Zeal Education Society's

# ZEAL COLLEGE OF ENGINEERING & RESEARCH, PUNE – 41

(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

*NBA Accredited, NAAC Accredited with **A**+ Grade / ISO 21001:2018*

## DEPARTMENT OF ELECTRICAL ENGINEERING

## Curriculum Structure and Syllabus of

## T.Y. B. Tech. – Electrical Engineering

## (With effect from - Academic Year 2026- 27)

## (Honors Course)

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## VISION OF THE INSTITUTE

To be a premier institute in technical education by imparting academic excellence, research, social and entrepreneurial attitude.

## MISSION OF THE INSTITUTE

- To achieve academic excellence through innovative teaching and learning process.
- To imbibe the research culture for addressing industry and societal needs.
- To inculcate social attitude through community engagement initiatives.
- To provide conducive environment for building the entrepreneurial skills.

# DEPARTMENT OF ELECTRICAL ENGINEERING

## VISION:

To be premier institute in technical education by imparting academic excellence, research, social and entrepreneurial attitude.

## MISSION:

**M1:** To achieve academic excellence through innovative teaching and learning process
**M2:** To imbibe the research culture for addressing industry and societal needs.
**M3:** To inculcate social attitude through community engagement initiatives.
**M4:** To provide conducive environment for building the entrepreneurial skills.

## PROGRAM EDUCATIONAL OBJECTIVES (PEOs):

**PEO1:** Graduates will be able to apply their technical skill sets and knowledge to solve engineering-based problems in industry, academic and diverse fields of Electrical Engineering.
**PEO2:** Graduates will demonstrate ethical and social responsibility while engaging in research, innovative practices and entrepreneurial activities, contributing positively to society and technological advancement.
**PEO3:** Graduates will embrace lifelong learning and adaptability, staying updated with emerging technologies, industry trends and advancements in electrical engineering.

## PROGRAM OUTCOMES (POs):

**PO1: Engineering Knowledge:** Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop the solution of complex engineering problems.
**PO2: Problem Analysis:** Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
**PO3: Design/Development of Solutions:** Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)
**PO4: Conduct Investigations of Complex Problems:** Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)
**PO5: Engineering Tool Usage:** Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems. (WK2 and WK6).

## DEPARTMENT OF ELECTRICAL ENGINEERING

**PO6: The Engineer and the World:** Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).

**PO7: Ethics:** Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9).

**PO8: Individual and Collaborative Team Work:** Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.

**PO9: Communication:** Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.

**PO10: Project Management and Finance:** Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.

**PO11: Life-Long Learning:** Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

**PROGRAM SPECIFIC OUTCOMES (PSOs):**

**PSO1:** To apply knowledge to build ability to design analyses and solve problems in the field of electrical engineering through power systems, electrical machines, control systems, electronics and automation.

**PSO2:** To develop solution to real time problems through appropriate techniques, modern engineering hardware and software tools related Electrical engineering.

## DEPARTMENT OF ELECTRICAL ENGINEERING

# LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| BSC | Basic Science Course |
| ESC | Engineering Science Course |
| PCC | Program Core Course |
| PEC | Program Elective Course |
| MDM | Multidisciplinary Minor |
| OE | Open Elective - Other than a particular program |
| VSEC | Vocational and Skill Enhancement Course |
| AEC | Ability Enhancement Course |
| ENTR | Entrepreneurship |
| EC | Economics |
| MC | Management Courses |
| IKS | Indian Knowledge System |
| VEC | Value Education Courses |
| RM | Research Methodology |
| CEP | Community Engagement Project |
| FP | Field Project |
| PROJ | Project |
| INT | Internship |
| OJT | On Job Training |
| CC | Co-curricular Courses |
| HSSM | Humanities Social Science and Management |
| ELC | Experiential Learning Course |
| B. Tech | Bachelor of Technology |
| L | Lecture |
| P | Practical |
| T | Tutorial |
| H | Hours |
| CR | Credits |
| CIE | Continuous Internal Evaluation |
| ETE | End Term Evaluation |
| TW | Term Work |
| OR | Oral |
| PR | Project |

