ROHINI
COLLEGE OF ENGINEERING & TECHNOLOGY
(AUTONOMOUS)
Approved By AICTE & Affiliated to Anna University
NBA Accredited for All Eligible B.E/B.Tech Programs | NAAC Accredited with A+ Grade
Near Anjugramam - Kanyakumari Main Road, Palkulam, Variyoor P.O.-629401, Kanyakumari Dist, Tamil Nadu.

Minor Course

MICROGRID TECHNOLOGIES

Curriculum & Syllabus

(*2024-2025 Admitted Students Onwards*)

CREDIT INFO		
Sl.No	**Category**	**Credits**
1	Minor Courses	18

CREDIT DISTRIBUTION

Course Category	Credit/Semester								No. of Credits
	I	II	III	IV	V	VI	VII	VIII	
Minor Courses	-	-	-	-	**6**	**6**	**6**	-	**18**

MINOR COURSES						
MICROGRID TECHNOLOGIES						
Sl.No	**Course Code**	**Course Title**	**L**	**T**	**P**	**C**
1	24MS501	Fundamentals of Microgrid Systems	3	0	0	3
2	24MS502	Renewable Energy Sources and Distributed Generation	3	0	0	3
3	24MS601	Energy Storage Systems and Electric Mobility	3	0	0	3
4	24MS602	Power Electronics for Microgrids	3	0	0	3
5	24MS701	Smart Grid Communication, Protection and Cybersecurity	3	0	0	3
6	24MS702	Microgrid Design, Control and Energy Management Laboratory	0	0	6	3

Course Code:	24MS501	Course Title:	FUNDAMENTALS OF MICROGRID SYSTEMS
Credits:	**3**	**L – T – P**	**3-0-0**

Course Objectives:

The course enables the students to:

- Understand the concepts, architecture, and operational principles of modern microgrid systems.
- Explain the integration of renewable energy resources and distributed energy resources (DERs) into microgrids.
- Analyze the operation, control, and protection of AC, DC, and hybrid microgrids under different operating conditions.
- Apply energy management and optimization techniques to improve microgrid reliability, resilience, and sustainability.
- Develop practical knowledge of microgrid design using modern simulation tools and industry practices.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive lectures with real-world industrial examples
2. Case study-based learning using industrial microgrids
3. Problem-based learning (PBL)
4. Project-oriented learning
5. Simulation using MATLAB/Simulink, ETAP, OpenDSS, or HOMER Pro
6. Flipped classroom discussions
7. Industry expert lectures
8. Site visits to solar plants, substations, or smart grid facilities
9. Collaborative learning through group activities
10. Self-learning using IEEE papers, NPTEL, and technical reports

UNIT I – INTRODUCTION TO MICROGRID SYSTEMS	[9 hours]
Evolution of electric power systems – Conventional grid versus smart grid – Concept and need for microgrids – Types of microgrids (AC, DC, Hybrid) – Components of microgrids – Distributed Energy Resources (DERs) – Grid-connected and islanded operation – Advantages and challenges – Industrial applications of microgrids.	

UNIT II – DISTRIBUTED ENERGY RESOURCES AND RENEWABLE INTEGRATION	[9 hours]
Solar photovoltaic systems – Wind energy conversion systems – Biomass and biogas generation – Fuel cells – Microturbines – Diesel generators – Energy conversion interfaces – Renewable energy variability – Grid integration challenges – Hosting capacity – IEEE 1547 standards – Net metering.	

UNIT III – MICROGRID OPERATION AND CONTROL	[9 hours]
Modes of operation – Power flow in microgrids – Load sharing – Frequency and voltage regulation – Droop control – Hierarchical control (Primary, Secondary, Tertiary) – Grid synchronization – Islanding detection – Black start capability – Resilience enhancement.	

UNIT IV – PROTECTION, POWER QUALITY AND ENERGY MANAGEMENT	[9 hours]
Microgrid protection challenges – Fault analysis – Adaptive protection – Protection coordination – Relays and breakers – Harmonics – Voltage sag and swell – Power quality improvement – Energy Management Systems (EMS) – Demand response – Economic dispatch – Load forecasting – Peak shaving.	

UNIT V – EMERGING TRENDS AND INDUSTRIAL APPLICATIONS	[9 hours]
Smart microgrids – Multi-microgrid systems – Virtual Power Plants (VPP) – Vehicle-to-Grid (V2G) – Battery Energy Storage Systems (BESS) – Hydrogen energy systems – Blockchain-based energy trading – Cyber security in smart grids – Carbon-neutral energy systems – Industry 4.0-enabled energy management.	

