UNIVERSITY OF MUMBAI

Revised syllabus (Rev- 2016) from Academic Year 2016 -17
Under
FACULTY OF TECHNOLOGY

Electrical Engineering
Third Year with Effect from AY 2018-19

As per Choice Based Credit and Grading System
with effect from the AY 2016–17
Dean, Faculty of Science and Technology

Preamble:

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Technology of University of Mumbai has taken a lead in incorporating philosophy of outcome-based education in the process of curriculum development. Faculty of Technology, University of Mumbai, in one of its meeting unanimously resolved that, each Board of Studies shall prepare some Program Educational Objectives (PEOs) and give freedom to affiliated Institutes to add few (PEOs). It is also resolved that course objectives and course outcomes are to be clearly defined for each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner’s learning process. It was also resolved that, maximum senior faculty from colleges and experts from industry to be involved while revising the curriculum. I am happy to state that, each Board of studies has adhered to the resolutions passed by Faculty of Technology and developed curriculum accordingly. In addition to outcome-based education, semester-based credit and grading system is also introduced to ensure quality of engineering education. Choice based Credit and Grading system enables a much-required shift in focus from teacher-centric to learner centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. University of Mumbai has taken a lead in implementing the system through its affiliated Institutes and Faculty of Technology has devised a transparent credit assignment policy and adopted ten points scales to grade learner’s performance. Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 12-13 weeks and remaining 2-3 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc. Choice based Credit and grading system is implemented from the academic year 2016-17 through optional courses at department and institute level. This will be effective for SE, TE and BE from academic year 2017-18, 2018-19 and 2019-20 respectively.

Dr. S. K. Ukarande
Dean (I/c) Faculty of Science and Technology,
Member - Academic Council,
University of Mumbai, Mumbai
Preamble:

The overall technical education in our country is changing rapidly in manifolds. Now it is very much challenging to maintain the quality of education with its rate of expansion. To meet present requirement a systematic approach is necessary to build the strong technical base with the quality. Accreditation will provide the quality assurance in higher education and to achieve recognition of the institution or program meeting certain specified standards. The main-focus of an accreditation process is to measure the program outcomes, essentially a range of skills and knowledge that a student will have at the time of graduation from the program that is being accredited. Faculty of Technology of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

I, as a Chairman, Board of Studies in Electrical Engineering of University of Mumbai, happy to state here that, Program Educational Objectives (PEOs) were finalized for undergraduate program in Electrical Engineering, more than ten senior faculty members from the different institutes affiliated to University of Mumbai were actively participated in this process. Few PEOs and POs of undergraduate program in Electrical Engineering are listed below;

Program Educational Objectives (PEOs)

- Graduates will have successful career in industry or pursue higher studies to meet future challenges of technological development.
- Graduates will develop analytical and logical skills that enable them to analyze and design Electrical and Control Systems.
- Graduates will achieve professional skills to expose themselves by giving an opportunity as an individual as well as team.
- Graduates will undertake research activities in emerging multidisciplinary fields.

Program Outcomes (POs)

- **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **Conduct investigations of complex problems**: Use research-based knowledge and
research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

- **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

- **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

- **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

- **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

- **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

- **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

- **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

- **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Dr. S. R. Deore,
Chairman,
Board of Studies in Electrical Engineering,
Member - Academic Council
### Scheme for Semester V

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Theory</td>
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</tr>
<tr>
<td>EEC501</td>
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<td>EEDLO501X</td>
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<td>EEL501</td>
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**Out of four hours, 2 hours theory shall be taught to entire class and 2 hours practical in batches**
# Examination Scheme for Semester V

<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Theory</th>
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<td>Internal (CA)</td>
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### Program Structure for
**TE Electrical Engineering**
**University of Mumbai**
*(With Effect from 2018-19)*

#### Scheme for Semester VI

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<td>EEC603</td>
<td>Signal processing</td>
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<td>EEC604</td>
<td>Microcontroller and its Applications</td>
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## Examination Scheme for Semester VI

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<td>Min Marks</td>
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<td>Electrical Machines - IV</td>
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<td>EEC604</td>
<td>Microcontroller and its Applications</td>
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<td>Electrical Machines Lab - IV</td>
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<td>EEL603</td>
<td>Microcontroller Lab</td>
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<td>EEL604</td>
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List of Department Level Optional Courses

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<tr>
<td>EEDLO5011</td>
<td>Communication Engineering</td>
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<tr>
<td>EEDLO5012</td>
<td>Renewable Energy and Energy Storage</td>
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<td>EEDLO5013</td>
<td>Utilization of Electrical Energy</td>
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<td>EEDLO6021</td>
<td>Digital Communication Engineering</td>
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<tr>
<td>EEDLO6022</td>
<td>Micro-grid</td>
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<td>EEDLO6023</td>
<td>Advanced Power Electronics</td>
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<tr>
<td>EEC501</td>
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**Course Objectives**
- To impart knowledge on transmission line operation during fault.
- To study power system transients and insulation co-ordination.

**Course Outcomes**
- Student will be able
  - To understand different kind of faults on transmission line.
  - To analyse symmetrical fault
  - To analyse symmetrical components and unsymmetrical faults.
  - To illustrate and analyse power system transients
  - To understand insulation co-ordination in power system.
  - To understand and analyse corona on transmission line.

**Module**

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
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<tbody>
<tr>
<td>1</td>
<td><strong>Symmetrical Fault Analysis:</strong> Introduction to synchronous machine,</td>
<td>14</td>
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<tr>
<td></td>
<td>basic construction, operation and equivalent circuit diagram, short</td>
<td></td>
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<tr>
<td></td>
<td>circuit of synchronous machine: no load and loaded machine, transient</td>
<td></td>
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<tr>
<td></td>
<td>on a transmission line, selection of Circuit breaker, short circuit</td>
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<tr>
<td></td>
<td>MVA, algorithm for SC studies, Z Bus formulation, symmetrical fault</td>
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<tr>
<td></td>
<td>analysis using Z bus (numerical on Z bus formulation up to 3x3 matrix).</td>
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<td>2</td>
<td><strong>Symmetrical Components:</strong> Introduction, Symmetrical component</td>
<td>07</td>
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<tr>
<td></td>
<td>transformation, phase shift in star-delta transformers, sequence</td>
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<tr>
<td></td>
<td>impedances and sequence network of transmission line, synchronous</td>
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<td></td>
<td>machine and transformer, power invariance, construction of sequence</td>
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<tr>
<td></td>
<td>network of a power system.</td>
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<td><strong>Unsymmetrical Fault Analysis:</strong> Types of unsymmetrical faults,</td>
<td>07</td>
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<tr>
<td></td>
<td>Analysis of shunt type unsymmetrical faults: single line to ground</td>
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<tr>
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<td>(SLG) fault, line to line (L-L) fault, double line to ground (LLG)</td>
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<td></td>
<td>fault, bus impedance matrix method for analysis of shunt type unsymmetrical</td>
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<td>faults. Analysis of series type unsymmetrical faults: one open</td>
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<td>conductor faults, two open conductor fault.</td>
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<td><strong>Power System Transients:</strong> Review of transients in simple circuits,</td>
<td>12</td>
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<tr>
<td></td>
<td>recovery transient due to removal of short circuit, arcing grounds,</td>
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<tr>
<td></td>
<td>capacitance switching, current</td>
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chopping phenomenon. Travelling waves on transmission lines, wave equation, reflection and refraction of waves, typical cases of line terminations, attenuation, Bewely lattice diagram.

Lightning phenomenon, mechanism of Lightning stroke, shape of Lightning voltage wave, over voltages due to Lightning, Lightning protection problem, significance of tower footing resistance in relation to Lightning, insulator flashover and withstand voltages, protection against surges, surge arresters, surge capacitor, surge reactor and surge absorber, Lightning arresters and protective characteristics, dynamic voltage rise and arrester rating.

<table>
<thead>
<tr>
<th>5</th>
<th><strong>Insulation Coordination:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volt time curve, basic approach to insulation co-ordination in power system, over voltage protection, ground wires, insulation coordination based on lightning, surge protection of rotating machines and transformers.</td>
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<table>
<thead>
<tr>
<th>6</th>
<th><strong>Corona:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phenomenon of corona, Disruptive critical voltage, Visual critical voltage, corona loss, factors affecting corona loss, Radio interference due to corona, practical considerations of corona loss, corona in bundled conductor lines, corona ring, corona pulses- their generation and properties in EHV lines, charge voltage ($q-v$) diagram and corona loss.</td>
</tr>
</tbody>
</table>

**Books Recommended:**

**Text Books:**
8. J.B.Gupta, “Course in power system” kataria Publication

**Reference Books:**
1. Stevenson, *Modern power system analysis*, TMH publication
2. TuranGonen, Modern power system analysis, Wiley, 1988
Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Term work:
Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:
Tutorials : 15 marks
Assignments : 05 marks
Attendance (Theory and Tutorial) : 05 marks
The final certification and acceptance of term work ensures minimum passing in the term work

Theory Examination:
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3: Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4: Remaining question will be randomly selected from all the modules.
University of Mumbai

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
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<th>Examination Scheme</th>
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<td>Electrical Machines –III</td>
<td>Theory</td>
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<td></td>
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<td>Test 1</td>
<td>Test 2</td>
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**Course Objectives**
- To impart knowledge on performance and operation of an induction motor.
- To study design aspects of an induction motor.