## DEPARTMENT OF ELECTRICAL ENGINEERING

# B. Tech. with Honours – Electrical Engineering

### Power Electronics & Drives Honours Courses

| Course Code | Course Type | Course Name | Teaching Scheme (hrs/Week) | | | | | | | Evaluation Scheme | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L | P | T | H | CR | | | CIE | ETE | TW | PR | OR | Total |
| | | | | | | | TH | PR/Tut | Total | | | | | | |
| EEHC501 | Hon | Advanced Power Electronic Converters | 3 | - | 1 | 4 | 4 | - | 4 | - | 100 | - | - | - | 100 |
| EEHC603 | Hon | Modelling & Control of Electrical Drives | 3 | - | 1 | 4 | 4 | - | 4 | - | 100 | - | - | - | 100 |
| EEHC705 | Hon | Digital Control of Power Electronic Systems | 3 | - | 1 | 4 | 4 | - | 4 | - | 100 | - | - | - | 100 |
| EEHC806 | Hon | Mini Project | - | 12 | - | 12 | 6 | - | 6 | - | - | 50 | - | 50 | 100 |

### Power System Honours Courses

| Course Code | Course Type | Course Name | Teaching Scheme (hrs/Week) | | | | | | | Evaluation Scheme | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L | P | T | H | CR | | | CIE | ETE | TW | PR | OR | Total |
| | | | | | | | TH | PR/Tut | Total | | | | | | |
| EEHC502 | Hon | Advanced Power System Analysis | 3 | - | 1 | 4 | 4 | - | 4 | - | 100 | - | - | - | 100 |
| EEHC604 | Hon | Smart Grid Technologies & Applications | 3 | - | 1 | 4 | 4 | - | 4 | - | 100 | - | - | - | 100 |
| EEHC706 | Hon | Renewable Energy Integration in Power Systems | 3 | - | 1 | 4 | 4 | - | 4 | - | 100 | - | - | - | 100 |
| EEHC807 | Hon | Mini Project | - | 12 | - | 12 | 6 | - | 6 | - | - | 50 | - | 50 | 100 |

BoS Chairman

ZES's Zeal College of Engineering & Research PU/PN/Engg./285/2007 Narhe, Pune-41

Director

ZES's Zeal College of Engineering & Research Narhe, Pune - 411041.

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| 3 | EEHC705 | Digital Control of Power Electronic Systems | |
| 4 | EEHC806 | Mini Project | |
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| 8 | EEHC807 | Mini Project | |

**DEPARTMENT OF ELECTRICAL ENGINEERING**

# SYLLABUS

## Power Electronics & Drives

## Honours Course

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| **Program:** B. Tech. with Honours (Electrical Engineering) | | | | | | | **Semester: V** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Course: Advanced Power Electronic Converters** | | | | | | | **Code:** EEHC501 | | |
| **Teaching Scheme (Hrs/week)** | | | | **Evaluation Scheme (Marks)** | | | | | |
| **Lecture** | **Practical** | **Tutorial** | **Credit** | **CIE** | **ETE** | **TW** | **OR** | **PR** | **Total** |
| 3 | | 1 | 4 | | 100 | | | | 100 |

**Prerequisites:**

Basic knowledge of Power Electronics, Semiconductor devices (SCR, MOSFET, IGBT), Basic DC-DC converters, Inverters and Fundamental control techniques.

**Course Objectives:**

To provide advanced knowledge of modern power electronic converters, their operating principles, control strategies, modulation techniques and applications in renewable energy systems, electric vehicles, and industrial drives.