Course Outcomes:

On completion of the course, the student will have the ability to

CO No.	Course Outcomes	Highest Cognitive Level
CO1	Design suitable AC, DC, or hybrid microgrid architectures for residential, commercial, and industrial applications.	**K3**
CO2	Evaluate the performance of renewable energy sources and distributed energy resources for microgrid integration.	**K4**
CO3	Apply microgrid control strategies to achieve reliable operation during grid-connected and islanded modes.	**K3**
CO4	Analyze protection, power quality, and energy management issues using appropriate engineering tools.	**K4**
CO5	Develop sustainable microgrid solutions considering economic, environmental, and industrial requirements.	**K3**

COs and POs/PSOs Mapping:

COs	POs											PSOs		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**	**3**
CO1	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO2	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO3	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO4	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO5	3	2	1	-	1	-	-	1	-	-	1	2	1	-

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

<table>
<tr><th>Component</th><th>Type of assessment</th><th>Max Marks</th><th>Reduced Marks</th><th>Total</th><th>Final marks</th></tr>
<tr><td rowspan="5">Continuous Internal Examination (CIE)</td><td>CIE – I</td><td>100</td><td rowspan="2">50</td><td rowspan="5">100</td><td rowspan="5">40</td></tr>
<tr><td>CIE – II</td><td>100</td></tr>
<tr><td>MCQ</td><td>20</td><td>10</td></tr>
<tr><td>Skill Assessment - I</td><td>40</td><td rowspan="2">40</td></tr>
<tr><td>Skill Assessment - II</td><td>40</td></tr>
<tr><td>End Semester Examination (ESE)</td><td>Theory Exam</td><td>100</td><td>60</td><td>60</td><td>60</td></tr>
<tr><td colspan="5">Total</td><td>100</td></tr>
</table>

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern:

Bloom's Category	Continuous Internal Examination		End Semester Examination
	1	**2**	
Remember	10	10	10
Understand	10	10	10
Apply	48	48	48
Analyze	32	32	32
Evaluate	-	-	-
Create	-	-	-

Text Books:

1. Nikos Hatziargyriou, Microgrids: Architectures and Control, Wiley-IEEE Press, 2nd Edition, 2024.
2. James Momoh, Smart Grid: Fundamentals of Design and Analysis, Wiley-IEEE Press, 3rd Edition, 2023.
3. Stuart Borlase, Smart Grids: Infrastructure, Technology and Solutions, CRC Press, 3rd Edition, 2022.

Reference Books:

1. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley, 2021.
2. Ramesh C. Bansal, Handbook of Distributed Generation: Electric Power Technologies, Economics and Environmental Impacts, Springer, 2022.
3. Fangxing Li, Wei Qiao, Hongbin Sun et al., Smart Transmission Grid, Springer, 2021.
4. Thomas Ackermann (Ed.), Distributed Generation, IET, 2019.
5. IEEE Standards Association, IEEE Std 1547-2018 (with latest amendments): Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.

Suggested Skill Activities:

1. Design a microgrid for a college campus.
2. Model an AC and DC microgrid using MATLAB/Simulink.
3. Analyze renewable energy penetration using HOMER Pro.
4. Evaluate power quality issues in an industrial microgrid.
5. Develop a simple Energy Management System (EMS).
6. Perform load forecasting using Python or MATLAB.
7. Prepare a techno-economic feasibility report for a renewable microgrid.
8. Review IEEE 1547 and IEC 61850 standards.
9. Study industrial microgrid implementations in India.
10. Participate in a hackathon on smart energy solutions.

Course Code:	24MS502	Course Title:	RENEWABLE ENERGY SOURCES AND DISTRIBUTED GENERATION
Credits:	**3**	**L – T – P**	**3-0-0**

Course Objectives:

The course enables the students to:

- Understand the principles, technologies, and characteristics of renewable energy sources and distributed generation (DG) systems.
- Analyze the performance, sizing, and integration of renewable energy systems for residential, commercial, industrial, and utility-scale applications.
- Apply engineering principles to integrate distributed energy resources into modern power systems and microgrids while ensuring reliability and power quality.
- Evaluate the technical, economic, environmental, and regulatory aspects of renewable energy projects to support sustainable energy transitions.
- Develop competency in selecting appropriate renewable energy technologies and distributed generation solutions to address current industrial challenges such as decarbonization, energy security, and net-zero emissions.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive lectures with industrial case studies
2. Outcome-Based Learning (OBL)
3. Problem-Based Learning (PBL)
4. Project-Based Learning
5. Flipped classroom discussions
6. Simulation using PVsyst, HOMER Pro, MATLAB/Simulink, RETScreen, OpenDSS
7. Renewable energy resource assessment exercises
8. Industrial expert lectures
9. Site visits to solar parks, wind farms, biomass plants, and substations
10. Team-based design activities
11. NPTEL/MOOC-supported self-learning
12. Research paper presentations

UNIT I – RENEWABLE ENERGY RESOURCES AND ENERGY SCENARIO	[9 hours]
Global and Indian energy scenario – Energy demand and sustainability – Climate change and carbon emissions – Renewable energy policies – Renewable Energy Certificates (REC) – National Solar Mission – Distributed Generation (DG) concepts – Types and classifications of DG – Benefits and challenges – Energy transition and Net-Zero initiatives.	

UNIT II – SOLAR PHOTOVOLTAIC AND SOLAR THERMAL SYSTEMS	[9 hours]
Solar radiation fundamentals – Solar resource assessment – Photovoltaic (PV) technologies – PV modules and arrays – MPPT techniques – Grid-connected and off-grid PV systems – Solar thermal technologies – Concentrated Solar Power (CSP) – Rooftop solar systems – Floating solar plants – Industrial solar applications.	