**Course Outcomes**
Student will be able:
- To illustrate the working principle of three phase induction motor
- To analyse and evaluate performance of three phase induction motors under various operating conditions
- To illustrate various speed control and starting methods of three phase induction motor.
- To illustrate the working principle of single phase induction motor
- To analyse the performance of single phase induction motor.
- To design three phase induction motor

**Module | Contents | Hours**
---|----------|-------|
1 | **Three Phase Induction Motors:** Introduction, Construction, Principle of operation, Rotor emf & frequency, Current and Power, Power stages, phasor diagram, Analysis of Equivalent circuit, Torque-speed characteristics in braking, motoring and generating regions. Effect of voltage and frequency variations on Induction motor performance, Losses and efficiency, No load and block rotor test, Circle diagram, Applications of 3Φ IM, Relevant standards | 12 |
2 | **Three Phase Induction Motors: Speed Control and Starting:** Speed control methods including V/f method (excluding Slip power recovery scheme), Starting methods, High torque motors, Cogging and crawling. | 06 |
3 | **Single phase Induction Motor:** Introduction, Principle of operation, Double field revolving theory, Equivalent circuit of single phase induction motor, Determination of equivalent circuit parameters from no load and blocked rotor test. | 04 |
4 | **Types of Single phase Induction Motor & its Applications:** Starting methods, Split phase starting- Resistance spilt phase, capacitor split phase, capacitor start and run, shaded pole starting, Reluctance starting. Applications. | 04 |
5 | **Design of Three phase Induction motors:** Output equation, Choice of | 12 |
specific electric and magnetic loadings, Standard frames, Main dimensions, Design of stator and rotor windings, Stator and rotor slots, Design of stator core, air gap, Design of squirrel cage rotor, end rings, Design of wound rotor.

|   | Performance Measurement of Three Phase Induction Motors: Calculation of leakage reactance for parallel sided slot, Carter’s coefficients, Concept of B_{60}, Calculation of No load current, Short circuit current, Dispersion coefficient. Relevant standards | 10 |

Books Recommended:

Text Books:
1. Bimbhra P.S., *Electric Machinery*, Khanna Publisher,
2. Bimbhra P.S., *Generalized Machine Theory*, Khanna Publisher,
5. M.V. Deshpande, “*Design and Testing of Electrical Machines*”, PHI Learning

Reference Books:
4. K.G. Upadhyay, “*Design of Electrical Machines*”, New age publication

Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Theory Examination:
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3: Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4: Remaining question will be randomly selected from all the modules.
**University of Mumbai**

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<tbody>
<tr>
<td></td>
<td></td>
<td>Theory</td>
<td>Tutorial</td>
</tr>
<tr>
<td>EEC503</td>
<td>Control System -I (abbreviated as CS-I)</td>
<td>4</td>
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<tbody>
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<td></td>
<td></td>
<td>Internal Assessment</td>
<td>End Sem. Exam</td>
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<tr>
<td>EEC503</td>
<td>Control System –I</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

**Course Objectives**
- To impart knowledge on control system and modeling of system and its analysis.

**Course Outcomes**
- Student will be able
  - To model electrical and electromechanical system using transfer function.
  - To Illustrate methodology for simplification of system
  - To model and analyse given system in state space
  - To analyse steady state condition of given system
  - To analyse the transient and stability conditions of physical system

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Introduction to control system</strong>&lt;br&gt;Introduction, open loop and closed loop control system with examples, brief idea of multi variable control system.</td>
<td>02</td>
</tr>
<tr>
<td>2</td>
<td><strong>Mathematical Model of Physical System</strong>&lt;br&gt;Transfer function of electrical, mechanical (translational and rotational) and electro mechanical systems. Transfer function model of AC &amp; DC servomotor, potentiometer &amp; tacho-generator. Block diagram reduction technique and signal flow graph, Mason’s rule, Signal flow graph of electrical network. Conversion of BDR to SFGand vice versa.</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td><strong>Time domain Analysis</strong>&lt;br&gt;Time response analysis of first and second order systems, Under damped second order system with step input. System response with additional poles and zeros. Steady state error for unity feedback systems. Static error constants and system type. Concept of stability, absolute and relative stability using Routh Hurwitz criteria,</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td><strong>State Variable Analysis</strong>&lt;br&gt;Introduction to state variable, General state space representation, State space representation of Electrical and Mechanical systems. Conversion between state space and transfer function. Alternative representations in state space: (Phase variable, canonical, parallel &amp; cascade). Similarity transformations, diagonalizing a system matrix. Laplace Transform solution of state equation, stability in state space</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td><strong>Root locus techniques</strong>&lt;br&gt;Definition and properties of root locus, rules for plotting root locus,</td>
<td>05</td>
</tr>
</tbody>
</table>
| 6 | **Frequency Domain Analysis**  

**Books Recommended:**

**Text Books:**
1. Control system engineering by Norman Nise 2nd to latest edition
2. Control System engineering by Nagrath and Gopal, 5th to latest edition, Wiley Eastern
3. Modern control system engineering by K. Ogata, prntice Hal

**Reference Books:**

**Assessment:**

Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
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University of Mumbai

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<td>EEC504</td>
<td>Power Electronics (abbreviated as PE)</td>
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<td></td>
<td></td>
<td>Internal Assessment</td>
</tr>
<tr>
<td>EEC504</td>
<td>Power Electronics</td>
<td>20 20 02 80 03 - 100</td>
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</tbody>
</table>

**Course Objectives**
- To impart knowledge about various power semiconductor devices related to its characteristics, ratings, protection and to select semiconductor devices for various applications.
- To introduce different methods of power conversion such as ac to dc, dc to dc, dc to ac the underlying principles of converter operation and hence to analyze different converter circuits for power conversion.
- To keep abreast with the latest technologies and research going on in different areas related to power electronics.

**Course Outcomes**
Student will be able to
- Select and design power electronic converter topologies for a broad range of energy conversion applications.
- Analyse and simulate the performance of power electronic conversion systems.
- Analyse various single phase and three phase power converter circuits and understand their applications.
- Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and transmission and energy conversion, industrial applications.
- Identify and describe various auxiliary circuits and requirements in power electronics applications such as Gate driver circuit, and snubber circuits along with electrical isolation and heat sinks.

**Module**

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<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
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<tbody>
<tr>
<td>1</td>
<td><strong>Thyristors:</strong> Basic operation of silicon controlled rectifier, two transistor analogy, Static and Dynamic characteristics, Gate characteristics, Firing circuits, Commutation circuits, Protection circuit of SCR, Basic operation and characteristic of Triac, GTO, Diac.</td>
<td>04</td>
</tr>
<tr>
<td>2</td>
<td><strong>Power semiconductor devices:</strong> Basic operation and characteristics of power diodes, power BJTs, power MOSFETs, IGBTs, Silicon Carbide (SiC)and GaN devices, Safe Operation Area (SOA) for each devices. Comparison of devices, selection of devices for various applications, conduction and switching losses; Gate Drive Circuitry for Power Converters and snubber circuits, heat sinks.</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td><strong>Controlled Rectifiers:</strong> Single phase half wave rectifiers, full wave rectifiers (mid-point and bridge configuration) for R and R-L load,</td>
<td>08</td>
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<td>Description</td>
<td>Page</td>
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<tr>
<td>4</td>
<td><strong>Inverter:</strong> Principle of operation, Performance parameters, Single phase voltage source bridge Inverters, Three phase VSI (120° and 180° conduction mode), control of inverter output voltage, PWM techniques-Single PWM, Multiple PWM, Sinusoidal PWM, Introduction to Space vector modulation, Current source inverters, comparison of VSI and CSI, Applications.</td>
<td>06</td>
</tr>
<tr>
<td>5</td>
<td><strong>DC to DC Converter:</strong> Basic principle of dc to dc conversion, switching mode regulators – Buck, Boost, Buck-Boost, Cuk regulators, bidirectional dc to dc converters, all with resistive load and only CCM mode, Applications: Power Factor Correction Circuits, LED lamp driver, Numerical included.</td>
<td>08</td>
</tr>
<tr>
<td>6</td>
<td><strong>AC voltage controllers:</strong> On-Off and phase control, Single phase AC voltage controllers with R and RL loads. <strong>Cyclo converters, Matrix converter:</strong> Basic working principle.</td>
<td>10</td>
</tr>
</tbody>
</table>

### Books Recommended:

**Text Books:**
1. “Power Electronics” M.H.Rashid, Prentice-Hall of India
3. “Power Electronics”, P.C Sen, Tata McGrawhill
4. “Power Electronics: Devices, Circuits and Matlab Simulations” by Alok Jain, Penram International
5. “Power Electronics”, V.R Moorthi, Oxford University press
6. “Thyristors & their applications”, Ramamurthy
7. “Power Electronics”, M.D Singh and Khanchandani, Tata McGrawhill
8. “ Silicon Carbide Power Devices” B. Jayant Baliga

**Reference Books:**
2. “Power Electronics”, P.S Bhimbra, Khanna Publishers
3. “Elements of power electronics” Philip T Krein, Oxford University Press
5. “Power Electronics”, Joseph Vithayathil, Tata McGrawhill
7. “Power Electronics Converters and Regulators,” Dokić, Branko L. and Blanuša, Branko

**Website Reference:**
1. [http://nptel.iitm.ac.in](http://nptel.iitm.ac.in): ‘Power Electronics’ web-course
Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Theory Examination:
1. Question paper will comprise of 6 questions, each carrying 20 marks.
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<td>Tutorial</td>
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<tr>
<td>EEDLO 5011</td>
<td>Communication Engineering (abbreviated as CE)</td>
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<td></td>
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<td>Theory</td>
<td>Internal Assessment End Sem. Exam Exam Duration (Hrs.) Term Work Total</td>
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<tr>
<td>EEDLO 5011</td>
<td>Communication Engineering</td>
<td>20</td>
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</table>

**Course Objectives**
- To impart knowledge on various modulation techniques in communication engineering.
- To study different sampling techniques used in communication engineering.