**Course Outcomes:** After completion of this course, students will be able to -

| | |
|---|---|
| **CO1** | Explain the operation and performance of advanced non-isolated and isolated DC-DC converters. |
| **CO2** | Describe the working of multipulse converters and high-power converter configurations. |
| **CO3** | Explain soft-switching techniques and resonant converter topologies. |
| **CO4** | Evaluate the application of advanced power converters in renewable energy systems, electric vehicles and industrial drives. |

**Course Contents:**

| **Unit** | **Description** | **Duration (Hrs.)** |
|---|---|---|
| 1. | **Advanced DC-DC Converters:**<br>Review of basic DC-DC converters (Buck, Boost, Buck-Boost, Cuk); Cascaded and quadratic converters; SEPIC and Zeta converters; Interleaved DC-DC converters; Isolated DC-DC converters – Flyback, Forward, Push-Pull, Half-bridge and Full-bridge converters; Dual Active Bridge (DAB) converter; Comparison of isolated and non-isolated topologies; Design considerations and applications. | 10 |
| 2. | **Multilevel Inverters: Need for multilevel inverters:**<br>Classification of multilevel inverters; Diode Clamped (Neutral Point Clamped – NPC) multilevel inverter; Flying Capacitor multilevel inverter; Cascaded H-Bridge (CHB) multilevel inverter; Modular Multilevel Converter (MMC) – basic concept; Comparison of multilevel inverter topologies; Advantages and applications in high-power systems.<br>**Multipulse and High-Power Converters:**<br>Concept of multipulse converters; 12-pulse, 18-pulse and 24-pulse converters; Phase-shifting transformers; Harmonic reduction in multipulse converters; Load-commutated inverters; Current Source Inverters (CSI); Voltage Source Inverters (VSI) for high-power applications; Introduction to cycloconverters and matrix converters. | 12 |
| 3. | **Soft-Switching and Resonant Converters:**<br>Hard switching vs Soft switching; Need for soft-switching techniques; Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS); Resonant converters – Series Resonant Converter, Parallel Resonant Converter, Series-Parallel Resonant Converter; | 10 |

| | | |
|---|---|---|
| | Quasi-resonant converters; Phase-shifted full-bridge ZVS converter; Advantages and limitations of soft-switching techniques. | |
| 4. | **Advanced Modulation and Control Techniques:** Review of Sinusoidal PWM (SPWM); Space Vector PWM (SVPWM) – principle and implementation; Selective Harmonic Elimination (SHE) PWM; Hysteresis current control; Predictive control techniques (basic concept); Voltage-oriented control and Field-oriented control (introductory level); Digital control of power converters using DSP/FPGA (overview). **Applications of Advanced Power Converters:** Power converters for renewable energy systems (Solar PV and Wind); Grid-connected inverters and synchronization; Power converters for Electric Vehicle battery charging (On-board and Off-board chargers); Bidirectional converters for V2G applications; Power converters for HVDC and FACTS devices (overview); Case studies and emerging trends in power electronic converters. | 12 |
| | **TOTAL** | **42** |

**Text Books:**

1. Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson.
2. Ned Mohan, Tore M. Undeland and William P. Robbins, Power Electronics: Converters, Applications, and Design, Wiley.
3. Bin Wu and Mehdi Narimani, High-Power Converters and AC Drives, Wiley – IEEE Press.
4. V. Ramanarayanan, Course Material on Power Electronics, IISc Bangalore.

**Reference Books:**

1. Andrzej M. Trzynadlowski, Introduction to Modern Power Electronics, Wiley.
2. Fang Lin Luo and Hong Ye, Advanced DC/DC Converters, CRC Press.
3. Bin Wu, High-Power Converters and AC Drives, IEEE Press.
4. Erickson and Maksimovic, Fundamentals of Power Electronics, Springer.