UNIT III – WIND, BIOMASS AND EMERGING RENEWABLE ENERGY TECHNOLOGIES	[9 hours]
Wind energy conversion systems – Wind turbine components – Power curve analysis – Offshore wind energy – Biomass resources – Biogas plants – Waste-to-energy technologies – Small hydro systems – Fuel cells – Hydrogen energy – Ocean energy – Geothermal energy – Hybrid renewable systems.	

UNIT IV – DISTRIBUTED GENERATION AND GRID INTEGRATION	[9 hours]
Distributed Generation technologies – Grid-connected DG systems – Smart inverters – Interconnection standards (IEEE 1547, IEC standards) – Power quality issues – Voltage regulation – Frequency control – Reactive power management – Protection coordination – Hosting capacity – Virtual Power Plants (VPP) – Microgrid integration.	

UNIT V – ENERGY STORAGE, ECONOMICS AND FUTURE TRENDS	[9 hours]
Battery Energy Storage Systems (BESS) – Lithium-ion batteries – Flow batteries – Super capacitors – Hydrogen storage – Pumped hydro storage – Techno-economic analysis – Levelized Cost of Energy (LCOE) – Carbon footprint analysis – Renewable project financing – Carbon credits – Artificial Intelligence for renewable forecasting – IoT-enabled monitoring – Digital Twin – Blockchain-based energy trading – Renewable-powered smart industries.	

Course Outcomes:

On completion of the course, the student will have the ability to

CO No.	Course Outcomes	Highest Cognitive Level
CO1	Assess renewable energy resources and select appropriate technologies for distributed generation applications.	**K3**
CO2	Design and size solar, wind, biomass, and hybrid renewable energy systems based on site-specific energy demand.	**K4**
CO3	Apply distributed generation technologies for reliable grid integration while addressing power quality and operational challenges.	**K3**
CO4	Analyze the techno-economic feasibility and environmental impact of renewable energy projects using industry-standard methodologies.	**K4**
CO5	Develop sustainable distributed generation solutions that support smart grids, microgrids, electric mobility, and carbon-neutral industrial operations.	**K3**

COs and POs/PSOs Mapping:

COs	POs											PSOs		
	1	2	3	4	5	6	7	8	9	10	11	1	2	3
CO1	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO2	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO3	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO4	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO5	3	2	1	-	1	-	-	1	-	-	1	2	1	-

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	Type of assessment	Max Marks	Reduced Marks	Total	Final marks
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern:

Bloom's Category	Continuous Internal Examination		End Semester Examination
	1	2	
Remember	10	10	10
Understand	10	10	10
Apply	48	48	48
Analyze	32	32	32
Evaluate	-	-	-
Create	-	-	-

Text Books:

1. Gilbert M. Masters, Renewable and Efficient Electric Power Systems, 3rd Edition, Wiley, 2023.
2. G. N. Tiwari and M. K. Ghosal, Renewable Energy Resources: Basic Principles and Applications, Narosa Publishing House, 2022.
3. Mukund R. Patel, Wind and Solar Power Systems: Design, Analysis and Operation, 3rd Edition, CRC Press, 2021.

Reference Books:

1. Godfrey Boyle (Ed.), Renewable Energy: Power for a Sustainable Future, 5th Edition, Oxford University Press, 2023.
2. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley, 2021.
3. Thomas Ackermann (Ed.), Distributed Generation, IET, 2019.
4. Ramesh C. Bansal, Handbook of Distributed Generation: Electric Power Technologies, Economics and Environmental Impacts, Springer, 2022.
5. Bent Sorensen, Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning, 6th Edition, Academic Press, 2024.

Suggested Skill Activities:

1. Design a rooftop solar PV system for an industrial facility.
2. Perform wind resource assessment using real meteorological data.
3. Develop a hybrid renewable energy system using HOMER Pro.
4. Analyze battery storage requirements for renewable integration.
5. Estimate Levelized Cost of Energy (LCOE) for different renewable technologies.
6. Conduct a techno-economic feasibility study of a renewable energy project.
7. Design an EV charging station powered by renewable energy.
8. Perform energy audits to identify renewable integration opportunities.
9. Study IEEE 1547 and Indian Grid Code requirements for distributed generation.
10. Prepare a carbon reduction plan for a manufacturing industry using distributed renewable energy.

Course Code:	24MS601	Course Title:	ENERGY STORAGE SYSTEMS AND ELECTRIC MOBILITY
Credits:	3	L – T – P	3-0-0

Course Objectives:

The course enables the students to:

- Understand the principles, characteristics, and applications of various energy storage technologies used in modern power systems and microgrids.
- Analyze the design, operation, and performance of battery energy storage systems (BESS) and advanced storage technologies for renewable energy integration.
- Apply energy storage solutions to improve grid stability, reliability, power quality, and energy management in smart grids and microgrids.
- Evaluate electric vehicle technologies, charging infrastructure, and Vehicle-to-Grid (V2G) integration for sustainable transportation.
- Develop innovative energy storage and electric mobility solutions using emerging technologies such as AI, IoT, digital twins, and battery analytics to address industrial and environmental challenges.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive lectures with industrial case studies
2. Problem-Based Learning (PBL)
3. Project-Based Learning
4. Flipped classroom methodology
5. Simulation using MATLAB/Simulink, HOMER Pro, PSCAD, ETAP, OpenDSS
6. Battery sizing and EV charging design exercises
7. Industry expert lectures
8. Site visits to EV charging stations, battery manufacturing plants, and renewable energy installations
9. Research paper review and technical seminars
10. NPTEL/MOOC-supported self-learning
11. Team-based design and innovation challenges