**Course Outcomes**
- Student will be able
  - To understand basic communication system and its components.
  - To illustrate and analyse amplitude modulation and demodulation techniques.
  - To illustrate and analyse phase modulation and demodulation techniques.
  - To illustrate and analyse frequency modulation and demodulation techniques.
  - To illustrate and analyse pulse modulation and demodulation techniques.
  - To understand and analyse radio receivers and sampling techniques.

**Module** | **Contents** | **Hours**
---|---|---
1 | Basics of Communication System
Types of signals, Block diagram, electromagnetic spectrum, signal bandwidth and power, types of communication channels, types of noise, signal to noise ratio, noise figure, and noise temperature | 04 |
2 | Amplitude Modulation and Demodulation
Basic concept, signal representation, need for modulation, Spectrum, waveforms, modulation index, bandwidth, voltage distribution, and power calculation
DSBFC: Principles, modulating circuits, low level and high level transmitters
DSB suppressed carrier:- Multiplier modulator, nonlinear modulator, and switching Modulator,
Single Side Band (SSB):-Principle, filter method, phase shift method and third method, independent sideband (ISB) and Vestigial Side Band (VSB) principles and transmitters
Amplitude demodulation: Diode detector, practical diode detector, and square law Detector. | 08 |
3 | Angle Modulation and Demodulation
Frequency Modulation (FM): Basic concept, mathematical analysis, | 08 |
frequency spectrum of FM wave, sensitivity, phase deviation and modulation index, frequency deviation and percent modulated waves, bandwidth requirement of angle modulated waves, deviation ratio, narrow band FM, and wide band FM. Varactor diode modulator, FET reactance modulator. Direct FM transmitter, indirect FM Transmitter, noise triangle in FM, pre-emphasis and de-emphasis.

**Phase Modulation (PM):** Principle and working of transistor direct PM modulator, relationship and comparison between FM and PM.

**FM demodulation:** Balance slope detector, Foster-Seely discriminator, ratio detector, comparison between FM demodulators, comparison between AM, FM and PM. Applications of FM and PM.

| 4 | Radio Receivers | TRF, Super-heterodyne receiver, receiver parameters, and choice of IF. AM receiver circuits and analysis, simple AGC, delayed AGC, forward AGC, and communication receiver, FM receiver circuits, comparison with AM receiver | 06 |
| 5 | Pulse Modulation and Demodulation | PAM, PWM, PPM waveform generation and detection, principle, generation and detection of delta modulation and adaptive delta modulation. Applications of pulse communication | 06 |
| 6 | Sampling Techniques | Theorem for low pass and band pass signals, proof with spectrum, Nyquist criteria, sampling techniques, aliasing error and aperture effect | 04 |

**Books Recommended:**

**Text Books:**

**Reference Books:**

**Assessment:**
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

**Term work:**
Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:
- Tutorials: 15 marks
- Assignments: 05 marks
- Attendance (Theory and Tutorial): 05 marks
The final certification and acceptance of term work ensures minimum passing in the term work.

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3. Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
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University of Mumbai

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<td>EEDLO 5012</td>
<td>Renewable Energy and Energy Storage (abbreviated as REES)</td>
<td>Theory 3, Tutorial 1</td>
<td>Theory 3, Tutorial 1, Total 4</td>
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<th>Examination Scheme</th>
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<td>EEDLO 5012</td>
<td>Renewable Energy and Energy Storage</td>
<td>Theory Internal Assessment Test 1 20</td>
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<td>Term Total Work Test 2 03</td>
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</table>

Course Objectives

- To introduce the new paradigm of power generation in the form of renewable energy and the various means used for power processing and optimization.
- To relate and study the various energy storage technology and their significance in the context of renewable energy based applications.

Course Outcomes

Student will be able to

- Identify and describe the issues related to use of fossil fuels and to recognize means of mitigation through adoption of renewable energy (RE).
- Identify and analyze the process of power generation through solar thermal and solar photovoltaic technologies.
- Identify and describe the various components and types of Wind Energy system Fuel cell technology, tidal, wave, and biomass systems.
- Identify and describe the importance of various forms of energy storage (ES) in new power generation scenario based on renewable energy.
- Analyze, formulate and propose the power sharing mechanisms and to evaluate the fault scenarios in hybrid RE and ES sources.
- Recognize the need to adapt and engage in operations RE/ES related activities for sustainable future.

Module | Contents                                                                 | Hours |
<table>
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<tbody>
<tr>
<td>1</td>
<td><strong>Introduction</strong>- World’s and India’s production and reserves of commercial energy sources, energy alternatives, review of conventional and non conventional energy sources. Statistic of net potential and current generation status of different energy alternatives. Distributed generation, Future trends in power generation and distribution.</td>
<td>03</td>
</tr>
<tr>
<td>2</td>
<td><strong>Solar Energy- Solar Thermal applications</strong>-Review of solar thermal applications-solar thermal conversion devices and storage applications. <strong>Solar Photovoltaic</strong>- solar cell: characteristics, losses, model of a solar cell, emerging solar cell technologies; Solar PV modules, mismatch in module, hot spots, bypass diode; PV module: I-V and power curve, effect of variation in temperature and solar radiations; MPPT, types, different algorithms for electrical MPPT, distributed MPPT, MPPT converters. Types of PV systems: standalone, grid connected systems; BOS of PV</td>
<td>12</td>
</tr>
</tbody>
</table>
|   | **system**, Battery charge controllers, Power Conditioning Unit, Solar PV Micro-inverters  
| Solar Plant design: mounting of PV panels supporting structures, Calculation and Design methodology of standalone PV system and grid connected system  
| Review of regulatory standards for solar PV installations, net-metering. |  |
| 3 | **Wind Energy** Review of wind energy system and its components, types of wind turbines, characteristics; Power generation and control in wind energy systems, performance calculations of wind energy systems. Topologies of WES, WES with rectifier / inverter system, Power Converters for Doubly Fed Induction Generators (DFIG) in Wind Turbines. | 04 |
| 4 | **Fuel Cell**- Review of fuel cells and their principle of operation, Review of types of fuel cell and their performance comparison. Topologies of fuel cell power systems, applications. | 03 |
| 5 | **Other Sources**- Review of other nonconventional sources, their features and applications; Biomass, Tidal, Ocean Thermal Electric Conversion, geothermal, and Micro-hydro. | 04 |
| 6 | **Energy Storage** Forms of energy storage, importance of storage system in new power generation scenario; Types, characteristics and performance evaluation of: batteries, ultra-capacitors, flywheels, SME, pumped hydro storage system; Applications of Energy storage in distributed generation, smart grid systems, Electric and Hybrid electric vehicles. Hybrid power system based on renewable energy and energy storage. | 10 |

**Books Recommended:**

**Reference Books:**


**Website Reference:**

1. [http://nptel.iitm.ac.in](http://nptel.iitm.ac.in): ‘Energy Resources and Technology’ web-course

2. [http://nptel.iitm.ac.in](http://nptel.iitm.ac.in): ‘Non conventional Energy Systems’ web-course

**Other References Material**


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- **Assignments**: 05 marks
- **Attendance (Theory and Tutorial)**: 05 marks

The final certification and acceptance of term work ensures minimum passing in the term work

**Theory Examination:**

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2. Total four questions need to be solved.

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<tbody>
<tr>
<td>EEDLO 5013</td>
<td>Utilization of Electrical Energy (abbreviated as UEE)</td>
<td>3</td>
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<tbody>
<tr>
<td>EEDLO 5013</td>
<td>Utilization of Electrical Energy</td>
<td>Theory</td>
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<td>Internal Assessment</td>
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<td></td>
<td>Test 1</td>
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</table>

**Course Objectives**
- To impart the knowledge on different types of drives used in electric traction.
- To impart the basic knowledge of some domestic electric appliances.

**Course Outcomes**
- Students will be able
  - To understand and analyse the power factor for improving the quality of supply.
  - To analyse different type of traction systems.
  - To understand modern tools to control electric traction motors.
  - To understand concept of electrical heating and welding and their application.
  - To understand different methods of cooling systems used in domestic electric appliances.

**Module**

<table>
<thead>
<tr>
<th></th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Power Factor</strong>&lt;br&gt;Power factor, disadvantages of low power factor, Causes of low power factor, methods of power factor improvement, advantages of power factor improvement and economics of power factor improvement.</td>
<td>04</td>
</tr>
<tr>
<td>2</td>
<td><strong>Electric Traction</strong>&lt;br&gt;Requirement of an ideal traction system. Traction system- Non electric traction system, electric traction system, diesel traction. System of Track electrification- DC system, single phase, three phase, composite system (Kando system), single phase AC to DC system. Different accessories for track electrification- overhead wire, conductor rail system, current collector- pantograph, catenary. Traction mechanics-Types of services, speed time curve, trapezoidal and quadrilateral speed time curves, power and energy output from driving axles, average and schedule speed (numerical), specific energy consumption, factors affecting specific energy consumption, dead weight, accelerating weight and adhesive weight.</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td><strong>Electric Traction Motors and Controls</strong>&lt;br&gt;Desirable characteristics of traction motors, suitability of DC series motors, AC series motors, three phase induction motors and linear</td>
<td>10</td>
</tr>
</tbody>
</table>

4 Electric Heating
Classification of electric heating methods, Resistance heating- Direct resistance heating, indirect resistance heating, application, Arc heating- Direct arc heating, indirect arc heating, applications of arc heating, Induction heating. Core type induction furnaces- Ajax Wyatt furnace, coreless induction furnace, Application of induction heating. Dielectric heating- principle, choice of frequency for dielectric heating, application of dielectric heating. Eddy current heating principle and applications.

5 Electric Welding
Electric welding- welding methods, electric arc welding, resistance types welding and application, modern welding techniques. Electric arc welding- Formation and characteristics of electric arc, effect of arc length, arc blow, Electrode used in arc welding, spot welding machine.