**E-Resources:**

1. NPTEL Course: Advanced Power Electronics – Prof. Vivek Agarwal / Prof. A. K. Chattopadhyay https://nptel.ac.in/courses/108102584
2. NPTEL Course: Power Electronics – Prof. G. Bhuvaneswari / Prof. B. G. Fernandes https://nptel.ac.in/courses/108102145
3. NPTEL Course: Pulse Width Modulation for Power Electronic Converters https://nptel.ac.in/courses/108101038
4. IEEE Xplore tutorials and application notes on Multilevel Inverters and Dual Active Bridge converters

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# DEPARTMENT OF ELECTRICAL ENGINEERING

| **Program:** B. Tech. with Honours (Electrical Engineering) | | | | | | | **Semester: VI** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Course: Modelling & Control of Electrical Drives** | | | | | | | **Code:** EEHC603 | | |
| **Teaching Scheme (Hrs/week)** | | | | **Evaluation Scheme (Marks)** | | | | | |
| **Lecture** | **Practical** | **Tutorial** | **Credit** | **CIE** | **ETE** | **TW** | **OR** | **PR** | **Total** |
| 3 | | 1 | 4 | | 100 | | | | 100 |

**Prerequisites:**

Basic knowledge of Electrical Machines (DC Motors, Induction Motors, Synchronous Motors), Power Electronics, and fundamental control systems.

**Course Objectives:**

To provide a comprehensive understanding of mathematical modelling, dynamic behaviour and advanced control techniques of electric drive systems for industrial, traction and electric vehicle applications.

**Course Outcomes:** After completion of this course, students will be able to -

| | |
|---|---|
| **CO1** | Develop mathematical models of DC and AC machines for drive applications. |
| **CO2** | Analyze the steady-state and dynamic performance of electrical drives. |
| **CO3** | Explain control methods for D.C. Motor Drives and Induction Motor drives. |
| **CO4** | Evaluate advanced control techniques and applications of electrical drives in modern systems. |

**Course Contents:**

| **Unit** | **Description** | **Duration (Hrs.)** |
|---|---|---|
| 1. | **Introduction to Electrical Drives and Modelling Fundamentals:** Components of an electrical drive system; Classification of drives; Advantages of electrical drives; Multi-quadrant operation; Equivalent circuit and mathematical modelling of separately excited DC motor; Transfer function model of DC motor drive; State-space modelling of DC motor; Load torque characteristics and drive selection criteria. | 10 |
| 2. | **Modelling of AC Machines:** Three-phase to two-phase transformation (Clarke transformation); Rotating reference frame transformation (Park transformation); Dynamic modelling of three-phase Induction Motor in stationary and rotating reference frames; Modelling of Permanent Magnet Synchronous Motor (PMSM); Modelling of Brushless DC Motor (BLDC); Introduction to modelling of Switched Reluctance Motor (SRM). | 10 |
| 3. | **Control of DC Motor Drives:** Single-phase and three-phase fully controlled converter-fed DC motor drives; Chopper-controlled DC motor drives; Closed-loop speed control of DC motor drives; Armature voltage control and field weakening control; Current control and speed control loops; Design of controllers (P, PI) for DC motor drives; Dynamic response and stability aspects. **Control of Induction Motor Drives:** Stator voltage control and slip power recovery schemes (overview); V/f (Scalar) control of induction motor – principle, open-loop and closed-loop operation; Voltage Source Inverter (VSI) and Current Source Inverter (CSI) fed induction motor drives; Static frequency changers; Rotor resistance control and cascade control (basic concepts); Comparison of different control methods. | 12 |

| | | |
|---|---|---|
| 4. | **Vector Control and Advanced Control of Induction Motor Drives:**<br>Principle of Vector Control (Field Oriented Control – FOC); Direct and Indirect vector control; Implementation of vector control using voltage source inverters; Introduction to Direct Torque Control (DTC); Comparison of FOC and DTC; Sensorless control of induction motor drives (basic concept); Applications in high-performance industrial drives.<br>**Control of Special Machine Drives and Applications:**<br>Control of Permanent Magnet Synchronous Motor (PMSM) drives – sinusoidal and trapezoidal control; Control of Brushless DC (BLDC) motor drives; Control of Switched Reluctance Motor (SRM) drives; Introduction to Model Predictive Control (MPC) of drives; Applications of advanced electrical drives in Electric Vehicles, Traction, Robotics and Renewable energy systems; Case studies and emerging trends. | 12 |
| | **TOTAL** | **42** |

**Text Books:**

1. R. Krishnan, Electric Motor Drives: Modeling, Analysis, and Control, Pearson.
2. Bimal K. Bose, Modern Power Electronics and AC Drives, Pearson.
3. G. K. Dubey, Fundamentals of Electrical Drives, Narosa Publishing House.
4. P. C. Sen, Principles of Electric Machines and Power Electronics, Wiley.

