's / PEO's**
CO1	Conceptual knowledge of the technology, economics and regulation related issues associated with energy conservation and energy auditing	PO1, PO2, PO3, PO4,PO12
CO2	Ability to analyze the viability of energy conservation projects .	PO1, PO2, PO3, PO4
CO3	Capability to integrate various options and assess the business and policy environment regarding energy conservation and energy auditing	PO1,PO2, PO3, PO4,PO5
CO4	Advocacy of strategic and policy recommendations on energy conservation and energy auditing	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**General Aspects :**	**06 hours**
General Philosophy and need of Energy Audit and Management. Definition and Objective of Energy Management, General Principles of Energy Management, Energy Management Skills, Energy Management Strategy. Energy Audit: Need, Types, Methodology and Approach. Energy Management Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution		

Module No. 2	**Procedures and Techniques:**	**09 Hours**
Data gathering: Level of responsibilities, energy sources, control of energy and uses of energy get Facts, figures and impression about energy /fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering. Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation. Evaluation of saving opportunities: Determining the savings in Rs, Noneconomic factors, Conservation opportunities, estimating cost of implementation. Energy Audit Reporting: The plant energy study report- Importance, contents, effective organization, report writing and presentation.		

Module No. 3	Energy Policy Planning and Implementation:	07 Hours
Key Elements: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation. Format and Ratification, Organizing: Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability. Motivating Motivation of employees, Requirements for Energy Action Planning. Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning		

Module No. 4	Energy Balance & MIS	6 Hours
First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses, Improvements. Energy Balance sheet and Management Information System (MIS) Energy Modeling and Optimization		

Module No. 5	Energy Audit Instruments	05 Hours
Instruments for Audit and Monitoring Energy and Energy Savings, Types and Accuracy		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Power Quality	
Course Type	Theory	
Course Code	22EE7PE02T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	Power quality refers to the characteristics of the electrical power delivered to equipment, ensuring it operates as intended without performance degradation or damage. It encompasses aspects like voltage magnitude, frequency, waveform purity, and stability. Essentially, it's about maintaining a reliable and clean power supply	
Objectives and	1. Causes & Mitigation techniques of various PQ events. 2. Various Active & Passive power filters	
	1. Ability to understand various sources, causes and effects of power quality issues, electrical systems and their measures and mitigation.	

Outcomes	2. Ability to analyze the causes & Mitigation techniques of various PQ events And various Active & Passive power filters. 3. Ability to understand the concepts about Voltage and current distortions, harmonics. 4.To acquire knowledge on compensation techniques and DVR	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	[1] Roger. C. Dugan, Mark. F. Mc Granagham, Surya Santoso, H.WayneBeaty, 'Electrical Power Systems Quality' McGraw Hill,2003.(For Chapters1,2,3, 4 and 5). [2] Eswald.F.Fudis and M.A.S.Masoum, "Power Quality in Power System and Electrical Machines," Elseviar Academic Press, 2013. [3] J. Arrillaga, N.R. Watson, S. Chen, 'Power System Quality Assessment', Wiley, 2011.	
Reference Book(s)	[1] G.T. Heydt, 'Electric Power Quality', 2nd Edition. (West Lafayette, IN, Stars in a Circle Publications, 1994). (For Chapter 1, 2, 3 and 5) [2] M.H.J Bollen, 'Understanding Power Quality Problems: Voltage Sags and Interruptions', (New York: IEEE Press, 1999). (For Chapters 1, 2, 3 and 5) [3] G.J.Wakileh, "Power Systems Harmonics – Fundamentals, Analysis and	

Filter Design," Springer 2007.

[4] E.Aeha and M.Madrigal, "Power System Harmonics, Computer Modelling and Analysis, " Wiley India, 2012.

[5] R.S.Vedam, M.S.Sarma, "Power Quality – VAR Compensation in Power Systems," CRC Press 2013.

[6] C. Sankaran, 'Power Quality', CRC press, Taylor & Francis group, 2002

Digital Learning Resources

Course Name	Power Quality
Course Link	https://onlinecourses.nptel.ac.in/noc21_ee103/preview
Course Instructor	Dr. Bhim Singh, IIT Delhi

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Ability to understand various sources, causes and effects of power quality issues, electrical systems and their measures and mitigation	PO1, PO2, PO3, PO4,PO12
CO2	Ability to analyze the causes & Mitigation techniques of various PQ events and various Active & Passive power filters	PO1, PO2, PO3, PO4
CO3	Ability to understand the concepts about Voltage and current distortions, harmonics	PO1,PO2, PO3, PO4,PO5
CO4	To acquire knowledge on compensation techniques and DVR	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	Introduction to power quality	08 hours
Terms and definitions: Overloading – under voltage – over voltage. Concepts of transients – short duration variations such as interruption – long duration variation such as sustained interruption. Sags and swells – voltage sag – voltage swell – voltage imbalance – voltage fluctuation – power frequency variations. International standards of power quality. Computer Business Equipment Manufacturers Associations (CBEMA) curve.		

Module No. 2	Voltage Sags And Interruptions	08 Hours
Sources of sags and interruptions – estimating voltage sag performance. Thevenin's equivalent source – analysis and calculation of various faulted condition. Voltage sags due to induction motor starting. Estimation of the sag severity – mitigation of voltage sags, active series compensators. Static transfer switches and fast transfer switches, **Reliability indices**		

Module No. 3	Over voltages	06 Hours
Sources of over voltages – Capacitor switching – lightning – ferro resonance. Mitigation of voltage swells – surge arresters – low pass filters – power conditioners. Lightning protection – shielding – line arresters – protection of transformers and cables. An introduction to computer analysis tools for transients, PSCAD and EMTP		

Module No. 4	Harmonics	08 Hours
Harmonic sources from commercial and industrial loads, locating harmonic sources. Power system response characteristics – Harmonics Vs transients. Effect of harmonics – harmonic distortion – voltage and current distortion – harmonic indices – inter harmonics – resonance. Harmonic distortion evaluation – devices for controlling harmonic distortion – passive and active filters. IEEE and IEC standards.		

Module No. 5	Power Quality Monitoring	09 Hours
Monitoring considerations – monitoring and diagnostic techniques for various power quality problems – modeling of power quality (harmonics and voltage sag) problems by mathematical simulation tools – power line disturbance analyzer – quality measurement equipment – harmonic / spectrum analyzer – flicker meters – disturbance analyzer. Applications of expert systems for power quality monitoring		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Smart Grid Technology	
Course Type	Theory	
Course Code	22EE7PE03T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	A smart grid is an advanced electricity network that utilizes digital technologies and two-way communication to improve the efficiency, reliability, and sustainability of electricity delivery. It integrates digital technologies like sensors, smart meters, and automation to monitor, control, and optimize the flow of electricity from generation to consumption	

<table>
<tr><td rowspan="2">Objectives
and
Outcomes</td><td colspan="2">1. Smart electric power grids, including definition, design criteria and technology. Information processing and communications to the power grid.
2. Understanding the development of the smart grid, Smart grid design, implementation, evaluation and management of smart electricity infrastructure.
3. To provide students with a working knowledge of fundamentals and development of Smart Grid, from the basic concepts of power systems.</td></tr>
<tr><td colspan="2">1. Understand features of Smart Grid in the context of Indian Grid.
2. Analyze the role of automation in Transmission/Distribution
3. Apply Evolutionary Algorithms for the Smart Grid/Distribution Generation.
4. Understand operation and importance of PMUs, PDCs, WAMS, Voltage and Frequency control in Micro Grids</td></tr>
<tr><td rowspan="9">Assessment/
Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
<tr><td>End-Term Examination</td><td>50 %</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2">[1] Mani Vadari, Smart Grid Redefined: Transformation of the electric utility, Artech House, 2018.
[2] Stuart Borlase, Smart Grids, Infrastructure, Technology and Solutions, CRC Press,2013
[3] A.G. Phadke and J.S. Thorp, “Synchronized Phasor Measurements and their Applications”, Springer Edition, 2010</td></tr>
</table>

Reference Book(s)	[1] M. L. Scala, S. Bruno, C. A. Nucci, S. Lamonaca, U. Stecch, "Smart Grids to the Smart Cities: New Paradigms for Future Networks", Vol-II, Wiley publication, 2017 [2] Gil Masters, Renewable and Efficient Electric Power System, Wiley–IEEE Press, 2004. [3] T. Ackermann, Wind Power in Power Systems, Hoboken, NJ, USA, John Wiley,2005 [4] N. Ramesh Babu, Smart Grid Systems: Modeling and Control, 1st ed, CRC Press, 2019 .
Digital Learning Resources	

Course Name	Introduction to Smart Grid
Course Link	https://nptel.ac.in/courses/108107113
Course Instructor	Dr. N.P.Padhy and Dr. Premalata Jena, IIT Roorkee

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Understand features of Smart Grid in the context of Indian Grid	PO1, PO2, PO3, PO4,PO12
CO2	Analyze the role of automation in Transmission/Distribution .	PO1, PO2, PO3, PO4
CO3	Apply Evolutionary Algorithms for the Smart Grid/Distribution Generation	PO1,PO2, PO3, PO4,PO5
CO4	Understand operation and importance of PMUs, PDCs, WAMS, Voltage and Frequency control in Micro Grids	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**Introduction to Smart Grid:**	**06 hours**
Introduction to Smart Grid - Working definitions of Smart Grid and Associated Concepts – Smart Grid Functions – Traditional Power Grid and Smart Grid – New Technologies for Smart Grid – Advantages – Indian Smart Grid – dimensions of smart grid-Key Challenges for Smart Grid.		