UNIT I – FUNDAMENTALS OF ENERGY STORAGE SYSTEMS	[9 hours]
Introduction to energy storage – Role of storage in renewable energy integration – Classification of energy storage systems – Electrical, electrochemical, mechanical, thermal, and chemical energy storage – Performance parameters – Energy density – Power density – Round-trip efficiency – Lifecycle analysis – Safety considerations – Applications in smart grids and microgrids.	

UNIT II – BATTERY ENERGY STORAGE SYSTEMS (BESS)	[9 hours]
Battery fundamentals – Battery chemistry – Lead-acid batteries – Lithium-ion batteries – Sodium-ion batteries – Solid-state batteries – Flow batteries – Battery sizing and selection – Battery Management System (BMS) – State of Charge (SOC) – State of Health (SOH) – Battery degradation – Thermal management – Battery safety standards.	

UNIT III – ADVANCED ENERGY STORAGE TECHNOLOGIES	[9 hours]
Super capacitors – Flywheel Energy Storage Systems – Pumped Hydro Energy Storage – Compressed Air Energy Storage (CAES) – Hydrogen production and storage – Fuel cells – Hybrid Energy Storage Systems (HESS) – Comparison of storage technologies – Techno-economic analysis – Selection criteria for industrial applications.	

UNIT IV – ELECTRIC MOBILITY AND CHARGING INFRASTRUCTURE	[9 hours]
Electric vehicles (EVs) – Types of EVs (BEV, HEV, PHEV, FCEV) – Electric traction systems – Electric motors for EVs – Power electronic converters – Charging technologies (AC, DC Fast Charging, Wireless Charging) – Charging standards (CCS, CHAdeMO, GB/T, Bharat DC-001) – Charging station planning – Vehicle-to-Grid (V2G) – Vehicle-to-Home (V2H) – Vehicle-to-Building (V2B).	

UNIT V – SMART ENERGY STORAGE AND FUTURE MOBILITY	[9 hours]
Grid-scale Battery Energy Storage Systems – Renewable-powered EV charging stations – AI-based battery health prediction – IoT-enabled battery monitoring – Digital Twin for batteries – Blockchain-enabled EV charging – Smart charging strategies – Demand response – Carbon-neutral transportation – Second-life battery applications – Battery recycling and circular economy – Green hydrogen mobility – Emerging trends in electric mobility.	

Course Outcomes:

On completion of the course, the student will have the ability to

CO No.	Course Outcomes	Highest Cognitive Level
CO1	Select suitable energy storage technologies for renewable energy integration and microgrid applications.	**K3**
CO2	Design Battery Energy Storage Systems (BESS) considering capacity, efficiency, lifecycle, and operational requirements.	**K4**
CO3	Apply battery management, charging strategies, and electric vehicle technologies for sustainable transportation systems.	**K3**
CO4	Analyze Vehicle-to-Grid (V2G), charging infrastructure, and grid integration for smart energy management.	**K4**
CO5	Develop intelligent energy storage and electric mobility solutions using AI, IoT, and predictive analytics to improve industrial energy efficiency and sustainability.	**K3**

COs and POs/PSOs Mapping:

COs	**POs**											**PSOs**		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**	**3**
CO1	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO2	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO3	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO4	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO5	3	2	1	-	1	-	-	1	-	-	1	2	1	-

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	Type of assessment	Max Marks	Reduced Marks	Total	Final marks
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern:

Bloom's Category	Continuous Internal Examination		End Semester Examination
	1	2	
Remember	10	10	10
Understand	10	10	10
Apply	48	48	48
Analyze	32	32	32
Evaluate	-	-	-
Create	-	-	-

Text Books:

1. Ru-Shi Liu, Leif Asp and Xueliang Sun (Eds.), Handbook of Energy Storage: Demand, Technologies, Integration and Applications, 2nd Edition, Springer, 2024.
2. Sheldon S. Williamson, Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles, Springer, 2022.
3. James Larminie and John Lowry, Electric Vehicle Technology Explained, 3rd Edition, Wiley, 2022.

Reference Books:

1. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley, 2021.
2. Chris Mi, M. Abul Masrur and David Wenzhong Gao, Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, 3rd Edition, Wiley, 2023.
3. Ibrahim Dincer and Halil S. Hamut, Energy Storage Systems for Sustainable Energy Applications, Springer, 2022.
4. Mehrdad Ehsani, Yimin Gao, Ali Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, 4th Edition, CRC Press, 2021.
5. B. K. Bose, Power Electronics and Motor Drives: Advances and Trends, Academic Press, 2021.