**Reference Books:**

1. Werner Leonhard, Control of Electrical Drives, Springer.
2. Peter Vas, Vector Control of AC Machines, Oxford University Press.
3. Ion Boldea and S. A. Nasar, Electric Drives, CRC Press.
4. K. Venkataratnam, Special Electrical Machines, Universities Press.

**E-Resources:**

1. NPTEL Course: Advanced Electric Drives – Prof. Shyama Prasad Das, IIT Kanpur https://nptel.ac.in/courses/108104140
2. NPTEL Course: Electric Drives – Prof. S. P. Das / Prof. G. Bhuvaneswari https://nptel.ac.in/courses/108104011
3. NPTEL Course: Power Electronics and Electric Drives https://nptel.ac.in/courses/108102145
4. MATLAB / Simulink based drive system simulation resources

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# SYLLABUS

## Power System

## Honours Courses

## DEPARTMENT OF ELECTRICAL ENGINEERING

| **Program:** B. Tech. with Honours (Electrical Engineering) | | | | | | | **Semester: V** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Course: Advanced Power System Analysis** | | | | | | | **Code:** EEHC502 | | |
| **Teaching Scheme (Hrs/week)** | | | | **Evaluation Scheme (Marks)** | | | | | |
| **Lecture** | **Practical** | **Tutorial** | **Credit** | **CIE** | **ETE** | **TW** | **OR** | **PR** | **Total** |
| 3 | | 1 | 4 | | 100 | | | | 100 |

**Prerequisites:**

Basic knowledge of Power System Analysis, Transmission line parameters, Load flow studies, Symmetrical and Unsymmetrical fault analysis, and Power system stability fundamentals.

**Course Objectives:**

To provide advanced knowledge of modern power system analysis techniques including advanced load flow methods, contingency analysis, state estimation, power system security, optimal power flow, and stability studies for large interconnected power systems.

**Course Outcomes:** After completion of this course, students will be able to -

| | |
|---|---|
| **CO1** | Apply advanced numerical methods for load flow analysis of large power systems. |
| **CO2** | Analyze power system security and perform contingency analysis. |
| **CO3** | Formulate and solve Optimal Power Flow (OPF) problems for economic and secure operation. |
| **CO4** | Apply modern computational tools and techniques for advanced power system studies. |

**Course Contents:**

| **Unit** | **Description** | **Duration (Hrs.)** |
|---|---|---|
| 1. | **Advanced Load Flow Studies:**<br>Review of Gauss-Seidel and Newton-Raphson load flow methods; Fast Decoupled Load Flow (FDLF) method; DC load flow analysis; Three-phase load flow analysis; Load flow for radial distribution systems; Handling of voltage-controlled buses, generator reactive power limits and transformer tap settings; Comparison of load flow methods for large systems; Sparse matrix techniques (overview). | 10 |
| 2. | **Power System Security and Contingency Analysis:**<br>Concept of power system security; Security levels and security assessment; Contingency analysis – definition and importance; Contingency selection and screening methods; Linear sensitivity factors – Generation Shift Factor (GSF) and Line Outage Distribution Factor (LODF); AC contingency analysis; Security-constrained economic dispatch (basic concept); Remedial action and security enhancement techniques.<br>**State Estimation in Power Systems:**<br>Need for state estimation; Difference between load flow and state estimation; Weighted Least Squares (WLS) state estimation method; Measurement model and Jacobian matrix; Observability analysis (basic concept); Bad data detection and identification using Chi-squares test and normalized residual method; Role of PMUs (Phasor Measurement Units) in state estimation; Applications of state estimation in modern power systems. | 12 |
| 3. | **Optimal Power Flow (OPF):**<br>Economic Load Dispatch (ELD) review; Formulation of Optimal Power Flow problem; Objective functions – fuel cost minimization, loss minimization and emission minimization; Equality and inequality constraints; Solution methods – Gradient method, Newton method and Linear Programming method (overview); Security-constrained | 10 |