Module No. 2	**Smart Grid Architecture:**	**09 Hours**
Components and Architecture of Smart Grid Design – Review of the proposed architectures for Smart Grid. The fundamental components of Smart Grid designs – Transmission Automation – Distribution Automation – Renewable and distributed energy Integration Tools and Techniques for Smart Grid: Computational Techniques – Static and Dynamic Optimization Techniques – Computational Intelligence Techniques – Evolutionary Algorithms, Artificial Intelligence techniques.		

Module No. 3	Distribution Generation Technologies	07 Hours
:Introduction to Renewable Energy Technologies – Micro grids– Storage Technologies –Electric Vehicles and plug – in hybrids – Environmental impact and Climate Change – Economic Issues		

Module No. 4	Communication Technologies and Smart Grid	6 Hours
Introduction to Communication Technology-Synchro-Phasor Measurement Units (PMUs) – Wide Area Measurement Systems (WAMS)		

Module No. 5	Control of Smart Power Grid System and Smart Cities:	05 Hours
Load Frequency Control (LFC) in Micro Grid System – Voltage Control in Micro Grid System – Reactive Power Control in Smart Grid. Case Studies and Test beds for the Smart Grids, Smart Grids to the Smart Cities: New Paradigms for Future Networks		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Artificial Intelligence and Machine Learning	
Course Type	Theory	
Course Code	22EE7PE04T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	Artificial intelligence encompasses the idea of a machine that can mimic human intelligence, machine learning does not. Machine learning aims to teach a machine how to perform a specific task and provide accurate results by identifying patterns.	
Objectives and Outcomes	1. Introduce the basic principles, techniques, and applications of Artificial Intelligence. 2. Demonstrate fundamental understanding of the history of artificial intelligence (AI) and its foundations. 3. Apply basic principles of AI in solutions that require problem solving, inference, perception, knowledge representation, and learning.	

	4. To understand the basic theory underlying machine learning. 5. To be able to formulate machine learning problems corresponding to different applications. 6. To understand a range of machine learning algorithms along with their strengths and weaknesses. 7. To be able to apply machine learning algorithms to solve problems of moderate complexity.	
	1. Analyze AI and searching methods. 2. Plan knowledge management, uncertainty management. 3. Apply neural network learning. 4. Construct and implement extended neural network learning methods. and Develop probabilistic and statistical learning	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Applied Machine Learning, M.Gopal, McGraw-Hill. 2. Artificial Intelligence and Soft Computing: Behavioral and Cognitive Modeling of the Human Brain, Amit Konar, CRC Press 3. Artificial Intelligence, Dan W Patterson, Prentice Hall of India	

<table>
<tr><td></td><td>4. S. Russel and P. Norvig, “Artificial Intelligence – A Modern Approach”, Second Edition, Pearson Education .</td></tr>
<tr><td>Reference Book(s)</td><td>1. Artificial Intelligence, Nils J.Nilsson, ELSEVIER.
2. E.Rich and K.Knight, Artificial Intelligence, - TMH</td></tr>
<tr><td>Digital Learning Resources</td><td>
<table>
<tr><td>Course Name</td><td>Machine Learning, ML</td></tr>
<tr><td>Course Link</td><td>https://nptel.ac.in/courses/106106202</td></tr>
<tr><td>Course Instructor</td><td>Prof. Carl Gustaff Janssan, Prof. Henrik Bostorm, Prof. Fredrik Kilander</td></tr>
<tr><td>Course Name</td><td>Artificial Intelligence</td></tr>
<tr><td>Course Link</td><td>https://nptel.ac.in/courses/106105077</td></tr>
<tr><td>Course Instructor</td><td>Prof. Anupam Basu and Prof. S. Sarkar, IIT Kharagpur</td></tr>
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CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Analyze AI and searching methods.	PO1, PO2, PO3, PO4,PO12
CO2	Plan knowledge management, uncertainty management	PO1, PO2, PO3, PO4
CO3	Apply neural network learning	PO1,PO2, PO3, PO4,PO5
CO4	Construct and implement extended neural network learning methods. And Develop probabilistic and statistical learning.	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**Introduction to AI and Search Techniques:**	**06 hours**
Introduction to AI, production system, production rules, State-space problem, Problem Solving by Intelligent search: BFS, DFS, Iterative Deepening Search, Hill Climbing, Simulated Annealing, heuristic Search: A*,AO* , Adversary Search: MIN-MAX Algorithm, Alpha-Beta Cut-off algorithm.		

Module No. 2	**Knowledge and Reasoning Propositional Logic**	**07 Hours**
Theorem Proving by Propositional Logic, Resolution principle, Predicate Logic, wff conversion to clausal form, Dealing with Imprecision and Uncertainty: Probabilistic Reasoning, Dempster-Shafer Theory for Uncertainty Management.		

Module No. 3	**Machine Learning:**	**06 Hours**

Supervised learning, unsupervised learning, Reinforcement learning, Artificial Neural Net, perceptron model, feed-forward neural network, Back propagation

Module No. 4	**Computational learning**	**08 Hours**
Computational learning tasks for predictions, learning as function approximation, generalization concept. Linear models and Nearest-Neighbors (learning algorithms and properties, regularization). Neural Networks (MLP and deep models, SOM		

Module No. 5	**Probabilistic graphical models**	**08 Hours**
Principles of learning processes: elements of statistical learning theory, model validation. Support Vector Machines and kernel-based models. Introduction to applications and advanced models		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Flexible AC Transmission Systems	
Course Type	Theory	
Course Code	22EE7PE05T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	A Flexible AC Transmission System (FACTS) is a power electronics-based system designed to enhance the controllability and power transfer capability of AC transmission networks. It utilizes static controllers to improve the dynamic and static transmission capacity of electrical grids, addressing limitations like power flow control, voltage stability, and transient oscillations	
Objectives and Outcomes	1. The students would be able to learn the general concepts of power system, Power Flow and Dynamic Stability Considerations of a Transmission Interconnection, classification of FACTS controller, objective of shunt and series compensation. 2. The students should learn how to represent the variable impedance type shunt compensators system and VSC based shunt compensator. 3. The students should learn how to represent the variable impedance type series compensators system and VSC based series compensator.	

	4. Students can be able to learn generalized and multifunctional FACTS Controller.	
	1. Describe how FACTS controllers are designed. 2. Explain and analyze the various controllers used in shunt and series compensators. 3. Perform calculations on different control strategies for these shunt and series controllers. 4. Analyze performance characteristics of system using various FACTS controller methods	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Understanding FACTS: Concepts & Technology of Flexible AC Transmission Systems" By N.G.Hingorani & L.Gyugyi, IEEE Press, Standard Publishers Distributors, Delhi	
Reference Book(s)	1. Facts Controllers in Power Transmission & Distribution by K.R.Padiyan, New Age International. 2. Modeling & Simulation in Power Networks, Enrique Acha, Clandio Esquival & H.A.Perez, CA Camcho, John Wiley & Sons	

Digital Learning Resources	

Course Name	FACTS
Course Link	https://nptel.ac.in/courses/108107114
Course Instructor	Prof. Avik Bhattacharya, IIT Roorkee

CO's Mapping with PO's and PEO's

Course Outcomes	**Course Outcome Statement**	**PO's / PEO's**
CO1	Describe how FACTS controllers are designed	PO1, PO2, PO3, PO4,PO12
CO2	Explain and analyze the various controllers used in shunt and series compensators.	PO1, PO2, PO3, PO4
CO3	Perform calculations on different control strategies for these shunt and series controllers	PO1,PO2, PO3, PO4,PO5
CO4	Analyze performance characteristics of system using various FACTS controller methods	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**Introduction:**	**08 hours**
FACTS concept and General System Considerations: Transmission Interconnections, Flow of Power in an AC System, Loading Capability, Power Flow and Dynamic Stability Considerations of a Transmission Interconnection, Relative Importance of Controllable Parameters, and FACTS Controllers.		