Suggested Skill Activities:

1. Design a Battery Energy Storage System (BESS) for a solar-powered microgrid.
2. Size a battery bank for an industrial load using real demand data.
3. Analyze battery charging and discharging characteristics using simulation tools.
4. Design an EV charging station for a commercial or institutional campus.
5. Evaluate Vehicle-to-Grid (V2G) operation for peak load management.
6. Develop an IoT-based battery monitoring dashboard.
7. Perform battery lifecycle and degradation analysis using real-world datasets.
8. Conduct a techno-economic analysis of different energy storage technologies.
9. Prepare a battery recycling and second-life utilization strategy.
10. Develop a sustainable electric mobility plan for a smart city or industrial estate.

Course Code:	**24MS602**	**Course Title:**	**POWER ELECTRONICS FOR MICROGRIDS**
Credits:	**3**	**L – T – P**	**3-0-0**

Course Objectives:

The course enables the students to:

- Understand the role of power electronic converters in renewable energy systems, distributed generation, and microgrid applications.
- Analyze the operation and performance of AC–DC, DC–DC, DC–AC, and AC–AC converters used in microgrids.
- Apply converter control techniques for integrating renewable energy sources, energy storage systems, and electric vehicles into AC and DC microgrids.
- Evaluate power quality improvement, grid synchronization, and protection techniques for reliable microgrid operation.
- Develop intelligent converter-based solutions using digital control, AI, IoT, and wide-bandgap semiconductor devices to address emerging industrial challenges.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive lectures supported by industrial case studies
2. Problem-Based Learning (PBL)
3. Project-Based Learning (PjBL)
4. Flipped classroom methodology
5. Simulation using MATLAB/Simulink, PSIM, PLECS, PSCAD, ETAP
6. Converter modeling and design exercises
7. Industrial expert lectures and webinars
8. Site visits to renewable power plants and power electronics industries
9. NPTEL/MOOC-supported self-learning

UNIT I – FUNDAMENTALS OF POWER ELECTRONICS FOR MICROGRIDS	**[9 hours]**
Introduction to power electronics – Role of converters in smart grids and microgrids – Review of power semiconductor devices – MOSFET, IGBT, SiC MOSFET, GaN HEMT – Switching characteristics – Gate drivers – Converter classifications – Efficiency improvement – Thermal management – Applications in renewable energy systems and distributed generation.	

UNIT II – POWER ELECTRONIC CONVERTERS FOR RENEWABLE ENERGY SYSTEMS	[9 hours]
AC–DC converters – Controlled and uncontrolled rectifiers – DC–DC converters (Buck, Boost, Buck-Boost, Cuk, SEPIC) – MPPT techniques – Bidirectional DC–DC converters – DC–AC inverters – Voltage Source Inverters (VSI) – Current Source Inverters (CSI) – Multilevel inverters – PWM techniques – Grid-tied converters.	

UNIT III – CONVERTER CONTROL AND MICROGRID INTEGRATION	[9 hours]
Grid-connected and islanded operation – Synchronization techniques – Phase-Locked Loop (PLL) – Droop control – Grid-following and Grid-forming converters – Active and reactive power control – Harmonic mitigation – Soft switching techniques – Digital control of converters – Converter coordination in hybrid AC/DC microgrids.	

UNIT IV – POWER QUALITY, PROTECTION AND SMART CONVERTER TECHNOLOGIES	[9 hours]
Power quality issues – Voltage sag, swell, harmonics and flicker – Active Power Filters (APF) – Static VAR Compensator (SVC) – STATCOM – Fault Ride Through (FRT) – Islanding detection – Converter protection – Cyber security for converter-based systems – IEC and IEEE standards.	

UNIT V – EMERGING TRENDS IN POWER ELECTRONICS FOR SMART MICROGRIDS	[9 hours]
Wide-bandgap semiconductor devices – Silicon Carbide (SiC) and Gallium Nitride (GaN) converters – AI-based converter control – IoT-enabled converter monitoring – Digital Twin for power converters – Predictive maintenance – Electric vehicle charging converters – Vehicle-to-Grid (V2G) power converters – Hydrogen power conversion – Smart Energy Routers – Future converter technologies.	

Course Outcomes:

On completion of the course, the student will have the ability to

CO No.	Course Outcomes	Highest Cognitive Level
CO1	Select appropriate power electronic converters for renewable energy, battery energy storage, and microgrid applications.	**K3**
CO2	Design and analyze converter systems to improve efficiency, voltage regulation, and power quality in AC and DC microgrids.	**K4**
CO3	Apply converter control strategies for grid-connected and islanded microgrid operations.	**K3**
CO4	Evaluate advanced converter technologies, synchronization methods, and protection schemes for smart microgrids.	**K4**
CO5	Develop intelligent power electronic solutions incorporating AI, IoT, digital control, and wide-bandgap semiconductor technologies for sustainable energy systems.	**K3**

COs and POs/PSOs Mapping:

COs	POs											PSOs		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**	**3**
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CO2	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO3	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO4	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO5	3	2	1	-	1	-	-	1	-	-	1	2	1	-

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	Type of assessment	Max Marks	Reduced Marks	Total	Final marks
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern:

Bloom's Category	Continuous Internal Examination		End Semester Examination
	1	2	
Remember	10	10	10
Understand	10	10	10
Apply	48	48	48
Analyze	32	32	32
Evaluate	-	-	-
Create	-	-	-

Text Books:

1. Ned Mohan, Tore M. Undeland and William P. Robbins, Power Electronics: Converters, Applications and Design, 4th Edition, Wiley, 2023.
2. Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, 5th Edition, Pearson, 2024.
3. Frede Blaabjerg (Ed.), Control of Power Electronic Converters and Systems, Academic Press, 2021.