6 Other application of Electrical Energy
Terminology, Refrigeration and Air conditioning, Refrigeration cycle, Vapour compression type, vapour absorption type, Electrical circuit of a Refrigerator, Room Air conditioner window type and split type.

Books Recommended:

Text Books:

Reference Books:
2. Electric Traction by H. Pratap, Dhanpat Rai & Sons
3. Designing with light- A Lighting Handbook by Anil Valia, Lighting System
4. Generation and Utilization of Electric Energy by S. Sivanagaraju, Pearson Education India
6. “Lamps and lighting” by M.A. Cayless, J.R. Coaton and A.M. Marsden

Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project
**Term work:**
Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:
Tutorials  : 15 marks
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Attendance (Theory and Tutorial)  : 05 marks
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<tr>
<td>EEL501</td>
<td>Business Communication and Ethics (abbreviated as BCE)</td>
<td>- 4** -</td>
<td>2 2</td>
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<td>Business Communication and Ethics</td>
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</table>

**Course Objectives**
- To inculcate professional and ethical attitude at the workplace
- To enhance effective communication and interpersonal skills
- To build multidisciplinary approach towards all life tasks
- To hone analytical and logical skills for problem-solving

**Course Outcomes**
The students will be able to
- Design a technical document using precise language, suitable vocabulary and apt style.
- Develop the life skills/interpersonal skills to progress professionally by building stronger relationships.
- Demonstrate awareness of contemporary issues knowledge of professional and ethical responsibilities.
- Apply the traits of a suitable candidate for a job/higer education, upon being trained in the techniques of holding a group discussion, facing interviews and writing resume/SOP.
- Deliver formal presentations effectively implementing the verbal and non-verbal skills.

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Report Writing</td>
<td>05</td>
</tr>
<tr>
<td>1.1</td>
<td>Objectives of Report Writing</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Language and Style in a report</td>
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</tr>
<tr>
<td>1.3</td>
<td>Types : Informative and Interpretative (Analytical, Survey and Feasibility)and Formats of reports (Memo, Letter, Short and Long Report )</td>
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<tr>
<td>02</td>
<td>Technical Writing</td>
<td>03</td>
</tr>
<tr>
<td>2.1</td>
<td>Technical Paper Writing (IEEE Format)</td>
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</tr>
</tbody>
</table>
### 03 Introduction to Interpersonal Skills

| 3.1 | Emotional Intelligence |
| 3.2 | Leadership and Motivation |
| 3.3 | Team Building |
| 3.4 | Assertiveness |
| 3.5 | Conflict Resolution and Negotiation Skills |
| 3.6 | Time Management |
| 3.7 | Decision Making |

### 04 Meetings and Documentation

| 4.1 | Strategies for conducting effective meetings |
| 4.2 | Notice, Agenda and Minutes of a meeting |
| 4.3 | Business meeting etiquettes |

### 05 Introduction to Corporate Ethics

| 5.1 | Professional and work ethics (responsible use of social media - Facebook, WA, Twitter etc.) |
| 5.2 | Introduction to Intellectual Property Rights |
| 5.4 | Ethical codes of conduct in business and corporate activities (Personal ethics, conflicting values, choosing a moral response and making ethical decisions) |

### 06 Employment Skills

| 6.1 | Group Discussion |
| 6.2 | Resume Writing |
| 6.3 | Interview Skills |
| 6.4 | Presentation Skills |
| 6.5 | Statement of Purpose |

**Books Recommended:**

10. Dr. Alex, K., ”Soft Skills”, S Chand and Company
11 Subramaniam, R., “Professional Ethics” Oxford University Press.

Suggested List of Assignments:

1. Report Writing (Theory)
2. Technical Proposal
4. Interpersonal Skills (Group activities and Role plays)
5. Interpersonal Skills (Documentation in the form of soft copy or hard copy)
6. Meetings and Documentation (Notice, Agenda, Minutes of Mock Meetings)
7. Corporate ethics (Case studies, Role plays)
8. Writing Resume and Statement of Purpose

Term work:
Term work shall consist of all assignments from the list. The distribution of marks for term work shall be as follows:

Book Report: 10 Marks
Assignments: 10 Marks
Project Report Presentation: 15 Marks
Group Discussion: 10 Marks
Attendance: 05 Marks

The final certification and acceptance of term work ensures the minimum passing in the term work.
University of Mumbai

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEL502</td>
<td>Control System Lab (abbreviated as CS Lab)</td>
<td>- 2 -</td>
<td>1 1</td>
</tr>
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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Examination Scheme</th>
<th>Practical</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEL502</td>
<td>Control System Lab</td>
<td>- - -</td>
<td>25 - 25</td>
</tr>
</tbody>
</table>

Course Objectives
- To study basic concepts of control system
- To impart knowledge on various components of control systems.

Course Outcomes
- Students will be able
  - To illustrate the functioning of various components of control system.
  - To analyse the response of physical system for various inputs.
  - To analyse the stability of the system using time domain and frequency domain techniques by simulation.

Syllabus: Same as that of Course EEC503 Control System – I

Suggested List of Laboratory Experiment:
(A) Laboratory Experiments
1. Study of AC Servomotor
2. Study of DC Servomotor
3. Study of potentiometer as an error detector
4. Study of Synchros as an error detector
5. Study of AC position control system
6. Study of DC position control system
7. Obtain time response of first order to step ramp and parabolic input
8. Obtain time response of second order system to step input.

(B) Simulation Based Experiments
1. Draw root locus and hence obtain steady state stability of control system
2. Draw Bode plot and hence obtain steady state stability of control system
3. Draw Nyquist plot and hence obtain steady state stability of control system

Any other experiment based on syllabus which will help students to understand topic/concept.

Term work:
Term work shall consist of minimum eight experiments. The distribution of marks shall be as follows:
Experiments Performance : 10 marks
Journal : 10 marks
Attendance (Theory and Practical) : 05 marks

The final certification and acceptance of term work ensures the minimum passing in the term work.

**Oral Examination:**

Oral examination will be based on entire syllabus.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Theory</td>
<td>Practical</td>
</tr>
<tr>
<td>EEL503</td>
<td>Electrical Machines Lab - III (abbreviated as EMC Lab - III)</td>
<td>-</td>
<td>2</td>
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</tbody>
</table>

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<tr>
<th>Course Code</th>
<th>Course Name</th>
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<td></td>
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<td>Theory</td>
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<td></td>
<td>Internal Assessment</td>
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<td></td>
<td></td>
<td>Test 1</td>
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<tr>
<td>EEL503</td>
<td>Electrical Machines Lab –III</td>
<td>-</td>
</tr>
</tbody>
</table>

**Course Objectives**
- To impart practical knowledge of single phase and three phase induction motor.

**Course Outcomes**
- Students will be able
  - To evaluate performance of single phase and three phase induction motor by carrying load test.
  - To analyse performance of single phase and three phase induction motor by carrying no load and blocked rotor test.
  - To illustrate the operation of various type of starters.
  - To illustrate different methods of speed control for three phase induction motor.

**Syllabus**: Same as that of Course EEC502 Electrical Machines - III

**Suggested List of Laboratory Experiment:**
1) Load Test on three phase sq. cage Induction Motor.
2) Load test on three phase slip ring induction motor.
3) No load and Blocked rotor test on three phase Induction Motor.
4) Performance analysis of three phase Induction Motor using Circle diagram.
5) Load Test on single phase Induction Motor.
6) No load and Blocked rotor test on single phase Induction Motor.
7) Study of different types of starters.
8) Speed control by v/f method.

Any other experiment based on syllabus which will help students to understand topic/concept.

**Term work:**
Term work shall consist of minimum six experiments, minimum two drawing sheets (full imperial size) or software based drawing of individual parts and the assembled views of three phase induction motor. Design should be based on the Indian Standard Specifications. The distribution of marks shall be as follows:
- Experiments Performance: 10 marks
- Journal: 10 marks
- Attendance (Theory and Practical): 5 marks
The final certification and acceptance of term work ensures the minimum passing in the term work.

**Practical/Oral Examination:**
Practical/Oral examination will be based on entire syllabus.
<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Teaching Scheme (Contact Hours)</th>
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<td></td>
<td></td>
<td>Theory</td>
<td>Practical</td>
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<tr>
<td>EEL504</td>
<td>Power Electronics Lab (abbreviated as PE Lab)</td>
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<td>Internal Assessment</td>
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<td>Test 1</td>
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<tr>
<td>EEL504</td>
<td>Power Electronics Lab</td>
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</tbody>
</table>

### Course Objectives
- To impart knowledge about various power semiconductor devices related to its characteristics, ratings, protection and to select semiconductor devices for various applications.
- To introduce different methods of power conversion such as ac to dc, dc to dc, dc to ac the underlying principles of converter operation and hence to analyse different converter circuits for power conversion.
- To keep abreast with the latest technologies and research going on in different areas related to power electronics.

### Course Outcomes
- Student will be able to
  - Draw V-I characteristics of power electronic devices.
  - Simulate the performance of power electronic conversion systems.
  - Analyse various single phase and three phase power converter circuits and understand their applications.
  - Apply the basic concepts of power electronics to design the circuits in the fields of AC and DC drives, power generation and transmission and energy conversion, industrial applications.
  - Identify and describe various auxiliary circuits and requirements in power electronics applications such as Gate driver circuit, and snubber circuits along with electrical isolation and heat sinks.