Module No. 2	**Static Shunt Compensation:**	**08 Hours**
Objectives of shunt compensation, Methods of controllable VAR generation, Static Var Compensator, its characteristics, TCR, TSC, FC-TCR configurations, STATCOM, basic operating principle, control approaches and characteristics		

Module No. 3	**Series Compensation**	**08 Hours**
Objectives of series compensator, variable impedance type of series compensators, TCSC, TSSC-operating principles and control schemes, SSSC, Power Angle characteristics, Control range and VAR rating, Capability to provide reactive power compensation, external control		

Module No. 4	**Static Voltage and Phase Angle Regulators:**	**06 Hours**
Objectives of Voltage and Phase Angle Regulators, Approaches to Thyristor-Controlled Voltage and Phase Angle Regulators (TCVRs and TCPARs).		

Module No. 5	**Combined Compensators:**	**06 Hours**
Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC), Generalized and Multifunctional FACTS Controllers		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Communication Engineering	
Course Type	Theory	
Course Code	22EE7PE06T	
Category	PE (Professional Elective Course)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	Communication engineering focuses on the systems and technologies that enable the transmission of information. It involves designing, developing, and maintaining the hardware and software that underpin communication networks, including everything from basic circuits to complex systems like the internet and satellite communication. Essentially, it's about making sure information gets from one place to another reliably and efficiently.	
Objectives and Outcomes	**Objectives:** 1. Concept of time and frequency domain analysis of signals used in communication systems. 2. Understand various analog modulation techniques and their applications in real world scenario.	

	3. Application of the Sampling theorem in analog-to-digital conversion process and understand the limits of practical sampling techniques. 4. Various modulation techniques used for digital representation of analog signals.	
	Outcomes: 1. Analyze frequency response of signals and illustrate the concepts of random variables used in communication systems. 2. Explain the concept of continuous wave modulation techniques and evaluate in terms of Power, bandwidth, etc. 3. Summarize the concept of sampling in various pulse modulation techniques in signal transmission. 4. Explain and analyze techniques used for transmission of analog signal in digital form.	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	[1] H. Taub, D. L Schilling, G. Saha; *Principles of Communication System*, 4th Edition; 2013, McGraw Hill, India. [2] B. P. Lathi, Zhi Ding; *Modern Digital and Analog Communication Systems*, 4th Edition; 2017, Oxford University Press	

Reference Book(s)	[1] Masoud Salehi, John G. Proakis; *Communication System Engineering*, 2nd Edition, Pearson, 2015. [2] P Ramakrishna Rao; *Analog Communication*, 1st Edition, Tata McGraw-Hill, 2011.		
Digital Learning Resources	Course Name	Analog Communication	
	Course Link	https://www.nptel.ac.in/courses/117/105/117105143/	
	Course Instructor	Prof. Goutam Das, Department of ECE, IIT Kharagpur	

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Analyze frequency response of signals and illustrate the concepts of random variables used in communication systems.	PO1, PO2, PO3, PO5
CO2	Explain the concept of continuous wave modulation techniques and evaluate in terms of Power, bandwidth, etc.	PO1, PO2, PO3, PO4,PO5
CO3	Summarize the concept of sampling in various pulse modulation techniques in signal transmission	PO1,PO2, PO3, PO4,PO5, ,PO7
CO4	Explain and analyze techniques used for transmission of analog signal in digital form	PO1, PO2, PO3, PO5, PO7.PO8

DETAILED SYLLABUS:

Module No. 1	Frequency Domain Analysis of Signals and Systems	6 hrs
Signals and Spectra: Elements of communication System, Communication Channels and their Characteristics, Mathematical Models for Communication Channels. Fourier series, Fourier Transforms, Properties, Power and Energy signal. **(Ref: TB 1, Ch 1)**		

Module No. 2	Amplitude Modulation Systems	10 hrs
Need of modulation, linear and nonlinear type of modulation, Frequency translation, Amplitude Modulation: Time and frequency analysis of DSB-C, DSB-SC, SSB and VSB Modulation. Modulators and demodulators: Square law modulator, switching modulator, square law detection and envelope detection, Concept of Frequency Division Multiplexing. **(Ref: TB 1, Ch 2)**		

Module No. 3	Angle Modulation:	7 hrs
Angle Modulation, types of angle modulation (FM and PM), Comparison: modulation index, sidebands, power and phasor diagram, Tone Modulated FM Signal, Arbitrary Modulated FM signal, Concept of narrowband and wideband FM(PM), FM Modulators: Direct & Indirect methods, Demodulators: limiter and discriminator. **(Ref: TB 1, Ch 3)** Radio Transmitter and Receiver: FM and AM Super heterodyne receiver, image frequency and its rejection, FM stereo broadcasting.		

Module No. 4	Digital Transmission of Analog Signal and Pulse Modulation:	7 hrs
Concept of sampling, types of sampling, Time and frequency analysis of Sampling Theorem **(Ref: TB 2, Ch 5/TB1. Ch 4)** **Pulse Modulation:** Pulse Amplitude Modulation: bandwidth, generation and recovery, Time division multiplexing of PAM signals, Pulse Width Modulation and Pulse Position Modulation. **(Ref: TB 1, Ch 4)**		

Module No. 5	Digital Representation of Analog Signal	6 hrs
Quantization of signals, Quantization error, Pulse Code Modulation, Commanding, Line coding techniques, Delta Modulation, Adaptive delta modulation. **(Ref: TB 1, Ch 4)**		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Energy Storage Systems and Applications	
Course Type	Theory	
Course Code	22EE7PE07T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	Energy storage systems (ESS) are designed to store energy for later use, addressing mismatches between energy supply and demand. They play a crucial role in integrating renewable energy sources like solar and wind into the grid by mitigating intermittency and variability. ESS applications range from personal devices and appliances to large-scale grid support, including power quality, microgrids, and utility-level storage.	
Objectives and Outcomes	To energy storage systems and provides a broad understanding and appreciation of the scientific principles that underpin the operation of such systems. To provide a foundation for understanding the general principles and fundamentals of Li-Ion battery technology design and operation. To learn basic electrochemical principles of the hydrogen fuel cells, basic fuel cell design concepts, fuel cell systems concepts.	

	The on grid-scale (or utility-scale) energy storage as a means of addressing the intermittency of renewable energy components (e.g. solar or wind power systems) of modern electricity networks	
	Understand various energy storage technologies. Develop an algorithm to estimate the state of charge and state of health of a battery Develop the energy management control of a storage system in a grid connected Develop the control algorithm to a grid-connected storage system to improve the grid reliability	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Grid-scale Energy Storage Systems and Applications, Fu-Bao Wu, Bo Yang, Ji-Lei Ye, Elsevier - Academic Press, 2019, 1st edition. 2. Energy Storage Devices for Renewable Energy-Based Systems, Nihal Kularatna Kosala Gunawardane, Elsevier - Academic Press, 2019, 2nd edition. 3. Ultra-Capacitors in Power Conversion Systems: Applications, Analysis, and Design from Theory to Practice, Petar J. Grbovic, Wiley-IEEE Press, 2013, 1st edition.	

Reference Book(s)	1. Energy Storage: A New Approach, Ralph Zito, Haleh Ardebili, Wiley, 2019, 2nd Edition. 2. Energy Storage for Power System Planning and Operation, Zechun Hu , Wiley, 2020, 1st edition. 3. Fuel Cell Systems Explained, Andrew L. Dicks, David A. J. Rand, Wiley, 2018, 3rd Edition
Digital Learning Resources	Course Name: Electrochemical Energy Storage Course Link: https://nptel.ac.in/courses/113105102 Course Instructor: Prof. Subhasish Basu Majumder, IIT Kharagpur

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Understand various energy storage technologies	PO1, PO2, PO3, PO4,PO12
CO2	Develop an algorithm to estimate the state of charge and state of health of a battery	PO1, PO2, PO3, PO4
CO3	Develop the energy management control of a storage system in a grid connected	PO1,PO2, PO3, PO4,PO5
CO4	Develop the control algorithm to a grid-connected storage system to improve the grid reliability	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**Development of energy storage technology:**	**08 hours**
Basic concept, history of energy storage technologies, demand functions of energy storage technology in power system, application outlook and challenges of energy storage technology in power system		

Module No. 2	**Technology of energy storage systems:**	**09 Hours**
Electrochemical energy storage: lead-acid battery, lithium-ion battery, vanadium redox battery, zinc-bromine, sodium sulphur; physical energy storage: pump hydro storage compressed air energy storage, flywheel energy storage; electromagnetic energy storage: super capacitor energy storage, superconducting magnetic energy storage; new type energy storage: advanced lead-acid batter, lithium-sulphur battery, sodium-ion battery, heat pump storage, gravity energy storage; comprehensive comparison of energy storage technologies: technical maturity, performance parameters, applications		

Module No. 3	**Technologies for battery management:**	**08 Hours**
Battery management systems: typical structures, main functions; state of charge (SOC) estimation method: definition, the methods of SOC estimation; state of health (SOH) estimation technology: definition, methods for SOH estimation; balance management technology; protection technology: overvoltage protection, under voltage protection, overcurrent protection, short circuit protection, over temperature protection.		