Reference Books:

1. Frede Blaabjerg and Yongheng Yang (Eds.), Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications, Wiley-IEEE Press, 2022.
2. Bimal K. Bose, Power Electronics and Motor Drives: Advances and Trends, Academic Press, 2021.
3. Fang Lin Luo and Hong Ye, Advanced DC/DC Converters, 3rd Edition, CRC Press, 2022.
4. Remus Teodorescu, Marco Liserre and Pedro Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems, Wiley-IEEE Press, 2021.
5. Mohan Kolhe and Kaushik Rajashekara (Eds.), Smart Grid Integration of Renewable Energy Systems, Springer, 2022.

Suggested Skill Activities:

1. Design and simulate a grid-connected solar PV inverter.
2. Develop a bidirectional DC–DC converter for battery energy storage.
3. Implement Maximum Power Point Tracking (MPPT) algorithms using MATLAB/Simulink.
4. Analyze harmonic distortion and design an active power filter.
5. Design a multilevel inverter for microgrid applications.
6. Evaluate grid-forming and grid-following inverter performance.
7. Design a fast DC charger for electric vehicles.
8. Study converter efficiency using Si, SiC, and GaN semiconductor devices.
9. Develop an IoT-based converter monitoring system.
10. Prepare a techno-economic comparison of converter technologies used in industrial microgrids.

Course Code:	24MS701	Course Title:	SMART GRID COMMUNICATION, PROTECTION AND CYBERSECURITY
Credits:	3	L – T – P	3-0-0

Course Objectives:

The course enables the students to:

- Understand smart grid communication architectures, standards, protocols, and automation technologies for modern power systems.
- Analyze communication networks, protection schemes, and monitoring systems for reliable operation of renewable-integrated smart grids and microgrids.
- Apply SCADA, IoT, PMUs, cloud computing, and edge intelligence for real-time monitoring, automation, and energy management.
- Evaluate cybersecurity threats, vulnerabilities, standards, and mitigation strategies for securing critical power infrastructure.
- Develop intelligent, secure, and resilient smart grid solutions using Artificial Intelligence, Digital Twins, Blockchain, and next-generation communication technologies.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Interactive lectures using real-world utility case studies
2. Problem-Based Learning (PBL)
3. Project-Based Learning (PjBL)
4. Case studies on smart grid cyber incidents
5. Simulation using MATLAB/Simulink, ETAP, DIgSILENT PowerFactory, OpenDSS, NS-3, OMNeT++, Wireshark, and SCADA simulation software
6. Laboratory demonstrations on communication protocols and IoT devices
7. Flipped classroom and collaborative learning
8. Industry expert lectures and webinars
9. Technical seminars and IEEE paper discussions
10. Site visits to smart substations, renewable energy control centers, and utility dispatch centers
11. NPTEL/MOOC-supported self-learning
12. Mini design challenges and hackathons on smart grid communication and cybersecurity

UNIT I – SMART GRID COMMUNICATION ARCHITECTURE	[9 hours]
Evolution of conventional power grids to smart grids – Smart grid architecture – Functional layers – Communication hierarchy – Home Area Network (HAN), Building Area Network (BAN), Industrial Area Network (IAN), Neighborhood Area Network (NAN), Wide Area Network (WAN) – Smart meters – Advanced Metering Infrastructure (AMI) – Intelligent Electronic Devices (IEDs) – Phasor Measurement Units (PMUs) – Wide Area Measurement Systems (WAMS).	

UNIT II – COMMUNICATION PROTOCOLS AND SMART GRID AUTOMATION	**[9 hours]**
SCADA architecture – Remote Terminal Units (RTUs) – Programmable Logic Controllers (PLCs) – Distributed Control Systems (DCS) – IEC 61850 – IEC 60870-5-104 – DNP3 – Modbus – MQTT – OPC UA – IEEE C37.118 – GPS and IEEE 1588 Precision Time Protocol (PTP) – Cloud-based SCADA – Edge computing – Fog computing – Virtual substations – Digital substations.	

UNIT III – PROTECTION AND INTELLIGENT MONITORING OF SMART GRIDS	**[9 hours]**
Protection requirements in inverter-dominated grids – Adaptive protection – Numerical relays – Distance, differential, overcurrent, directional and differential protection – Islanding detection – Fault location techniques – PMU-based monitoring – Wide Area Protection Systems (WAPS) – State estimation – Distribution automation – Self-healing grids – Power quality monitoring – Condition monitoring.	

UNIT IV – CYBERSECURITY FOR SMART GRIDS	**[9 hours]**
Cybersecurity fundamentals – Cyber-Physical Systems (CPS) – Smart grid vulnerabilities – Attack vectors – Malware – Ransomware – Phishing – Insider attacks – Denial-of-Service (DoS) and Distributed DoS – Secure communication architecture – Encryption – Authentication – Public Key Infrastructure (PKI) – Identity and Access Management (IAM) – Firewalls – Intrusion Detection and Prevention Systems (IDS/IPS) – Security Information and Event Management (SIEM) – Security Operations Center (SOC) – Zero Trust Architecture – IEC 62443 – NERC CIP – ISO/IEC 27001.	