### Syllabus: Same as that of Course EEC504 Power Electronics

### Suggested List of Laboratory Experiment:

#### (A) Hardware Based Experiments
1. V-I Characteristics of SCR
2. Firing Circuit of SCR
3. Single phase half/full controlled rectifier circuit
4. Three phase half/full controlled rectifier circuit with R load
5. Triac - Diac circuit based speed control of single phase motor
6. Gate Drive Circuit and snubber circuits (IGBT/MOSFET based)
7. Single phase Inverter (IGBT/MOSFET based)
8. Three phase Inverter (IGBT/MOSFET based)
9. Implementation of PWM techniques
10. Buck converter
11. Boost Converter /Buck-Boost
12. AC-AC converter

(B) **Applications of Power Electronics Circuits Demonstration**
13. Closed loop control of DC-DC converter
14. Power factor correction in converters
15. LED lamp intensity control
16. Solar PV based converter / inverter system

(C) **Simulation**
17. Three phase controlled rectifier including source inductance
18. PWM Rectifier
19. Three phase VSI (120° and 180° conduction mode)
20. Bidirectional DC-DC Converter
21. Buck Converter
22. AC voltage controllers: On-Off and phase control

Any other experiment based on syllabus which will help students to understand topic/concept.

**Term work:**
Term work shall consist of minimum six experiments and at least four simulations. The distribution of marks shall be as follows:

- Experiments Performance : 10 marks
- Journal : 10 marks
- Attendance (Theory and Practical) : 05 marks

The final certification and acceptance of term work ensures the minimum passing in the term work.

**Practical/Oral Examination:**
Practical/Oral examination will be based on entire syllabus.
### Course Details

<table>
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<tbody>
<tr>
<td>EEC601</td>
<td>Protection and Switchgear Engineering (abbreviated as PSE)</td>
<td>3 - 3 - 3</td>
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<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Substation Equipment and switching devices</td>
<td>03</td>
</tr>
<tr>
<td></td>
<td>Substation Equipment:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Switchgear-Definition, Types, Location of switchgear in typical power system</td>
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<tr>
<td></td>
<td>Switching Devices:</td>
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<tr>
<td></td>
<td>Isolator &amp; Earthing switch (Requirements &amp; definitions, types and construction, Pantograph Isolators, Ratings), Contactors: Basic working principle, Terms &amp; Definitions, contactors as starters for motors, rated characteristics/ Utilization categories of contactors</td>
<td></td>
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<tr>
<td>2</td>
<td>Circuit Breakers and Fuses:</td>
<td>09</td>
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<tr>
<td></td>
<td>Circuit Breaker:</td>
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<tr>
<td></td>
<td>Arc initiation, arc quenching principles, Restriking voltage, RRRV, Recovery voltage, Types of Circuit Breakers: MCB, MCCB, ELCB, air circuit breakers, oil circuit breakers, SF6 circuit breakers, vacuum circuit breakers (working principle, Construction, operating mechanisms, ratings &amp; applications), Mechanical life, Electrical life and testing of circuit breakers</td>
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<tr>
<td></td>
<td>HRC Fuses &amp; their applications:</td>
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<tr>
<td></td>
<td>Introduction, types of devices with</td>
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</table>
fuse, definitions, construction, fuse link of HRC fuse, Action of HRC fuse, shape of fuse element, specification of a fuse link, characteristics of fuse, cut-off, classification & categories, selection of fuse links, fuse for protection of motor, discrimination, fuse for protection of radial lines/meshed feeders, equipment incorporating fuses, high voltage current limiting fuses, expulsion type high voltage fuses, drop out fuse.

3 Introduction to Protective relaying: About protective relaying, Shunt & Series Faults, causes and Effects of faults, Importance of protective relaying, Protective zones, primary & Back-up protection, Back-up protection by time grading principle, desirable qualities of protective relaying, some terms in protective relaying, Distinction between relay unit, protective scheme and Protective system, Actuating quantities, Thermal Relays, Electromechanical relays and static relays, Power line carrier channel, programmable relays, system security, role of engineers.

Electromagnetic relays - Introduction, basic connections of relay, Auxiliary switch, sealing and auxiliary relays, measurement in relays, Pick up, drop off, Attracted armature & induction disc relays, Thermal, bimetal relays, Frequency relays, under/over voltage relays, DC relays, All or nothing relays.


4 Protection Schemes Provided for major Apparatus:
Generators - Stator side (Differential, Restricted Earth fault, protection for 100% winding, Negative phase sequence, Reverse power, turn-turn fault), Rotor side (Field suppression, field failure, Earth fault, turn to turn fault)
Transformers-Differential protection for star delta Transformer, Harmonic restraint relay, REF protection, Protection provided for incipient faults (Gas actuated relay).
Induction motors - Protection of motor against over load, short circuit, earth fault, single phasing, unbalance, locked rotor, phase reversal, under voltage, winding temperature.

5 Protection of Transmission Lines:
Feeder protection - Time grading, current grading, combined time & current grading protection provided for Radial, Ring Main, Parallel, T-Feeder.
Bus Zone Protection - Differential protection provided for different types of bus zones.
LV, MV, HV Transmission Lines - Protection provided by over current, earth fault, Differential and Stepped distance protection.
EHV & UHV Transmission lines - Need for auto-reclosure schemes, Carrier aided distance protection (Directional comparison method), Power Line Carrier Current protection (Phase comparison method).

6 Introduction to Static & Numerical Relays:
Static Relays- Introduction, Definition, Advantages and Disadvantages, Application of op-amps, logic gates, DSP, in static/ digital Relays. Relays as comparators (Amplitude & phase), Distance relays as
comparators.

**Numerical Relays** - Introduction, Block diagram of numerical relay, Signal sampling, Anti –Aliasing Filter, Introduction to the concept of Phase Measurement Unit

Books Recommended:

**Text Books:**
2. Power system Protection & Switchgear by Badriram Vishwakarma, TMH
3. Power System Protection And Switchgear by Bhuvanesh A O, Nirmal CN, Rashesh PM, Vijay HM, Mc Graw Hill

**Reference Books:**
2. Static Relays by Madhava Rao, TMH
4. Protective Relaying by Lewis Blackburn, Thomas.J.Domin
5. Power System Protection by P.M.Anderson, Wiley Interscience
*6. A Web Course on Digital protection of power system by Prof. Dr. S.A.Soman, IIT Bombay.
*7. Modern Power System Protection – DivyeshOza, TMH Publication

Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3: Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4: Remaining question will be randomly selected from all the modules.
University of Mumbai

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEC602</td>
<td>Electrical Machines -IV (abbreviated as EMC - IV)</td>
<td>4 - 4 - 4 - 4</td>
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<table>
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<th>Course Name</th>
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</tr>
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<tbody>
<tr>
<td>EEC602</td>
<td>Electrical Machines -IV</td>
<td>Test 1</td>
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</table>

**Course Objectives**
- To impart knowledge of performance and operation of synchronous machine.
- To study working, control and applications of brushless motor.

**Course Outcomes**
- Students will be able
  - To determine the performance parameters of synchronous machines graphically and analytically by conducting different test.
  - To analyse the performance parameters of synchronous machines.
  - To understand the concept of direct and quadrature axis parameters of synchronous machines.
  - To understand and analyse the operation of synchronous motor.
  - To analyse abc to dq0 transformation and steady state operation of synchronous machine.
  - To understand the operation and analyse control of BLDC motors.

**Module** | **Contents** | **Hours**
--- | --- | ---
1 | **Synchronous Generator:** Construction, E.M.F. equation, Winding factors, Armature reaction, Phasor diagrams for cylindrical rotor generator, Voltage regulation, No load (OC) and SC test, Voltage regulation methods: EMF; MMF; ZPF; ASA; Saturated Synchronous Reactance. | 12 |
2 | **Performance of Synchronous Generator:** Power flow equations and maximum power conditions, Need for parallel operation and conditions, Effect of variation of field current and prime mover input on parallel operation, Concept of infinite bus, Effect of variation of field current on alternator connected to infinite bus, Numericals on parallel operation | 08 |
3 | **Salient pole synchronous generator:** Concept of direct and quadrature reactance, Blondel’s two reaction theory, Phasor diagram of salient pole machine, Power angle characteristics, Synchronising power and torque. | 05 |
4 | **Synchronous Motor:** Principle of operation, Self starting methods, Phasor diagram, Load angle (δ), Power flow equations and maximum power conditions, Effect of change in excitation and mechanical power on performance of motor, V and Inverted V curves, Power factor control, Hunting, Excitation and power circles, Measurement of \( X_d \) and | 12 |
X_q by slip test, Starting against high torques

<table>
<thead>
<tr>
<th></th>
<th>Theory of Synchronous Machines: Ideal synchronous machine, Transformation to direct and quadrature axis variables, basic machine relations in dq0 variables, Steady state analysis.</th>
<th>06</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>BLDC Motor: Classification, Construction, Electronic commutation, Principal of operation, Microprocessor/DSP based control scheme of BLDC motor (block diagram and flow chart), Sensor less control, Comparison with DC motor, Applications.</td>
<td>05</td>
</tr>
</tbody>
</table>

Books Recommended:

Text Books:
1. Bimbhra P.S., Electric Machinery, Khanna Publisher,
2. Bimbhra P.S., Generalized Machine Theory, Khanna Publisher,
3. V. K. Mehta, Principles of Electrical Machines, S Chand Publication
4. E.G.Janardanan, Special Electrical Machines, PHI Publisher, 2016.