| | | |
|---|---|---|
| | OPF; Reactive power optimization and voltage control; Introduction to meta-heuristic techniques for OPF (basic awareness). | |
| 4. | **Advanced Power System Stability Analysis:**<br>Review of rotor angle stability and swing equation; Equal Area Criterion for multi-machine systems (overview); Numerical solution of swing equation – Modified Euler and Runge-Kutta methods; Multi-machine transient stability analysis; Voltage stability – concept, P-V and Q-V curves; Voltage stability indices; Voltage collapse and prevention methods; Introduction to small-signal stability and eigenvalue analysis (basic concept).<br>**Modern Trends and Computational Aspects:**<br>Introduction to Wide Area Monitoring Systems (WAMS) and PMUs; Application of Artificial Intelligence and Machine Learning in power system analysis (overview); Real-time power system analysis and Energy Management System (EMS) functions; Power system analysis under high renewable energy penetration; Introduction to available software tools (MiPower, ETAP, PSCAD, MATPOWER, PowerWorld – overview); Case studies on advanced power system analysis. | 12 |
| | **TOTAL** | **42** |

**Text Books:**

1. Hadi Saadat, Power System Analysis, McGraw-Hill Education.
2. John J. Grainger and William D. Stevenson, Power System Analysis, McGraw-Hill.
3. Allen J. Wood, Bruce F. Wollenberg and Gerald B. Sheblé, Power Generation, Operation, and Control, Wiley.
4. D. P. Kothari and I. J. Nagrath, Modern Power System Analysis, McGraw-Hill.

**Reference Books:**

1. J. Duncan Glover, Mulukutla S. Sarma and Thomas Overbye, Power System Analysis and Design, Cengage Learning.
2. P. Kundur, Power System Stability and Control, McGraw-Hill.
3. A. R. Bergen and V. Vittal, Power System Analysis, Pearson.
4. G. L. Kusic, Computer-Aided Power System Analysis, CRC Press.

**E-Resources:**

1. NPTEL Course: Power System Analysis – Prof. A. K. Sinha, IIT Kharagpur https://nptel.ac.in/courses/108105067
2. NPTEL Course: Advanced Power System Security / Related courses by IIT Faculty https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_ee110
3. NPTEL Course: Power System Stability and Control https://nptel.ac.in/courses/108106026
4. MATPOWER, PowerWorld Simulator and open-source power system analysis tools documentation

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# DEPARTMENT OF ELECTRICAL ENGINEERING

| **Program:** B. Tech. with Honours (Electrical Engineering) | | | | | | | **Semester: VI** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Course: Smart Grid Technologies & Applications** | | | | | | | **Code:** EEHC604 | | |
| **Teaching Scheme (Hrs/week)** | | | | **Evaluation Scheme (Marks)** | | | | | |
| **Lecture** | **Practical** | **Tutorial** | **Credit** | **CIE** | **ETE** | **TW** | **OR** | **PR** | **Total** |
| 3 | | 1 | 4 | | 100 | | | | 100 |

**Prerequisites:**

Basic knowledge of Power Systems, Electrical Machines, Power Electronics, Renewable Energy Sources and fundamental communication systems.

**Course Objectives:**

To introduce the concepts, architecture, technologies and applications of Smart Grid, enabling students to understand modern power system transformation through automation, renewable integration, advanced metering, demand response and intelligent control.