UNIT V – INTELLIGENT SECURE SMART GRIDS AND FUTURE TRENDS	**[9 hours]**
Artificial Intelligence and Machine Learning for smart grid operation – IoT-enabled grid monitoring – Cloud and Edge AI – Blockchain-enabled peer-to-peer energy trading – Digital Twin-enabled grid operation – Cyber-physical resilience – Virtual Power Plants (VPP) – Vehicle-to-Grid (V2G) and Vehicle-to-Everything (V2X) communication – Federated learning – Quantum-safe cryptography – Autonomous grid management – Future trends in Smart Grid 2.0.	

Course Outcomes:

On completion of the course, the student will have the ability to

CO No.	Course Outcomes	Highest Cognitive Level
CO1	Design smart grid communication networks using modern communication architectures, protocols, and standards.	**K3**
CO2	Apply intelligent protection, automation, and monitoring techniques to enhance the reliability and resilience of smart grids and microgrids.	**K4**
CO3	Develop SCADA and IoT-based monitoring systems for real-time data acquisition, visualization, and energy management.	**K3**
CO4	Assess cybersecurity risks and implement secure communication architectures using industry-standard security frameworks.	**K4**
CO5	Design AI-enabled, cyber-secure smart grid solutions integrating communication, protection, renewable energy resources, and intelligent energy management.	**K3**

COs and POs/PSOs Mapping:

COs	POs											PSOs		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**	**3**
CO1	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO2	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO3	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO4	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO5	3	2	1	-	1	-	-	1	-	-	1	2	1	-

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

Component	Type of assessment	Max Marks	Reduced Marks	Total	Final marks
Continuous Internal Examination (CIE)	CIE – I	100	50	100	40
	CIE – II	100			
	MCQ	20	10		
	Skill Assessment - I	40	40		
	Skill Assessment - II	40			
End Semester Examination (ESE)	Theory Exam	100	60	60	60
				Total	100

End semester Examination: (QP PATTERN)

- Each unit consists of two 2 marks questions and one 16 marks question (either or).
- All the fifteen questions have to be answered.

Assessment Pattern:

Bloom's Category	Continuous Internal Examination		End Semester Examination
	1	2	
Remember	10	10	10
Understand	10	10	10
Apply	48	48	48
Analyze	32	32	32
Evaluate	-	-	-
Create	-	-	-

Text Books:

1. James Momoh, Smart Grid: Fundamentals of Design and Analysis, 3rd Edition, Wiley-IEEE Press, 2023.
2. Stuart Borlase, Smart Grids: Infrastructure, Technology and Solutions, 3rd Edition, CRC Press, 2022.
3. Nikos Hatziargyriou, Microgrids: Architectures and Control, 2nd Edition, Wiley-IEEE Press, 2024.

Reference Books:

1. Gilbert N. Sorebo and Michael C. Echols, Smart Grid Security: An End-to-End View of Security in the New Electrical Grid, 3rd Edition, CRC Press, 2022.
2. Eric D. Knapp and Raj Samani, Applied Cyber Security and the Smart Grid: Implementing Security Controls into the Modern Power Infrastructure, 2nd Edition, Elsevier, 2024.
3. Massoud Amin and Bruce F. Wollenberg, Toward a Smart Grid: Power Delivery for the 21st Century, Wiley-IEEE Press.
4. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley, 2021.
5. IEC 61850 Series, Communication Networks and Systems for Power Utility Automation, Latest Edition.
6. IEC 62443 Series, Industrial Communication Networks – Network and System Security, Latest Edition.
7. IEEE Std C37.118, IEEE Standard for Synchrophasor Measurements for Power Systems, Latest Edition.
8. NERC, Critical Infrastructure Protection (NERC CIP) Standards, Latest Edition.

Suggested Skill Activities:

1. Design an IEC 61850-based communication network for a smart substation.
2. Configure a SCADA system for monitoring renewable energy resources.
3. Develop an MQTT/OPC UA-based IoT energy monitoring application.
4. Simulate adaptive protection for an inverter-based microgrid.
5. Analyze PMU data for oscillation detection and state estimation.
6. Perform cybersecurity vulnerability assessment of a smart grid communication network.
7. Implement secure communication using TLS, VPN, and PKI.
8. Develop an AI-based fault detection model using smart meter data.
9. Simulate cyberattack scenarios using NS-3/Wireshark and propose mitigation strategies.
10. Design a secure communication and protection architecture for a campus microgrid integrating renewable energy and EV charging infrastructure.

Course Code:	**24MS702**	**Course Title:**	**MICROGRID DESIGN, CONTROL AND ENERGY MANAGEMENT LABORATORY**
Credits:	**3**	**L – T – P**	**0-0-6**

Course Objectives:

The course enables the students to:

- Design and simulate AC, DC, and hybrid microgrids using modern power system software tools.
- Apply renewable energy integration, battery energy storage, and distributed generation concepts in microgrid design.
- Implement control strategies, protection schemes, and energy management algorithms for grid-connected and islanded microgrid operation.
- Analyze the performance of microgrids under varying load, fault, and renewable energy conditions using simulation and hardware platforms.
- Develop industry-oriented solutions using AI, IoT, Digital Twin, and smart energy management technologies for sustainable microgrid operation.