Reference Books:
1. Ashfaq Husain, Electric Machines, Dhanpat Rai and co. publications

Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Theory Examination:
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3: Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4: Remaining question will be randomly selected from all the modules.
### University of Mumbai

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
</tr>
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<tbody>
<tr>
<td>EEC603</td>
<td>Signal Processing (abbreviated as SP)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Theory</td>
<td>Tutorial</td>
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<tr>
<td></td>
<td></td>
<td>Theory</td>
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<td></td>
<td></td>
<td>Internal Assessment</td>
</tr>
<tr>
<td>EEC603</td>
<td>Signal Processing</td>
<td>20</td>
</tr>
</tbody>
</table>

**Course Objectives**
- To impart knowledge on continuous and discrete time signals.

**Course Outcomes**
- Students will be able
  - To discriminate continuous and discrete time signals and systems.
  - To understand the transformation of discrete time signal to Z domain.
  - To analyse frequency response of systems using Z domain.
  - To understand discrete and fast Fourier transform.
  - To design FIR system.
  - To design IIR System.

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Introduction</strong>&lt;br&gt;<strong>Classification of Signal and System:</strong>&lt;br&gt;Definition and classification of continuous and discrete signals. Standard signals, periodic/non periodic, Even and odd, Energy and power signal, Sampling Theorem (Derivation is not Required), Basic operations on signal (Folding, Scaling and Time shifting). Definition and classification of systems: Causal /Anti causal, Time-Variant/Invariant, Linear/Non-Linear, stable/unstable, Memory/ Memory less System (static and dynamic). Convolution in DT domain (Matrix Method only)</td>
<td>06</td>
</tr>
<tr>
<td>2</td>
<td><strong>Z-Transform</strong>&lt;br&gt;Z-Transform of bilateral signal, Definition of ROC, Properties of ROC, Properties of Z-transform, Inverse Z-Transform (only partial fraction)</td>
<td>06</td>
</tr>
<tr>
<td>3</td>
<td><strong>Frequency Response</strong>&lt;br&gt;Pole-zero plot in DT domain, Minimum phase, Maximum phase, Mixed phase and Linear, Phase System based on location of zeros, Low pass, high pass, Band pass and band reject system based on pass band frequency, Formation of Difference Equation, Solution of difference Equation (with &amp; without initial Conditions), Zero input, zero state and Total Response of the system, Magnitude and phase response (only Analytical Method)</td>
<td>06</td>
</tr>
<tr>
<td>4</td>
<td><strong>Discrete and Fast Fourier Transform</strong>&lt;br&gt;DTFT, DFT &amp; IDFT (Only Matrix Method), Properties of DFT, DIT FFT Algorithm (Radix-2)</td>
<td>06</td>
</tr>
<tr>
<td>5</td>
<td><strong>Design of FIR System</strong></td>
<td>06</td>
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</table>
Introduction to FIR System, Group Delay, phase Delay, Condition for Linear phase FIR system, Window Technique (only Rectangular window function, Hamming Window function)

6 Design of IIR System
Introduction to IIR System & Bilinear Transformation, Digital Butterworth Filter design using Bilinear Transformation

Books Recommended:

Text Books:

Reference Books:

Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Term work:
Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:
Tutorials: 15 marks
Assignments: 05 marks
Attendance (Theory and Tutorial): 05 marks
The final certification and acceptance of term work ensures minimum passing in the term work

Theory Examination:
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3: Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4: Remaining question will be randomly selected from all the modules.
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<tr>
<th>Course Code</th>
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<tr>
<td>EEC604</td>
<td>Microcontroller and its Applications (abbreviated as MCA)</td>
<td>4 - 4 4 - 4</td>
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<tbody>
<tr>
<td>EEC604</td>
<td>Microcontroller and its Applications</td>
<td>Theory</td>
<td></td>
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<tr>
<td></td>
<td>Internal Assessment</td>
<td>End Sem. Exam</td>
<td>Exam Duration (Hrs.)</td>
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<td></td>
<td>Test 1</td>
<td>Test 2</td>
<td>Avg.</td>
</tr>
</tbody>
</table>

**Course Objectives**

- To impart knowledge on PIC 18 microcontroller based embedded system using C programming.

**Course Outcomes**

Students will be able
- To understand the features and architecture of PIC 18 microcontroller.
- To understand the instructional set and apply to basic arithmetic and logical operations.
- To understand the supportive devices of PIC 18 microcontrollers.
- To understand the interfacing of PIC 18 microcontroller and it’s peripheral.
- To understand the coding of PIC 18 microcontroller using C language.
- To design general purpose applications of PIC 18 microcontroller.

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Introduction to Microcontroller</strong></td>
<td>06</td>
</tr>
<tr>
<td></td>
<td>Block diagram of generic micro controller, Micro controller versus Microprocessor, A brief history of PIC microcontroller, Overview of PIC 18 family and features, Internal Bus structure of PIC microcontroller, Clock frequency, machine cycle and instruction cycle.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>PIC18F Programming Model and Instruction Set</strong></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PIC18 microcontroller programming model, Bus architecture, PIC microcontroller program memory and data memory organization, Special Function Registers (SFRs), General Purpose Registers (GPRs), CPU registers, Working Register (Wreg), Status Register, Bank Select Register (BSR), Instruction Decoder, Program Counter (PC) and program ROM, File Select Register (FSR) and File memory, Stack Pointer (STKPTR) and Stack, PIC 18 internal Architecture (ALU, EEPROM, RAM, IO Ports, Timer, CCP module, ADC), Concept of Pipelining, Instruction Set, Data transfer instructions, Arithmetic and Logical Instructions, Rotate instructions, Branch instructions, Bit manipulation instructions. (Assembly programs are restricted to basic</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>PIC 18 Support Devices</strong></td>
<td><strong>Parallel Ports and Serial Communication</strong></td>
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<tr>
<td>3</td>
<td><strong>Timer Module:</strong> Basic Concept of Timers and counters, Timer Registers, Control Registers, 8 bit and 16 bit operation (only for Timer 0 and 1), CCP module (Capture, Compare and PWM). ADC module: ADC Features, Block diagram of ADC module, ADC Registers, ADCON0, ADCON1. Interrupt Module: Basic concept of Interrupt, PIC 18 Interrupts, Interrupt versus polling, Interrupt sources, Interrupt vector, Interrupt service routine, Interrupt process, RCON Register, INTCON, IPR1, PIE1.</td>
<td><strong>IO PORT Module:</strong> Basic concept of I/O interfacing, Port Registers, TRIS registers, LAT registers, Simple port interfacing and addressing, Interfacing input peripherals, Interfacing output peripherals. <strong>Serial communication:</strong> Basics of serial communication, USART module, SPBRG, TXREG, RCREG, TXSTA, RCSTA, PIR1.</td>
</tr>
<tr>
<td></td>
<td><strong>PIC Programming in C</strong></td>
<td><strong>Microcontroller Applications</strong></td>
</tr>
</tbody>
</table>
|   | IO programming: Byte size IO, Bit addressable IO. **Timer programming:** Generating delay, generating frequency. **Interrupt programming:** Timer0 and Timer1 interrupt to generate square wave. **Serial port programming:** Transmit data serially, Receive data serially. | **Interfacing matrix keyboard and Seven segments LED display, LCD Interfacing, ADC Interfacing, Traffic signal controller, DC motor interfacing, Stepper motor interfacing, PWM signal generation.** | **Reference Books:**

1. Fundamentals of Microcontrollers and Applications in Embedded Systems (with the PIC 18 Microcontroller Family), Ramesh Gaonkar, Penram International publications (Ind) Pvt. Ltd.
2. PIC Microcontroller and Embedded Systems, Muhammad Ali Mazidi, Rolind D Mckinlay and Danny Causey, Pearson Education.

**Assessment:**
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3. Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4. Remaining question will be randomly selected from all the modules.
University of Mumbai

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
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<tbody>
<tr>
<td>EEC605</td>
<td>Control System -II (abbreviated as CS-II)</td>
<td>4 - 4 - 4 - 4</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course code</th>
<th>Course Name</th>
<th>Examination Scheme</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Theory</td>
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<tr>
<td></td>
<td></td>
<td>Internal Assessment</td>
</tr>
<tr>
<td>EEC605</td>
<td>Control System – II</td>
<td>20</td>
</tr>
</tbody>
</table>

**Course Objectives**
- To impart knowledge and skill on compensator design.
- To study basics of digital control system and design of digital compensator.

**Course Outcomes**
Students will be able
- To understand the basic design of various compensators.
- To design compensators using root locus techniques.
- To design compensators using frequency response techniques.
- To design compensators using state variable approach.
- To illustrate basics of digital control system.
- To design digital compensators.

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Introduction to the Compensator:</strong> Basic concept of compensator design, its requirement, position of compensator in a control system, cascade compensator, feedback compensator, gain compensation, lag, lead and lag-lead compensator, proportional, derivative, integral Compensation. Three term PID, physical realization of compensator with passive and active components, basic block diagrams of a compensated closed loop control system</td>
<td>04</td>
</tr>
<tr>
<td>2</td>
<td><strong>Design of Compensators using Root Locus Technique:</strong> Introduction, improving steady state error by gain compensation, transient response improvement by cascade compensation, improving steady state and transient response, design of rate feedback compensator, notch filter.</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td><strong>Design of Compensators using Frequency response Technique (Bode Plot):</strong> Introduction, transient response improvement by gain adjustment, Lag compensation, Lead compensation, Lag-lead compensation.</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td><strong>Design of Compensators using State variable approach:</strong> Introduction, pole placement topology, controller design by pole placement topology in phase variable form, controllability and complete controllability, controllability matrix, controllability by inspection, alternative approach to controller design, controller design by transformation. Introduction to Observer / estimator, full order and reduced order observer/ estimator, observability matrix, observability by inspection,</td>
<td>8</td>
</tr>
</tbody>
</table>
observer design by pole placement alternative approach to Observer design, Observer design by transformation, steady state error design using integral control.

| 5 | **Digital control System:** Introduction, advantage of digital control, components of digital control system, derivation of digital/ pulse transfer function, block diagram reduction, stability of digital system on Z-plane, bilinear transformation, steady state error and error constants |
| 6 | **Design of Digital Compensators:** Transient response on the Z-plane, gain design on Z plane for transient response using root locus, stability design by root locus, cascade compensation (design of digital lead, lag and lag-lead compensator) of digital system using s-plane, implementing the digital compensator. |