Module No. 4	**Operation control technology of energy storage systems:**	**06 Hours**
grid connected operation control technology: AC/DC converter control, DC/DC converter control, island detection, low voltage ride through; off-grid operation control technology: control of switching from on-grid to off-grid, synchronization control of the switching from off-grid to on-grid		

Module No. 5	Application of energy storage technology	05 Hours
Application of energy storage technology in grid-connected energy power generation: Impact of energy storage system on gird-connected energy storage power generation: smooth power fluctuation		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Introduction to Advanced Power Electronics	
Course Type	Theory	
Course Code	22EE7PE08T	
Category	PEC (Professional Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge		
Subject Description	Advanced Power Electronics delves into the design and application of electronic circuits that control and convert electrical power. It builds upon foundational concepts, exploring more complex devices, topologies, and control strategies used in high-power applications like renewable energy, electric vehicles, and industrial systems. The field also encompasses topics such as power quality improvement, FACTS (Flexible AC Transmission Systems), and HVDC (High Voltage Direct Current) transmission	
Objectives and Outcomes	5. To review basic concepts of power electronics in the field of power control and drives 6. To address the underlying concepts and methods behind Advanced Power Electronics 7. To impart knowledge of power semiconductor technologies and their advancement in the field of power conversion.	

	8. To design power electronic converter topologies for a broad range of energy conversion applications.	
	5. Select and design power electronic converter topologies for a broad range of energy conversion applications. 6. Analyze and simulate the performance of power electronic conversion systems. 7. Ability to model and design controllers for the closed loop operation of power converters. 8. Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and energy conversion, industrial applications, extraction of energy from renewable sources	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	[4] [Power Electronics: Circuits, Devices and Applications by M H Rashid, 3rd Edition, Pearson. [5] Power Electronics: Converters, Applications and Design by Mohan, Undeland and Robbin, Wiley India Edition.	

	[6] Modern Power Electronics and AC Drives by Bimal K Bose, Eastern Economy Edition, PHI.
Reference Book(s)	[1] Switched Mode Power Supplies: Design and Construction by H W Whittington, B.W Flynn and D E Macpherson, 2nd Edition, Universities Press.& Sons publications.
Digital Learning Resources	

Course Name	Biomedical Signal Processing
Course Link	https://nptel.ac.in/courses/108/105/108105101/
Course Instructor	Prof. Sudipta Mukhopadhyay , IIT Kharagpur

CO's **Mapping with PO's and PEO's**

Course Outcomes	**Course Outcome Statement**	**PO's / PEO's**
CO1	Select and design power electronic converter topologies for a broad range of energy conversion applications	PO1, PO2, PO3, PO4,PO12
CO2	Analyze and simulate the performance of power electronic conversion systems	PO1, PO2, PO3, PO4
CO3	Ability to model and design controllers for the closed loop operation of power converters	PO1,PO2, PO3, PO4,PO5
CO4	Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and energy conversion, industrial applications, extraction of energy from renewable sources	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**Review of power semiconductor devices:**	**06 hours**
Thyristor, IGBT, MOSFET, IGCT, GTO and their driver circuits, role of SiC in power semiconductor technology		

Module No. 2	**AC-DC converter:**	**08 Hours**
Semi-controlled rectifiers, fully controlled rectifiers with R, RL and RLE load, effect of source inductance on performance of converter, firing schemes and circuits, MULTIPULSE CONVERTERS: Multi-pulse converters: 12,18 and 24 pulse converters, phase shifting transformers POWER FACTOR: power factor improvement techniques, PWM rectifiers: equal area PWM, sine PWM, Single Phase and Three phase boost rectifier circuits		

Module No. 3	**DC-AC converters:**	**08 Hours**
Voltage Source Inverter: 120º and 180º conduction modes, PWM techniques of voltage fed converters: Selective Harmonic Elimination (SHE), sine modulation, Third harmonic injection, Hysteresis Current Control, Sigma-Delta Modulation, Space Vector Pulse Width Modulation: under modulation and over modulation and their implementation Current Source Inverter: Current Source inverters		

Module No. 4	Multilevel inverters:	08 Hours
Diode Clamped MLI, Flying Capacitor MLI, Cascaded H-Bridge topology: operation with equal and unequal DC voltages, Carrier modulation schemes of multilevel inverter, SVPWM of Multilevel inverter, Neutral Point Balancing schemes		

Module No. 5	Advance Electrical Drives	08 Hours
: Brushless DC motor: Sinusoidal and Trapezoidal BLDC motor, Electronic Commutator, Torque production in BLDC motor, Control of Brushless DC drives Switched Reluctance Motor: Elementary Operation and Principle of operation, Modes of operation, Converter circuits for SRM: Asymmetric Bridge Converter, R-Dump, Bifilar Type converter		

COURSE DESCRIPTION:

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Introduction to Advanced power electronics Lab	
Course Type	Laboratory	
Course Code	22EE7PC01L	
Category	PCC (Professional Core Courses)	
Credit Point	1	
Time Commitment	Lecture	Nil
	Tutorial	Nil
	Practice	20 Hours
	Total	20 Hours
Recommended Background Knowledge/Course Pre-requisites	Knowledge of basics of power Electronics and MTLAB	
Subject Description	This laboratory course is designed to provide hands-on experience in **advanced power electronic circuits, converters, and control techniques**. Students will implement, test, and analyze high-performance power conversion systems that are widely used in industrial automation, renewable energy systems, electric vehicles, and smart grid applications. The lab complements the theory course by focusing on practical realization, simulation, and hardware testing of devices such as **multi-level inverters, soft-switching converters, resonant converters, DC-DC converters**, and **PWM techniques**. Students will also learn to use modern simulation tools like	

	MATLAB/Simulink	
Objectives and Outcomes	[1] Provide hands-on experience with advanced power electronic circuits such as DC-DC converters, inverters, and multilevel converters. [2] Develop skills in using simulation tools like MATLAB/Simulink, [3] Facilitate understanding of key performance parameters like efficiency, THD, switching losses, and thermal behavior. [4] Promote safety awareness, experimental documentation, and teamwork in a lab environment. [5] Encourage practical design thinking through project-based learning or mini-projects.	
	[1] Analyze the working principles of advanced power electronic circuits and converter topologies [2] Implement and control converters and inverters [3] Apply knowledge to design and test converter circuits for real-time applications in EVs, PV, or motor drives. [4] Conduct experiments, collect data, and interpret performance parameters like THD and, efficiency	
Assessment/ Evaluation	Lab Experiments	20%
	Record Writing	10%
	Behavior/ Attitude	05%
	Quiz	10%
	Attendance	05%
	Final Lab Test	30%
	Final Viva/ Final Lab Quiz Test	20%
Prescribed Text	Power Electronics: Converters, Applications, and Design	

Book(s)	**Authors**: Ned Mohan, Tore M. Undeland, William P. Robbins **Edition**: 3rd Edition **Publisher**: Wiley India **ISBN**: 978-8126521901 *MATLAB/Simulink for Power Electronics Simulation* **Author**: Muhammad H. Rashid (or equivalent Simulink guidebooks)
Digital Learning Resources	Course Name: Advanced Power Electronics Course Link: https://nptel.ac.in/courses/108107128 Course Instructor: Prof. Avik Bhattacharya (IIT-Roorkee)

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Analyze the working principles of advanced power electronic circuits and converter topologies	PO1 and PO2
CO2	Implement and control converters and inverters	. PO3,PO5
CO3	Apply knowledge to design and test converter circuits for real-time applications in EVs, PV, or motor drives.	PO3,PO5,PO4
CO4	Conduct experiments, collect data, and interpret performance parameters like THD and, efficiency	PO3,PO5,PO4,PO6

DETAILED SYLLABUS (EXPERIMENTS):

Sl. No.	Name of Experiments	Duration in Hrs
1	Develop a Matlab/Simulink model of buck converter	2
2	Develop a Matlab/Simulink model of boost converter	2
3	Develop a Matlab/Simulink model of buck-boost converter	2
4	Develop a Matlab/Simulink model of flyback converter	2
5	Develop a Matlab/Simulink model of push-pull converter	2
6	Develop a Matlab/Simulink model of cuk regulator	2
7	Develop a Matlab/Simulink model of SVM technique	2
8	Develop a Matlab/Simulink model of a three level Inverter	2
9	Develop a Matlab/Simulink model of SPWM Technique	2
10	Develop a Matlab/Simulink model of PWM based three phase inverter	2