Teaching-Learning Process:

Suggested strategies that teachers may use to effectively achieve the course outcomes:

1. Hands-on laboratory sessions
2. Problem-Based Learning (PBL)
3. Project-Based Learning (PjBL)
4. Simulation-based learning
5. Case studies on industrial microgrids
6. Collaborative team projects
7. Industry expert demonstrations
8. Design thinking workshops
9. Flipped laboratory sessions
10. Self-learning through NPTEL/MOOCs and IEEE tutorials

LABORATORY EXPERIMENTS

Module I – MICROGRID DESIGN

1. Design and simulation of an AC microgrid using MATLAB/Simulink or ETAP.
2. Design and simulation of a DC microgrid with renewable energy sources.
3. Development of a hybrid AC/DC microgrid model.
4. Modeling and integration of distributed generation sources (Solar PV, Wind, Diesel Generator).

Module II – RENEWABLE ENERGY AND ENERGY STORAGE INTEGRATION

5. Design and sizing of Battery Energy Storage Systems (BESS) for a microgrid.
6. Simulation of Solar PV with Maximum Power Point Tracking (MPPT).
7. Modeling of hybrid renewable energy systems using HOMER Pro/OpenDSS.
8. Analysis of battery charging/discharging characteristics and State of Charge (SOC).

Module III – MICROGRID CONTROL AND PROTECTION

9. Simulation of grid-connected and islanded modes of microgrid operation.
10. Implementation of droop control and load-sharing techniques.
11. Synchronization of distributed generators with the utility grid.
12. Protection coordination and fault analysis in a microgrid using ETAP/DIgSILENT.

Module IV – ENERGY MANAGEMENT AND SMART MONITORING

13. Development of an Energy Management System (EMS) for optimal power dispatch.
14. Demand response and load management using smart scheduling algorithms.
15. IoT-based real-time monitoring of microgrid parameters.
16. AI-based load forecasting and energy optimization using Python/MATLAB.

Module V – EMERGING TECHNOLOGIES AND INDUSTRIAL APPLICATIONS

17. Digital Twin modeling of a microgrid.
18. Simulation of Electric Vehicle (EV) charging integrated with a microgrid.
19. Vehicle-to-Grid (V2G) energy management.
20. Capstone Mini Project: Design, simulation, optimization, and techno-economic analysis of a smart microgrid for a campus, hospital, industry, or rural community.

SOFTWARE TOOLS:

- MATLAB/Simulink (Simscape Electrical)
- ETAP
- DIgSILENT PowerFactory
- HOMER Pro
- OpenDSS
- PSCAD
- Python (Pandas, NumPy, Pyomo, TensorFlow)
- Arduino/ESP32/Raspberry Pi for IoT-based monitoring

Course Outcomes:

On completion of the course, the student will have the ability to

CO No.	Course Outcomes	Highest Cognitive Level
CO1	Design and simulate AC, DC, and hybrid microgrids using industry-standard software tools.	**K3**
CO2	Integrate renewable energy sources, battery energy storage systems, and distributed generators into microgrid architectures.	**K4**
CO3	Apply microgrid control, synchronization, protection, and energy management techniques under different operating conditions.	**K3**
CO4	Analyze microgrid performance using real-time monitoring, optimization, and fault analysis tools.	**K4**
CO5	Develop intelligent microgrid solutions using AI, IoT, Digital Twin, and predictive energy management techniques for industrial applications.	**K3**

COs and POs/PSOs Mapping:

COs	POs											PSOs		
	1	2	3	4	5	6	7	8	9	10	11	1	2	3
CO1	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO2	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO3	3	2	1	-	1	-	-	1	-	-	1	2	1	-
CO4	3	3	1	-	1	-	-	1	-	-	1	2	1	-
CO5	3	2	1	-	1	-	-	1	-	-	1	2	1	-

Level 3- Highly Mapped, Level 2- Moderately Mapped, Level 1- Low Mapped, Level 0- Not Mapped

Scheme of Evaluation:

S.No.	Component	Type of Assessment	Max Marks	Reduced Marks	Total	Final Marks
1.	Continuous Internal Examination(CIE)-Laboratory	Continuous Assessment	75	75	100	60
2.		Model Lab Exam	25	25		
3.	End Semester Examination (ESE)	Lab Exam	100	40	40	40
					Total	100

Assessment Pattern:

Bloom's Category	Terminal Examination
Remember	0
Understand	0
Apply	100
Analyze	0
Evaluate	0
Create	0

Text Books:

1. James Momoh, Smart Grid: Fundamentals of Design and Analysis, 3rd Edition, Wiley-IEEE Press, 2023.
2. Stuart Borlase, Smart Grids: Infrastructure, Technology and Solutions, 3rd Edition, CRC Press, 2022.
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3. Massoud Amin and Bruce F. Wollenberg, Toward a Smart Grid: Power Delivery for the 21st Century, Wiley-IEEE Press.
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