**Books Recommended:**

**Text books:**
1. Control system engineering by Norman Nise 2nd to latest edition
4. Introduction to Programmable Logic Controller by Dunning G, Delmar Thomson Learning, 2nd edition

**Reference books:**
5. Modern control system engineering by K. Ogata, printice Hall.
7. Process Control principles and applications, Surekha Bharot, Oxford Higher education

**Assessment:**
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3: Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4: Remaining question will be randomly selected from all the modules.
### University of Mumbai

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
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<tbody>
<tr>
<td>EEDLO 6021</td>
<td>Digital Communication Engineering (abbreviated as DCE)</td>
<td>3</td>
<td>1</td>
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<table>
<thead>
<tr>
<th>Course code</th>
<th>Course Name</th>
<th>Examination Scheme</th>
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</thead>
<tbody>
<tr>
<td>EEDLO 6021</td>
<td>Digital Communication Engineering</td>
<td>Theory</td>
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<tr>
<td></td>
<td></td>
<td>Internal Assessment</td>
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<td>Test 1</td>
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</tbody>
</table>

#### Course Objectives
- To impart knowledge and skill on digital communication engineering.

#### Course Outcomes
- Students will be able
  - To understand the concept and blocks of digital communication system.
  - To understand and analyse the performance of base band and pass band digital communication system.
  - To analyse the different modulation techniques used in digital communication system.
  - To identify the presence of error in coded signal and design the error control system.
  - To understand basic concept of different type of digital communication systems.

#### Module | Contents | Hours
--- | --- | ---
1 | **Information theory**
Block diagram of a digital communication system, Concept and measures of information, entropy and it’s properties. Transmission rate and channel capacity of noisy channels, Shannon’s theorem on channel capacity. Source Coding, Shannon’s Source Coding Theorem, Shannon-Fano Source Coding, Huffman Source Coding. Introduction to Lempel Ziv coding | 06 |
2 | **Baseband Modulation and Transmission**
Line codes and their desirable properties, PSD of digital data. Discrete PAM signals and its power spectra. Concept of inter channel and inter symbol interference, Nyquist criterion for zero ISI, sinusoidal roll-off filtering, correlative coding, equalizers, and eye pattern. Duo-binary encoding and modified duo-binary encoding | 06 |
3 | **Baseband Detection**
Orthogonality, representation of signals. Maximum likelihood decoding Correlation receiver, equivalence with matched filter | 04 |
4 | **Modulation Techniques**
Generation, detection, Coherent and non-coherent reception, signal | 08 |
<p>| | |</p>
<table>
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<tbody>
<tr>
<td></td>
<td>space diagram, spectrum, bandwidth efficiency, and probability of error analysis of: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) Modulations, Binary Phase Shift Keying (BPSK) Modulation, Quaternary Phase Shift Keying (QPSK)</td>
</tr>
<tr>
<td>5</td>
<td><strong>5. Error Control Systems:</strong>&lt;br&gt;5.1 Types of error control, error control codes, linear block codes, generator matrix, and systematic linear block codes, parity check matrix, syndrome testing, error correction, and decoder implementation&lt;br&gt;5.2 Cyclic codes: Algebraic structure of cyclic codes, binary cyclic code properties, encoding in systematic&lt;br&gt;5.3 Introduction of Convolution code: State diagram, code tree, trellis diagram</td>
</tr>
<tr>
<td>6</td>
<td><strong>Overview of different types of communication:</strong>&lt;br&gt;Power Line Carrier communication, Satellite communication, OFC (Block Diagram level)</td>
</tr>
</tbody>
</table>

**Books Recommended:**

**Text Books:**

**Reference Books:**

**Assessment:**
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

**Term work:**
Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:<br>Tutorials : 15 marks<br>Assignments : 05 marks<br>Attendance (Theory and Tutorial) : 05 marks
The final certification and acceptance of term work ensures minimum passing in the term work.

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3. Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4. Remaining question will be randomly selected from all the modules.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
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<tr>
<td>EEDLO 6022</td>
<td>Micro-Grid (abbreviated as MG)</td>
<td>Theory 3, Tutorial 1</td>
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<tr>
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<th>Course Name</th>
<th>Examination Scheme</th>
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<tr>
<td>EEDLO 6022</td>
<td>Micro-Grid</td>
<td>Theory</td>
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<td>Internal Assessment</td>
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<td>Test 1</td>
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</table>

**Course Objectives**
- To impart knowledge of renewable energy based Microgrid technology, types and issues associated in their practical realization.
- To elaborate the various control and operational strategies used for practical microgrids.

**Course Outcomes**
Students will be able
- To identify and describe the evolvement Microgrid, its features and barriers.
- To select, size and design the various microgrid resources.
- To model, analyze and design the power electronics (PE) interfaces for various microgrid sources.
- To identify and describe the role communication in Microgrid realization.
- To identify and describe various operational strategies and protection schemes suitable for Microgrid.
- To apprise the different standards applicable for microgrid deployment.

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
</tr>
</thead>
</table>
| 1      | Introduction to Microgrid:  
Microgrid: Definition, What is not a microgrid, Typical structure and configuration of a microgrid, Significance of microgrids, Sources of microgrid, Types of microgrids, AC, DC and hybrid microgrids; Technical implications and social fall out of microgrid, Market Models and business cases for microgrids. | 03 |
| 2      | Microgrid Sources and Power Electronic Interfaces:  
Review of Microgrid sources: basics characteristics and selection; Power Electronics (PE) interface and design for microgrid DC and AC sources. Protection and co-ordination, Power Quality issues and Solutions; Microgrid and Energy Storage Systems (ESS), Portable and Stationary ESS, Review of Flywheel, Battery and Ultra-capacitor; PE Interface design for ESS. | 08 |
| 3      | Control and Design of Power Electronic Interfaces:  
Determination of Control laws, Power relations and power control, Bi-directionality and its need in a Microgrid; Control of DC-DC converters and inverter and challenges in a Microgrid; Micro-grid Control Strategies: Centralized, Decentralized and Hierarchical control, Multi- | 10 |
Agent System based control; Power Control and Energy Management in Microgrids.

4 Communication Infrastructure:

5 Operation of Microgrid and Microgrid Protection:

6 Microgrid Standards and Deployment:
IEEE-1547 series, Review of worldwide Microgrid installations, Economic evaluation and planning for microgrids; Microgrids in smart grid scenario.

Books Recommended:

Text Books:

Reference Books:

Assessment:
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project

Term work:
Term work shall consist of minimum eight tutorials and assignments (minimum 2). The distribution of marks for term work shall be as follows:
Tutorials :15 marks
Assignments : 05 marks
Attendance (Theory and Tutorial) : 05 marks

The final certification and acceptance of term work ensures minimum passing in the term work

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3. Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4. Remaining question will be randomly selected from all the modules.
### Course Code: EEDLO 6023

**Course Name:** Advanced Power Electronics (abbreviated as APE)

<table>
<thead>
<tr>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
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<tbody>
<tr>
<td>Theory</td>
<td>Tutorial</td>
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<td></td>
<td>Theory</td>
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#### Examination Scheme

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<th>Course code</th>
<th>Course Name</th>
<th>Internal Assessment</th>
<th>End Sem. Exam</th>
<th>Exam Duration (Hrs.)</th>
<th>Term Work</th>
<th>Total</th>
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<tbody>
<tr>
<td>EEDLO 6023</td>
<td>Advanced Power Electronics</td>
<td>20</td>
<td>20</td>
<td>80</td>
<td>03</td>
<td>25</td>
</tr>
</tbody>
</table>

#### Course Objectives

- To understand dc to dc conversion with isolation, the underlying principles of converter operation and hence to analyze different converter circuits for power conversion.
- To understand the principles of design of magnetics such as high frequency transformers and inductors.
- To keep abreast with the latest technologies and research going on in different areas related to power electronics.
- To enhance the capability of problem solving skills.
- To model the converter and design the controller for deeper understanding and detailed analysis.

#### Course Outcomes

Student will be able to

- Select and design power electronic converter topologies for a broad range of energy conversion applications.
- Analyze and simulate the performance of power electronic conversion systems.
- Ability to model and design controllers for the closed loop operation of power converters.
- 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.
- Build and troubleshoot power electronics circuits.
- Deliver technological solution in the field of power electronics.