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Power System Protection Lab	
Course Type	Laboratory	
Course Code	22EE7PC02L	
Category	PCC (Professional Core Courses)	
Credit Point	1	
Time Commitment	Lecture	Nil
	Tutorial	Nil
	Practice	20 Hours
	Total	20 Hours
Recommended Background Knowledge/Course Pre-requisites	Knowledge of basics of Power System Protection	
Subject Description	Power system protection is the science and practice of detecting and isolating faults (like short circuits) in electrical power grids to prevent damage and maintain system stability. It ensures safety and reliability by quickly disconnecting faulty components while minimizing disruption to the rest of the system	
Objectives and Outcomes	1. To provide hands-on experience in operating and testing protective relays used for safeguarding generators and motors under abnormal conditions such as over/under voltage and frequency. 2. To familiarize students with fault detection techniques in power systems, such as earth faults and short circuits in underground cables using practical testing methods like the Varley loop test. 3. To introduce students to power system protection simulations using ETAP	

<table>
<tr><td></td><td colspan="2">software, enabling understanding of relay coordination, distance protection, and directional over current protection.
4. To develop analytical and diagnostic skills in evaluating protection schemes for electrical equipment and systems under various fault conditions.</td></tr>
<tr><td></td><td colspan="2">1. Demonstrate practical knowledge of relay-based protection for generators and motors against voltage and frequency abnormalities.
2. Perform and interpret fault location tests on underground cables using conventional test methods like the Varley loop test.
3. Apply ETAP software tools to model and simulate protection schemes such as relay coordination, distance relays, and directional over current relays.
4. Design and analyze reliable protection schemes to enhance system stability and prevent damage to electrical equipment under fault conditions.</td></tr>
<tr><td rowspan="7">Assessment/ Evaluation</td><td>Lab Experiments</td><td>20%</td></tr>
<tr><td>Record Writing</td><td>10%</td></tr>
<tr><td>Behavior/ Attitude</td><td>05%</td></tr>
<tr><td>Quiz</td><td>10%</td></tr>
<tr><td>Attendance</td><td>05%</td></tr>
<tr><td>Final Lab Test</td><td>30%</td></tr>
<tr><td>Final Viva/ Final Lab Quiz Test</td><td>20%</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Digital Learning Resources</td><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
</table>

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Demonstrate practical knowledge of relay-based protection for generators and motors against voltage and frequency abnormalities.	PO1, PO2, PO3
CO2	Perform and interpret fault location tests on underground cables using conventional test methods like the Varley loop test.	PO1, PO2, PO4
CO3	Apply ETAP software tools to model and simulate protection schemes such as relay coordination, distance relays, and directional overcurrent relays.	PO1, PO5, PO11
CO4	Design and analyze reliable protection schemes to enhance system stability and prevent damage to electrical equipment under fault conditions.	PO1, PO2, PO3, PO12

DETAILED SYLLABUS (EXPERIMENTS):

Sl. No.	Name of Experiments (7 Experiments out of 8 Hardware Experiments)	Duration in Hrs
1	Protection of Generator Using Overvoltage Relay	2
2	Protection of Generator Using Undervoltage Relay	2
3	Protection of Generator Using Under frequency Relay	2
4	Protection of Generator Using Over frequency Relay	2
5	Protection of Generator Using Earth fault Relay	2
6	To study the underground cable short circuit test using Varley loop test.	2
7	Relay Coordination Using ETAP	2
8	Distance relay protection using ETAP	2
9	Directional overcurrent relay using ETAP	2
10	Motor protection using ETAP	2

Open Elective for other Branches:

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Energy Storages	
Course Type	Theory	
Course Code	22EE7OE01T	
Category	OEC (Open Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	Energy storage is the process of capturing energy generated at one time and saving it for later use. This allows for a more reliable energy supply by balancing the demand and supply of energy, especially when dealing with intermittent sources like solar and wind. Essentially, it's about converting energy into a storable form and then retrieving it when needed	
Objectives and Outcomes	1. To energy storage systems and provides a broad understanding and appreciation of the scientific principles that underpin the operation of such systems. 2. To provide a foundation for understanding the general principles and fundamentals of Li-Ion battery technology design and operation.	

	3. To learn basic electrochemical principles of the hydrogen fuel cells, basic fuel cell design concepts, fuel cell systems concepts. 4. The on grid-scale (or utility-scale) energy storage as a means of addressing the intermittency of renewable energy components (e.g. solar or wind power systems) of modern electricity networks	
	1. Understand various energy storage technologies. 2. Develop an algorithm to estimate the state of charge and state of health of a battery 3. Develop the energy management control of a storage system in a grid connected 4. Develop the control algorithm to a grid-connected storage system to improve the grid reliability	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	[1] Grid-scale Energy Storage Systems and Applications, Fu-Bao Wu, Bo Yang, Ji-Lei Ye, Elsevier - Academic Press, 2019, 1st edition. [2] Energy Storage Devices for Renewable Energy-Based Systems, Nihal Kularatna Kosala Gunawardane, Elsevier - Academic Press, 2019, 2nd	

<table>
<tr><td></td><td>edition.
[3] Ultra-Capacitors in Power Conversion Systems: Applications, Analysis, and Design from Theory to Practice, Petar J. Grbovic, Wiley-IEEE Press, 2013, 1st edition</td></tr>
<tr><td>Reference Book(s)</td><td>[1] Energy Storage: A New Approach, Ralph Zito, Haleh Ardebili, Wiley, 2019, 2nd Edition.
[2] Energy Storage for Power System Planning and Operation, Zechun Hu , Wiley, 2020, 1st edition.
[3] Fuel Cell Systems Explained, Andrew L. Dicks, David A. J. Rand, Wiley, 2018, 3rd Edition</td></tr>
<tr><td>Digital Learning Resources</td><td><table><tr><td>Course Name</td><td>Electrochemical Energy Storage</td></tr><tr><td>Course Link</td><td>https://nptel.ac.in/courses/113105102</td></tr><tr><td>Course Instructor</td><td>Prof. Subhasish Basu Majumder, IIT Kharagpur</td></tr></table></td></tr>
</table>

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Understand various energy storage technologies	PO1, PO2, PO3, PO4,PO12
CO2	Develop an algorithm to estimate the state of charge and state of health of a battery	PO1, PO2, PO3, PO4
CO3	Develop the energy management control of a storage system in a grid connected	PO1,PO2, PO3, PO4,PO5
CO4	Develop the control algorithm to a grid-connected storage system to improve the grid reliability	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**Development of energy storage technology**:	**08 hours**
Basic concept, history of energy storage technologies, demand functions of energy storage technology in power system, application outlook and challenges of energy storage technology in power system		

Module No. 2	**Technology of energy storage systems**:	**09 Hours**
Electrochemical energy storage: lead-acid battery, lithium-ion battery, vanadium redox battery, zinc-bromine, sodium sulphur; physical energy storage: pump hydro storage compressed air energy storage, flywheel energy storage; electromagnetic energy storage: super capacitor energy storage, superconducting magnetic energy storage; new type energy storage: advanced lead-acid		

batter, lithium-sulphur battery, sodium-ion battery, heat pump storage, gravity energy storage; comprehensive comparison of energy storage technologies: technical maturity, performance parameters, applications

Module No. 3	**Technologies for battery management**:	**08 Hours**
Battery management systems: typical structures, main functions; state of charge (SOC) estimation method: definition, the methods of SOC estimation; state of health (SOH) estimation technology: definition, methods for SOH estimation; balance management technology; protection technology: overvoltage protection, under voltage protection, overcurrent protection, short circuit protection, over temperature protection		

Module No. 4	**Operation & Control technology of energy storage systems**:	**06 Hours**
Grid connected operation control technology: AC/DC converter control, DC/DC converter control, island detection, low voltage ride through; off-grid operation control technology: control of switching from on-grid to off-grid, synchronization control of the switching from off-grid to on-grid.		

Module No. 5	**Application of energy storage technology**	**05 Hours**
Application of energy storage technology in grid-connected energy power generation: Impact of energy storage system on gird-connected energy storage power generation: smooth power fluctuation.		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Energy Auditing and Management	
Course Type	Theory	
Course Code	22EEE7OE02T	
Category	OEC (Open Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	Energy Auditing is a process of examining energy consumption in a building, process, or system to identify areas for improvement and develop strategies to reduce energy usage without impacting productivity. It involves analyzing energy flows, identifying inefficiencies, and implementing measures to enhance energy efficiency and lower costs.	
	1. To facilitate the students to achieve a clear conceptual understanding of technical and commercial aspects of energy conservation and energy auditing.	