**Course Outcomes:** After completion of this course, students will be able to -

| | |
|---|---|
| **CO1** | Explain the concept, need, architecture and key features of Smart Grid. |
| **CO3** | Analyze the integration of renewable energy sources and energy storage in Smart Grid environment. |
| **CO3** | Explain Demand Side Management, Demand Response and distribution automation techniques. |
| **CO4** | Evaluate applications, challenges, cybersecurity issues and future trends in Smart Grid technologies. |

**Course Contents:**

| **Unit** | **Description** | **Duration (Hrs.)** |
|---|---|---|
| 1. | **Introduction to Smart Grid:**<br>Evolution of power system from conventional grid to Smart Grid; Definition, need and objectives of Smart Grid; Comparison between conventional grid and Smart Grid; Key characteristics and functions of Smart Grid; Conceptual model and architecture of Smart Grid; Smart Grid domains – Generation, Transmission, Distribution, Customer, Operations, Market and Service Provider; Drivers and benefits of Smart Grid implementation; Challenges in Smart Grid implementation. | 10 |
| 2. | **Renewable Energy Integration and Energy Storage in Smart Grid:**<br>Challenges of integrating solar and wind energy into the grid; Variability and intermittency issues; Role of Smart Grid in renewable energy integration; Distributed Energy Resources (DERs); Microgrids – concept, architecture and types (AC, DC and Hybrid); Energy storage systems in Smart Grid (Batteries, Flywheel, Supercapacitors); Virtual Power Plants (VPP); Grid-support functions of energy storage (peak shaving, load leveling, frequency regulation). | 10 |

| | | |
|---|---|---|
| 3. | **Demand Side Management and Distribution Automation:**<br>Concept of Demand Side Management (DSM); Demand Response (DR) – classification and techniques; Peak clipping, valley filling, load shifting and strategic conservation; Role of prosumers in Smart Grid; Distribution Automation – need and functions; Fault Location, Isolation and Service Restoration (FLISR); Automatic Voltage and VAR Control; Self-healing grid concept; Outage Management System (OMS).<br>**Wide Area Monitoring, Protection and Control:**<br>Introduction to Wide Area Monitoring System (WAMS); Phasor Measurement Units (PMUs) – principle, architecture and applications; Synchrophasor technology; Situational awareness in power systems; Adaptive protection and Smart Grid protection schemes; Islanding detection techniques; Wide Area Control systems; Role of SCADA and Energy Management System (EMS) in Smart Grid. | 12 |
| 4. | **Smart Grid Applications, Cybersecurity and Future Trends:**<br>Electric Vehicle integration and Vehicle-to-Grid (V2G) technology; Smart homes and Home Energy Management Systems (HEMS); Transactive energy and peer-to-peer energy trading; Cybersecurity challenges in Smart Grid; Common cyber threats and mitigation techniques; Data analytics and Artificial Intelligence applications in Smart Grid; Indian Smart Grid initiatives and policies; Case studies and emerging trends in Smart Grid technologies. | 10 |
| | **TOTAL** | **42** |

**Text Books:**

1. Janaka Ekanayake, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama and Nick Jenkins, Smart Grid: Technology and Applications, Wiley.
2. James Momoh, Smart Grid: Fundamentals of Design and Analysis, Wiley – IEEE Press.
3. Stuart Borlase, Smart Grids: Infrastructure, Technology and Solutions, CRC Press.
4. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, Wiley.

**Reference Books:**

1. Clark W. Gellings, The Smart Grid: Enabling Energy Efficiency and Demand Response, CRC Press.
2. Stephen F. Bush, Smart Grid: Communication-Enabled Intelligence for the Electric Power Grid, Wiley.
3. Nouredine Hadjsaid and Jean-Claude Sabonnadiere, Smart Grids, Wiley.
4. Bernd M. Buchholz and Zbigniew Styczynski, Smart Grids – Fundamentals and Technologies in Electricity Networks, Springer.

**E-Resources:**

1. NPTEL Course: Smart Grid – Prof. N. P. Padhy and Prof. Premalata Jena, IIT Roorkee https://nptel.ac.in/courses/108107113
2. NPTEL Course: Introduction to Smart Grid https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_ee68
3. NPTEL Course: Power System Operation and Control https://onlinecourses.nptel.ac.in/e-learning/preview/noc23_ee128
4. IEEE Smart Grid resources and Ministry of Power (India) Smart Grid initiatives

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