#### Module 1: Switching Voltage Regulators

- Introduction; Linear power supply (voltage regulators); Switching voltage regulators; unidirectional and bidirectional core excitation; Review of basic dc-dc voltage regulator configurations - Buck, Boost, Buck-Boost converters, Bidirectional Converter (BDC) and their analysis for continuous and discontinuous mode; Other converter configurations like Flyback converter, Forward converter, Push-pull converter; Design criteria for SMPS; Multi-output

<table>
<thead>
<tr>
<th>Module</th>
<th>Contents</th>
<th>Hours</th>
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<tbody>
<tr>
<td>1</td>
<td>Switching Voltage Regulators Introduction; Linear power supply (voltage regulators); Switching voltage regulators; unidirectional and bidirectional core excitation; Review of basic dc-dc voltage regulator configurations - Buck, Boost, Buck-Boost converters, Bidirectional Converter (BDC) and their analysis for continuous and discontinuous mode; Other converter configurations like Flyback converter, Forward converter, Push-pull converter; Design criteria for SMPS; Multi-output</td>
<td>10</td>
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<tr>
<td></td>
<td>switch mode regulator.</td>
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<tr>
<td>2</td>
<td><strong>Resonant dc to dc converters:</strong> Drawbacks of switch-mode converters, classification of resonant converters, basic resonant circuit concepts, Load resonant converters, series and parallel loaded, steady state operating characteristics, Resonant switch converters - ZVS, ZCS, comparison of resonant converters, applications of resonant converters</td>
<td>03</td>
</tr>
<tr>
<td>3</td>
<td><strong>Design of Magnetics (Boost, Buck, BDC and flyback only):</strong> Review of magnetic concepts, volt-sec balance, area product, design of inductor, design of high frequency transformer, numericals on design of inductor and transformer for dc to dc converters.</td>
<td>05</td>
</tr>
<tr>
<td>4</td>
<td><strong>Modeling and control converters and inverter (Boost, Buck, BDC and flyback only):</strong> State space model of various dc to dc converters, state space averaging techniques, small signal analysis, transfer function, feedback control, compensator design, voltage mode control, current mode control. Modeling of grid connected Inverter with LC filter, Compensator design with current mode control and DC link voltage control loop. Digital control of power electronic converters.</td>
<td>09</td>
</tr>
<tr>
<td>5</td>
<td><strong>Multi-Level Inverter:</strong> Need for multilevel inverters, Diode clamped, flying capacitor and cascaded MLI, Phase shifted and level shifted PWM techniques, introduction to SVM for three level inverter, Applications of multilevel inverters.</td>
<td>04</td>
</tr>
<tr>
<td>6</td>
<td><strong>Applications of power electronic converters:</strong> Solar PV Power Conditioning unit (PCU), Battery PCU, Active Filters, AC and DC drives. Thermal management and EMI issues in Practical power Electronics systems.</td>
<td>05</td>
</tr>
</tbody>
</table>

**Books Recommended:**

**Text Books:**
1. N.Mohan, T.M.Undeland, W.P Robbins, —Power Electronics, Converters, Applications & Design, Wiley India.
7. Simon Ang, Alejandro Oliva, "Power-Switching Converters" Taylor and Francis group

**Reference Books:**
1. P. T. Krein, Elements of Power Electronics, Oxford University Press.
**Assessment:**
Internal Assessment consists of two tests out of which; one should be compulsory class test (on minimum 02 Modules) and the other is either a class test or assignment on live problems or course project.

**Term work:**
Term work shall consist of minimum six tutorials and one group mini project.
Mini-project: Group of students (4 in a group) will choose a fairly complex power electronics application in their preferred area, complete the analysis and detailed design of power converter and control for this application, and finally validate the design using hardware implementation supported with simulation(if necessary). A formal technical report is required on the last day of class.
The distribution of marks for term work shall be as follows:
- Tutorials :10 marks
- Group Mini Project :10 marks
- Attendance (Theory and Tutorial) :05 marks
The final certification and acceptance of term work ensures minimum passing in the term work.

**Theory Examination:**
1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. Total four questions need to be solved.
3: Q.1 will be compulsory, based on entire syllabus wherein sub questions of 2 to 5 marks will be asked.
4: Remaining question will be randomly selected from all the modules.
### Course Objectives
- To introduce the concept of different protection schemes.

### Course Outcomes
- Students will be able
  - To understand the concept of various over current protection scheme and its applications in power system.
  - To understand the concept of various over/under voltage, over/under frequency and temperature protection scheme and its applications.
  - To understand the working principle of various protective devices.

### Syllabus:
Same as that of Course EEC601 protection and switchgear Engineering.

### Suggested List of Laboratory Experiment:
1. Demonstration of Inverse time Over-current Relay & Plotting the characteristics
2. Demonstration of Over-current protection Relay
3. Demonstration of Directional Over-current Protection Relay
4. Demonstration of Differential Over-current Protection Relay
5. Demonstration of Under/Overvoltage Protection
6. Demonstration of Motor winding temperature protection
7. Demonstration of Gas actuated Relays
8. Demonstration of working parts of different Fuses, MCB, MCCB, RCCB & Circuit Breakers.

Any other experiment based on syllabus which will help students to understand topic/concept.

### Term work:
Term work shall consist of minimum six experiments. The distribution of marks shall be as follows:
- Experiments Performance : 10 marks
- Journal : 10 marks
- Attendance (Theory and Practical) : 05 marks
The final certification and acceptance of term work ensures the minimum passing in the term work.

**Oral Examination:**
Oral examination will be based on entire syllabus.
### Course Objectives
- To impart practical knowledge on synchronous machines

### Course Outcomes
Students will be able
- To analyse the operation of synchronous machines.
- To analyse the voltage regulation of synchronous machines.
- To analyse the synchronization or parallel operation of synchronous machine.
- To determine the parameters of synchronous machines for its analysis.

### Syllabus:
Same as that of Course EEC602 Electrical machines - IV

### Suggested List of Laboratory Experiment:
1. Constructional details of Synchronous machine
2. Voltage regulation of Alternator by Direct loading method
3. Voltage regulation of Alternator by EMF and MMF method
4. Voltage regulation of Alternator by ZPF and ASA method
5. Synchronization / Parallel operation of Alternator
6. Starting methods of Synchronous motor
7. ‘V’ and inverted ‘V’ curve of Synchronous motor
8. Determination of X_d and X_q of Synchronous machine by Slip test
9. Use of Synchronous motor as a Synchronous condenser
10. Loading of Synchronous motor by Brake test with rated excitation

Any other experiment based on syllabus which will help students to understand topic/concept.
**Term work:**
Term work shall consist of minimum six experiments. The distribution of marks shall be as follows:

<table>
<thead>
<tr>
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<th>Marks</th>
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<tbody>
<tr>
<td>Experiments Performance</td>
<td>10 marks</td>
</tr>
<tr>
<td>Journal</td>
<td>10 marks</td>
</tr>
<tr>
<td>Attendance (Theory and Practical)</td>
<td>05 marks</td>
</tr>
</tbody>
</table>

The final certification and acceptance of term work ensures the minimum passing in the term work.

**Practical/Oral Examination:**
Practical/Oral examination will be based on entire syllabus.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEL603</td>
<td>Microcontroller Lab (abbreviated as MC Lab)</td>
<td>- 2</td>
<td>1 1</td>
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<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Examination Scheme</th>
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<td>Theory</td>
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<td>Test 1</td>
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<tr>
<td>EEL603</td>
<td>Microcontroller Lab</td>
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</tbody>
</table>

**Course Objectives**
- To impart the programming knowledge of PIC 18 microcontroller.

**Course Outcomes**
- Students will be able
  - To program simple arithmetic and logical operations using PIC 18 microcontroller.
  - To program timer and ADC of PIC 18 microcontroller for different applications.
  - To interface different IO devices with PIC 18 microcontroller.

**Syllabus:** Same as that of Course EEC604 Microcontroller and its applications

**Suggested List of Laboratory Experiment:**

**Basic Programming**
1. Addition, subtraction
2. Logical operations
3. Multiplication and division
4. Sort even and odd numbers
5. Sort negative and positive numbers
6. Toggle the bits of ports

**Timer programming**
1. Generate square wave
2. Generate time delay
3. Counter program
4. Generate the PWM pattern

**ADC programming**
1. Analog to digital conversion

**Peripheral Interface programming**
1. LCD interface
2. LED interface
3. Stepper motor interface
4. DC motor interface
5. Serial port interface
Any other experiment based on syllabus which will help students to understand topic/concept.

**Term work:**
The term work shall consist of minimum **eight** experiments based on PIC 18F microcontroller using embedded C language. The distribution of marks shall be as follows:

<table>
<thead>
<tr>
<th>Experiments Performance</th>
<th>10 marks</th>
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</thead>
<tbody>
<tr>
<td>Journal</td>
<td>10 marks</td>
</tr>
<tr>
<td>Attendance (Theory and Practical)</td>
<td>05 marks</td>
</tr>
</tbody>
</table>

The final certification and acceptance of term work ensures the minimum passing in the term work.

**Practical/Oral Examination:**
Practical/Oral examination will be based on entire syllabus.
University of Mumbai

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Teaching Scheme (Contact Hours)</th>
<th>Credits Assigned</th>
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<td>Practical</td>
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<tr>
<td>EEL604</td>
<td>Simulation Lab-II (abbreviated as Sim Lab - II)</td>
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<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Examination Scheme</th>
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<tr>
<td>EEL604</td>
<td>Simulation Lab-II</td>
<td>-</td>
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</tbody>
</table>

**Course Objectives**
- To impart knowledge on coding and simulation of electrical systems.

**Course Outcomes**
- Students will be able
  - To code or simulate signal systems for its analysis.
  - To code or simulate power system for its analysis.
  - To code or simulate power electronics converter for its analysis.
  - To code or simulate electrical machines for its analysis.

**Syllabus:** Same as that of all core courses of semester VI.

**Suggested List of Laboratory Experiment:**
1. Algorithm for Basic operation on signal
2. Algorithm for Linear and Circular Convolution
3. Algorithm for step, impulse and frequency Response in Digital system
4. Algorithm for FFT for DFT Computation
5. Algorithm for Design of FIR System using Rectangular Window
6. Algorithm for Design of Butterworth Digital IIR System
7. Simulation of 1-phase full wave Rectifier with R-L Load
8. Simulation of Fault Analysis
9. Simulation of OC & SC Test of 3-phase IM.
10. Simulation of 1-phase full wave Controlled Rectifier with R-L Load

Any other experiment based on syllabus which will help students to understand topic/concept.

**Term work:**
Term work shall consist of minimum six experiments. The distribution of marks shall be as follows:
- Experiments Performance : 10 marks
- Journal : 10 marks
- Attendance (Theory and Practical) : 05 marks

The final certification and acceptance of term work ensures the minimum passing in the term work.

**Oral Examination:**
Oral examination will be based on entire syllabus.