Objectives and Outcomes	2. To enable the students to develop managerial skills to assess feasibility of alternative approaches and drive strategies regarding energy conservation and energy auditing	
	1.Conceptual knowledge of the technology, economics and regulation related issues associated with energy conservation and energy auditing 2.Ability to analyze the viability of energy conservation projects 3.Capability to integrate various options and assess the business and policy environment regarding energy conservation and energy auditing 4.Advocacy of strategic and policy recommendations on energy conservation and energy auditing	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1.Energy Management: W. R. Murphy, G. Mckay (Butterworths). 2.Energy Management Principles: C. B. Smith (Pergamon Press). 3.Efficient Use of Energy : I. G. C. Dryden (Butterworth Scientific) 4.Energy Economics - A. V. Desai (Wiley Eastern) 5.Industrial Energy Conservation : D. A. Reay (Pergammon Press) 6.Energy Management Handbook – W. C. Turner (John Wiley and Sons, A Wiley Interscience Publication)	

Reference Book(s)	1.Industrial Energy Management and Utilization – L. C. Witte, P. S. Schmidt, D. R. Brown (Hemisphere Publication, Washington) 2.Industrial Energy Conservation Manuals, MIT Press, Mass, 1982 3.Energy Conservation guide book Patrick/Patrick/Fardo (Prentice Hall)
Digital Learning Resources	Course Name: Energy Management System Course Link: https://nptel.ac.in/courses/108106022 Course Instructor: Dr. K. Shanti Swarup, IIT Madras

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Conceptual knowledge of the technology, economics and regulation related issues associated with energy conservation and energy auditing	PO1, PO2, PO3, PO4,PO12
CO2	Ability to analyze the viability of energy conservation projects	PO1, PO2, PO3, PO4
CO3	Capability to integrate various options and assess the business and policy environment regarding energy conservation and energy auditing	PO1,PO2, PO3, PO4,PO5
CO4	Advocacy of strategic and policy recommendations on energy conservation and energy auditing.	PO1, PO2, PO3, PO4, PO5, PO12

DETAILED SYLLABUS:

Module No. 1	**General Aspects**	**08 hours**
General Philosophy and need of Energy Audit and Management. Definition and Objective of Energy Management, General Principles of Energy Management, Energy Management Skills, Energy Management Strategy. Energy Audit: Need, Types, Methodology and Approach. Energy Management Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements, Fuel and Energy substitution		

Module No. 2	**Procedures and Techniques**	**09 Hours**
Data gathering: Level of responsibilities, energy sources, control of energy and uses of energy get Facts, figures and impression about energy /fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering. Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation. Evaluation of saving opportunities: Determining the savings in Rs, Noneconomic factors, Conservation opportunities, estimating cost of implementation. Energy Audit Reporting: The plant energy study report- Importance, contents, effective organization, report writing and presentation		

Module No. 3	**Energy Policy Planning and Implementation**	**08 Hours**
Key Elements: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation. Format and Ratification, Organizing: Location of Energy Manager, Top Management Support, Managerial functions, Role and responsibilities of Energy Manager, Accountability. Motivating Motivation of employees, Requirements for Energy Action Planning. Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning		

Module No. 4	Energy Balance & MIS	05 Hours
First law of efficiency and Second law of efficiency, Facility as an Energy system, Methods for preparing process flow, Materials and Energy Balance diagram, Identification of losses, Improvements. Energy Balance sheet and Management Information System (MIS) Energy Modeling and Optimization		

Module No. 5	Energy Audit Instruments	04 Hours
Instruments for Audit and Monitoring Energy and Energy Savings, Types and Accuracy		

Open Elective Course [OEC] offered to EE students

Open Electives from other Branches:

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	INTERNET OF THINGS	
Course Type	Theory	
Course Code	22EC7OE01T	
Category	OEC (Open Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	The Internet of Things (IoT) refers to a network of physical objects, or "things," that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet. Essentially, it's about connecting previously unconnected devices and objects to the internet, allowing them to communicate and share data	
Objectives	1.To learn the basic issues, policy and challenges in the Internet. 2.To understand the role of IoT in various domains of Industry. 3.To understand the cloud and internet environment and various modes of communications with Internet.	

and **Outcomes**	4.To study the basics of IoT Data Analytics and supporting services..	
	1.Able to understand the basics of architectureand characteristics. IoT. 2.Able to understand IOT Applications in Industrial & realworld. 3.Understand design methodology and hardware platforms involved in IoT. 4.Understand how to analyze and organize the data for IoT and industry 4.0	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. VijayMadisetti, Arshdeep Bahga,"Internet of Things-A Hands-On-Approach", Universities Press, 2015, ISBN:9788 173719547 2. David Hanes Atzor et.al, "IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, Cisco Press, June 2017	
Reference Book(s)	1. Honbo Zhou,"The Internet of Things in the Cloud: A Middleware Perspective" — CRC Press, 2012. 2. Luigi Atzor et.al, "The Internet of Things: A survey, ", Journal on Networks, Elsevier Publications, October 2010. 3. Olivier Hersent, David Boswarthick, Omar Elloumi, "The Internet of Things – Key applications and Protocols", Wiley, 2012. 4. Adrian McEwen, "Designing the Internet of Things", Wiley Publishers, 2013.	

Digital Learning Resources	

Course Name	Introduction to internet of things
Course Link	NPTEL : Computer Science and Engineering - NOC:Introduction to internet of things
Course Instructor	Prof. Sudip Misra, IIT Kharagpur

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	To learn the basic issues, policy and challenges in the Internet	PO1, PO3, PO4,PO12
CO2	To understand the role of IoT in various domains of Industry	PO1, PO2, PO3, PO4
CO3	To understand the cloud and internet environment and various modes of communications with Internet	PO1,PO2, PO3
CO4	To study the basics of IoT Data Analytics and supporting services	PO1, PO2, PO3, PO4,

DETAILED SYLLABUS:

Module No. 1	**Introduction & Concepts:**	**08 hours**
Definition & Characteristics of IoT, IoT frameworks, Physical Design of IoT- Things in IoT, IoT Protocols, Logical Design of IoT- IoT Functional Blocks, IoT Communication Models, IoT Communication APIs , IoT Enabling Technologies, IoT Levels & Deployment Templates. **Domain Specific IOTs**: Home Automation, Cities, Environment, Energy, Retail, Logistics, Agriculture, Industry, Health & Life Style, Challenges and Issues.		

Module No. 2	**IoT and M2M**	**09 Hours**
Introduction, M2M-Difference between IoT and M2M, SDN and NFV for IoT-Software Defined Networking, Network Function Virtualization **IoT Platform Design Methodology:** Purpose & Requirements Specification, Process Specification, Domain Model Specification, Information Model Specification, Service Specifications, IoT Level Specification, Functional View Specification, Operational View Specification, Device & Component Integration, Case study on IoT system: smart lightning, weather monitoring system		

Module No. 3	**IoT Physical Devices & Endpoints:**	**08 Hours**
What is an IoT Device-Basic building blocks of an IoT Device, Exemplary Device: Raspberry Pi, About the Board, Linux on Raspberry Pi , Raspberry Pi Interfaces – Serial, SPI , I2C , Programming Raspberry Pi with Python-Controlling LED with Raspberry Pi , Interfacing an LED and Switch with Raspberry Pi ,Interfacing a Light Sensor (LDR) with Raspberry Pi.		

Module No. 4	Data and Analytics for IoT	05 Hours
Use of Big Data and Visualization in IoT, IoT Data Analytics Overview and Challenges, Big Data Analytics Tools and Technology.		

Module No. 5	IoT &Beyond Industry 4.0:	04 Hours
Industry 4.0 concepts, The Various Industrial Revolutions, ,Internet of Everything, Overview of RFID, Overview of Android.		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	**Robotics**	
Course Type	Theory	
Course Code	22EC7OE02T	
Category	OEC (Open Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	Robotics is an interdisciplinary field drawing from mechanical, electrical, and computer engineering, as well as computer science and artificial intelligence. It focuses on the design, construction, operation, and application of robots, including the computer systems for their control, sensory feedback, and information processing. Essentially, robotics aims to create machines that can perform tasks, often those traditionally done by humans, with greater efficiency and precision.	
Objectives and	1.To develop the student's knowledge in various robot structures and their workspace. 2.Acquire knowledge to perform kinematics analysis of robot systems. 3.To provide knowledge on the various robotic systems with the help of	

<table>
<tr><td rowspan="2">Outcomes</td><td colspan="2">mathematical models.
4.Understand the various flexures, actuators and sensor systems.
5. To provide the student with some knowledge and analysis skills associated with trajectory planning</td></tr>
<tr><td colspan="2">1. Differentiate the various types of Industrial Robots, their architecture and robot kinematics.
2. Describe the characteristics of a robotic system from its dynamic model.
3. Specify the characteristics of various actuators and sensor systems
4. Analyze the various path planning techniques by briefing about the robot’s environment and Analyze the applications of robots in various industrial application.</td></tr>
<tr><td rowspan="8">Assessment/ Evaluation</td><td>Mid-Term Examination</td><td>30 %</td></tr>
<tr><td>Quiz Test-1</td><td>2.5 %</td></tr>
<tr><td>Quiz-Test-2</td><td>2.5 %</td></tr>
<tr><td>Surprise Test</td><td>5 %</td></tr>
<tr><td>Assignment-1</td><td>2.5 %</td></tr>
<tr><td>Assignment-2</td><td>2.5 %</td></tr>
<tr><td>Attendance</td><td>5 %</td></tr>
<tr><td>End-Term Examination</td><td>50 %</td></tr>
<tr><td>Prescribed Text Book(s)</td><td colspan="2">1. Robotics and Control, R. K. Mittal and I. J. Nagrath, Tata McGraw-Hill, 2005
2. Introduction to Robotics: Mechanics and control, John J. Craig, PHI, 3rd edition, 2004
3. Robotics Technology and Flexible Automation, S. R. Deb and S. Deb, TMH, 2nd edition, 2017</td></tr>
</table>

Reference Book(s)	1. Introduction to Robotics, S. K. Saha, Tata McGraw Hill, 1st edition, 2008 2. Robotics: Control, Sensing, Vision and Intelligence, K.S.Fu, R.C.Gonzalez and C.S.G.Lee, McGraw Hill, 2008 3. Industrial Robotics Technology, programming and application, M. P. Groover, TMH, 2nd edition, 2017
Digital Learning Resources	1. Video course on "Robotics" by Prof. Dilip Kumar Pratihar, IIT Kharagpur available on NPTEL at Kanpur available on NPTEL at **https://onlinecourses.nptel.ac.in/noc21_me76/preview** 2. Video course on "Introduction to Robotics" by Prof. Asokan T, Prof. Balaraman Ravindran, Prof. Krishna Vasudevan , IIT Madras available on NPTEL at Kanpur available on NPTEL at **https://onlinecourses.nptel.ac.in/noc20_de11/preview**

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Differentiate the various types of Industrial Robots, their architecture and robot kinematics	PO1, PO3, PO4,PO12
CO2	Describe the characteristics of a robotic system from its dynamic model	PO1, PO2, PO3, PO4
CO3	Specify the characteristics of various actuators and sensor systems	PO1,PO2, PO3
CO4	Analyze the various path planning techniques by briefing about the robot's environment and Analyze the applications of robots in various industrial application	PO1, PO2, PO3, PO4,

DETAILED SYLLABUS:

Module No. 1	**Fundamentals of Robotics:**	08 hours
Evolution of robots and robotics, Definition of industrial robot, Laws of Robotics, Classification, Robot Anatomy, Work volume and work envelope, Human arm characteristics, Design and control issues, Manipulation and control, Resolution; accuracy and repeatability, Robot configuration, Economic and social issues, Present and future application		

Module No. 2	**Mathematical modeling of a robot**	07 Hours
Mapping between frames, Description of objects in space, Transformation of vectors. **Direct Kinematic model:** Mechanical Structure and notations, Description of links and joints, Kinematic modeling of the manipulator, Denavit-Hartenberg Notation, Kinematic relationship between adjacent links, Manipulator Transformation matrix		

Module No. 3	Inverse Kinematics & Dynamic modeling::	07 Hours
Manipulator workspace, Solvable of inverse kinematic model, Manipulator Jacobian, Jacobian inverse, Jacobian singularity, Static analysis. Lagrangian mechanics, 2D- Dynamic model, Lagrange-Euler formulation, Newton-Euler formulation		

Module No. 4	Robot Sensors & Robot Actuators:	07 Hours
Internal and external sensors, force sensors, Thermocouples, Performance characteristic of a robot. Hydraulic and pneumatic actuators, Electrical actuators, Brushless permanent magnet DC motor, Servomotor, Stepper motor, Micro actuator, Micro gripper, Micro motor, Drive selection		

Module No. 5	Trajectory Planning and Applications of Robotics:	07 Hours
. Definition and planning tasks, Joint space planning, Cartesian space planning. Capabilities of robots, Material handling, Machine loading and unloading, Robot assembly, Inspection, spot and continuous arc welding & spray painting , Obstacle avoidance		

Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	**Numerical Methods for Engineers**	
Course Type	Theory	
Course Code	22EC7OE02T	
Category	OEC (Open Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	The development of fast, efficient and inexpensive computers has significantly increased the range of engineering problems that can be solved reliably. Numerical Methods use computers to solve problems by step-wise, repeated and iterative solution methods, which would otherwise be tedious or unsolvable by hand-calculations. This course is designed to give an overview of numerical methods of interest to scientists and engineers. However, the focus being on the techniques themselves, rather than specific applications, the contents should be relevant to varied fields such as engineering, management, economics, etc.	
Objectives	1. Solve the nonlinear equations and finding the roots of the equation. 2. Realize the power of interpolation, numerical differentiation and integration	

and **Outcomes**	3. Solve ordinary differential equations, stability and convergence of numerical methods, 4. Solve elliptic partial differential equations with numerical methods 5. Solve hyperbolic partial differential equations with numerical methods.	
	1. Find the root of the nonlinear equations 2. Get experience of using interpolation, numerical differentiation and integration 3. Solve ordinary differential equations numerically and know order, stability and convergence of numerical methods 4. Solve the Laplace and Poisson equations by finite difference approximations. And Solve the hyperbolic differential equations by using simple solvers.	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Numerical methods for Engineers, S. C. Chapra and R. P. Canale, McGraw-Hill Higher Education, 5th edition, 2005. 2. Numerical analysis, K.E. Atkinson, John Wiley & Sons, 2nd edition, 2011. 3. Numerical Methods for Engineers and Scientists, Joe D. Hoffmann, CRC Press; 2nd edition, 2001.	

Reference Book(s)	1. Numerical Method for Scientific and Engineering Computation, M. K. Jain, S. R. K. Iyengar and R. K. Jain, New Age International Publishers, 7th edition, 2019. 2. Introductory Methods for Numerical Analysis, S. S. Sastry, PHI learning private limited, 4th edition, 2012
Digital Learning Resources	

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Find the root of the nonlinear equations	PO1, PO3, PO4,PO12
CO2	Get experience of using interpolation, numerical differentiation and integration	PO1, PO2, PO3, PO4
CO3	Solve ordinary differential equations numerically and know order, stability and convergence of numerical methods	PO1,PO2, PO3
CO4	Solve the Laplace and Poisson equations by finite difference approximations. And the hyperbolic differential equations by using simple solvers	PO1, PO2, PO3, PO4,

DETAILED SYLLABUS:

Module No. 1	**Nonlinear equations:**	**08 hours**
Approximation of numbers, significant figures, accuracy and precision, error definition, round off errors, error propagation, system of non-linear equations: interval halving false-position method, fixed point iteration, newton-raphson method, secant method, convergence and error analysis		

Module No. 2	**Interpolation, Numerical Differentiation and Integration:**	**07 Hours**
Introduction, Newton's divided difference interpolating polynomial, Lagrange interpolating polynomial, spline interpolation, trapezoidal rule, Simpson's rule, Newton-Cotes algorithm for equations, Romberg integration, Gauss quadrature		

Module No. 3	**Ordinary differential equation**	**07 Hours**
: Introduction, Taylor series method, finite difference grids and finite difference approximations, finite difference equations, consistency, order, stability and convergence, the modified differential equations, stability analysis		

Module No. 4	Elliptic Partial difference equations:	07 Hours
Introduction, finite difference approximations, consistency, order and convergence, finite difference solutions of Laplace equations and Poisson equation		

Module No. 5	Hyperbolic Partial Differential Equations	07 Hours
Introduction, The method of characteristics, the forward-time centered space method, Lax method, upwind methods, the leapfrog method		

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Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Biology For Engineers	
Course Type	Theory	
Course Code	22BT7OE01T	
Category	OEC (Open Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	This course is designed to introduce the fundamental concepts of modern biology to undergraduate engineering students. The curriculum bridges the gap between biology and engineering, highlighting how biological systems can be viewed as complex engineered entities. The course aims to equip students with the necessary biological knowledge to understand and contribute to emerging fields like biotechnology, biomedical engineering, biomimicry, and environmental engineering. It will foster an appreciation for how engineering principles can be applied to solve biological problems and how biological solutions can inspire novel engineering designs	
Objectives	1. **To impart** fundamental knowledge of cell biology, genetics, and molecular biology. 2. **To introduce** the concept of biology as a quantitative and engineering science. 3. **To convey** the principles of biomolecules, enzymes, and metabolic	

and **Outcomes**	pathways from an engineering perspective (e.g., materials, catalysts, energy systems). 4. **To motivate** students to explore and analyze bio-inspired engineering solutions and modern biotechnological applications	
	1. Describe the fundamentals of cell structure, function, and the hierarchy of life, comparing biological systems to engineered systems. 2. Explain the principles of genetics, information transfer (from DNA to protein), and basic gene regulation 3. Apply the concepts of biomolecules and enzymes to analyze their roles as building blocks, catalysts, and energy sources 4. Analyze various bio-inspired engineering systems and modern biotechnological applications in fields like healthcare, environment, and materials and Assess the role of biology in addressing contemporary engineering challenges related to sustainability and human health	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Thyaga Rajan, S., Selvamurugan, N., Rajesh, M. P., Nazeer, R. A., Thilagaraj, W., Barathi, S., &Jaganthan, M. K. (2018). *Biology for Engineers*. Tata McGraw-Hill Education. 2. Suraishkumar, G. K. (2018). *Biology for Engineers and Computer*	

	Scientists. Oxford University Press. 3. Singh, B. D. (2018). *Biotechnology: Expanding Horizons*. Kalyani Publishers
Reference Book(s)	1. Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Reece, J. B. (2020). *Campbell Biology* (12th Edition). Pearson. 2. Nelson, D. L., & Cox, M. M. (2021). *Lehninger Principles of Biochemistry* (8th Edition). W. H. Freeman. 3. Benyus, J. M. (2002). *Biomimicry: Innovation Inspired by Nature*. William Morrow Paperbacks. 4. Shuler, M. L., & Kargi, F. (2017). *Bioprocess Engineering: Basic Concepts* (3rd Edition). Prentice Hall
Digital Learning Resources	

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Describe the fundamentals of cell structure, function, and the hierarchy of life, comparing biological systems to engineered systems.	PO1, PO2, PO3, PO6, PO7
CO2	Explain the principles of genetics, information transfer (from DNA to protein), and basic gene regulation	PO1, PO2, PO12
CO3	Apply the concepts of biomolecules and enzymes to analyze their roles as building blocks, catalysts, and energy sources	PO1,PO2, PO4, PO7, PO12
CO4	Analyze various bio-inspired engineering systems and modern biotechnological applications in fields like healthcare, environment, and materials and Assess the role of biology in addressing contemporary engineering challenges related to sustainability and human health	PO1, PO2, PO3, PO4, PO6, PO7,. PO8,PO12

DETAILED SYLLABUS:

Module No. 1	Introduction to Biology & The Cell	07 hours

- **Why Biology for Engineers:** Introduction to the course, highlighting the interface between biology and engineering.
- **Hierarchy of Life:** From atoms to the biosphere.
- **The Cell as a Basic Unit of Life:** Cell theory, prokaryotic vs. eukaryotic cells, animal vs. plant cells.
- **Cellular Organelles:** Structure and function of major organelles (nucleus, mitochondria, chloroplasts, ribosomes, endoplasmic reticulum, Golgi apparatus). **Analogy:** The cell as a well-designed factory.
- **Introduction to Biomolecules:** Overview of carbohydrates, lipids, proteins, and nucleic acids as the building blocks of life.
- **Bio-membranes and Transport:** Structure of the cell membrane, passive and active transport mechanisms. **Analogy:** Gates and pumps in an engineered system

Module No. 2	Genetics, Information Transfer, and Control	08 Hours

- **The Blueprint of Life:** Structure of DNA (Watson-Crick model), concept of genes and chromosomes.
- **The Central Dogma of Molecular Biology:** DNA replication, Transcription (DNA to RNA), and Translation (RNA to Protein). **Analogy:** Information storage, copying, and execution in a computer system.
- **Introduction to Gene Regulation:** Simple models of gene expression control (e.g., Lac Operon) as biological switches.
- **Heredity and Mendelian Genetics:** Basic principles of inheritance.
- **Introduction to Recombinant DNA Technology:** Basic tools and applications (e.g., producing insulin in bacteria).

Module No. 3	Bioenergetics, Enzymes, and Biomaterials	08 Hours

- **Enzymes as Biocatalysts:** Structure, function, and mechanism of enzyme action. Factors affecting enzyme activity. **Analogy:** Highly specific industrial catalysts.
- **Enzyme Kinetics:** Michaelis-Menten kinetics as a model for catalytic efficiency.
- **Bioenergetics and Metabolism:** Concept of free energy, overview of key metabolic pathways like Glycolysis and the Krebs Cycle for energy

harvesting. **Analogy:** Biological power plants.

- **Photosynthesis:** The process of converting light energy to chemical energy. **Analogy:** Biological solar cells.
- **Biomaterials:** Introduction to natural polymers (e.g., collagen, cellulose, silk, chitin) and their mechanical and chemical properties for engineering applications

Module No. 4	Applied Biology	07 Hours

- **Introduction to Biotechnology:**
  - **Fermentation Technology & Bioreactors:** Design and application in producing antibiotics, enzymes, and biofuels.
  - **Environmental Biotechnology:** Role of microbes in bioremediation and waste treatment (e.g., activated sludge process).
- **Introduction to Biomedical Engineering:**
  - **Biosensors:** Basic principles and applications (e.g., glucose sensor).
  - **Tissue Engineering:** Basic concepts of scaffolds and cell culture

Module No. 5	Bio-inspired Engineering	06 Hours

- **Biomechanics:** Study of biological systems (e.g., human skeleton) from a mechanical perspective (levers, forces, stress, and strain).
- **Biomimicry (Bio-inspired Design):** Learning from nature to solve engineering problems.
  - **Case Studies:** Velcro (burrs), high-speed train design (kingfisher beak), self-cooling buildings (termite mounds), superhydrophobic surfaces (lotus leaf).

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Degree	B. Tech.	
Level	Undergraduate	
Branch	EE (Electrical Engineering)	
Semester	7th	
Subject Name	Introduction to Machine learning	
Course Type	Theory	
Course Code	22CS7OE01T	
Category	OEC (Open Elective Courses)	
Credit Point	3	
Time Commitment	Lecture	36 Hours
	Tutorial	Nil
	Practice	Nil
	Total	36 Hours
Recommended Background Knowledge	NA	
Subject Description	This course provides a foundational understanding of machine learning models (logistic regression, multilayer perceptrons, convolutional neural networks, natural language processing, etc.) and demonstrates how they can solve complex problems in various industries, from medical diagnostics to image recognition to text	
Objectives and Outcomes	1. Develop a concise knowledge of the understanding of the fundamental concept of machine learning. 2. Understand the different learning algorithms and implement them. 3. Gain experience in applying machine learning algorithms to real-world problems.	
	1. Equip students with knowledge of fundamentals concepts in machine learning. 2. Ability to analyse and validate different learning algorithms.	

	3. Fine tune machine learning algorithms 4. Evaluate models generated from data	
Assessment/ Evaluation	Mid-Term Examination	30 %
	Quiz Test-1	2.5 %
	Quiz-Test-2	2.5 %
	Surprise Test	5 %
	Assignment-1	2.5 %
	Assignment-2	2.5 %
	Attendance	5 %
	End-Term Examination	50 %
Prescribed Text Book(s)	1. Saikat Dutt, Subramanian Chandramouli, Amit Kumar Das, "Machine Learning", Pearson Education2: C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2010	
Reference Book(s)	1. J. Friedman, T. Hastie, and R. Tibshirani.The elements of statistical learning.Vol. 1, no. 10. New York:Springer series in statistics, 2001. 2. S. Shalev-Shwartz, and S. Ben-David. Understanding machine learning: From theory to algorithms. Cambridge university press, 2014	
Digital Learning Resources	Course Name Introduction to Machine Learning Course Link https://nptel.ac.in/courses/106/106/106106139/ Course InstructorDr. Balaraman Ravindran, IIT Madras	

CO's Mapping with PO's and PEO's

Course Outcomes	Course Outcome Statement	PO's / PEO's
CO1	Equip students with knowledge of fundamentals concepts in machine learning	PO1,PO2,PO4,PO7
CO2	Ability to analyze and validate different learning algorithms	PO1,PO2,PO4,PO5
CO3	Fine tune machine learning algorithms	PO1,PO3,PO5,PO9
CO4	Evaluate models generated from data	PO1,PO2,PO3,PO4,PO5

DETAILED SYLLABUS:

Module No. 1	**Introduction to Machine Learning,**	**08 hours**

Model Preparation, Modelling and Evaluation, Human learning versus machine learning, types of machine learning, applications of machine learning, tools for machine learning, Machine Learning Activities, Data structures for machine learning, Data Pre-processing, selecting a model, training a model, model representation and interpretability, evaluating the performance of a model, improving the performance of a model, Learning theory, Hypothesis and target class, Hilbert space, Inductive bias and bias-variance trade-off.

Module No. 2	**Interpolation, Numerical Differentiation and Integration:**	**07 Hours**
Feature Engineering, Bayesian Concept Learning, Introduction to feature engineering, feature transformation, feature subset selection, Importance of Bayesian methods, Bayes' theorem, concept learning through Bayes' theorem, Bayesian Belief Network		

Module No. 3	**Supervised Learning**	**07 Hours**
Classification, Regression, Example of supervised learning, classification model, classification learning steps, common classification algorithms – KNN, Decision trees random forest, SVM, an example of regression, common regression algorithms,		

Module No. 4	Unsupervised learning	07 Hours
Clustering, pattern finding using association rules, Unsupervised learning versus supervised learning, applications of unsupervised learning, clustering and its types, Apriori algorithm for association rule learning		

Module No. 5	Neural Network:	07 Hours
Understanding the biological neuron, exploring artificial neuron, types of activation functions, early implementation of artificial neural network, architectures of neural network, learning process in artificial neural network, back propagation, Overview of Deep Learning		