AC- 29/6/2021
Item No.- 6.4

UNIVERSITY OF MUMBAI

Bachelor of Engineering

in

Electrical Engineering

Third Year with Effect from AY 2021-22

(REV- 2019 'C' Scheme) from Academic Year 2019 – 20

Under

FACULTY OF SCIENCE & TECHNOLOGY

(As per AICTE guidelines with effect from the academic year 2019–2020)

AC: 29/6/2021
Item No.-6.4

UNIVERSITY OF MUMBAI

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	**Third Year in Bachelor of Electrical Engineering**
2	Eligibility for Admission	**After Passing Second Year Engineering as per the Ordinance 0.6243**
3	Passing Marks	**40%**
4	Ordinances / Regulations (if any)	**Ordinance 0.6243**
5	No. of Years / Semesters	**8 semesters**
6	Level	**Under Graduation**
7	Pattern	**Semester**
8	Status	**Revised**
9	To be implemented from Academic Year	**With effect from Academic Year: 2021-2022**

Date:29/6/2021

Dr. S. K. Ukarande
Associate Dean, Faculty of Science and Technology
University of Mumbai

Dr Anuradha Muzumdar
Dean, Faculty of Science and Technology
University of Mumbai

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 Science and Technology (in particular Engineering) of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty 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. 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. Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 13 weeks and remaining 2 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc.

There was a concern that the earlier revised curriculum more focused on providing information and knowledge across various domains of the said program, which led to heavily loading of students in terms of direct contact hours. In this regard, faculty of science and technology resolved that to minimize the burden of contact hours, total credits of entire program will be of 170, wherein focus is not only on providing knowledge but also on building skills, attitude and self learning. Therefore in the present curriculum skill based laboratories and mini projects are made mandatory across all disciplines of engineering in second and third year of programs, which will definitely facilitate self learning of students. The overall credits and approach of curriculum proposed in the present revision is in line with AICTE model curriculum.

The present curriculum will be implemented for Third Year of Engineering from the academic year 2021-22. Subsequently this will be carried forward for Final Year Engineering in the academic year 2022-23.

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Incorporation and Implementation of Online Contents from NPTEL/ Swayam Platform

The curriculum revision is mainly focused on knowledge component, skill based activities and project based activities. Self learning opportunities are provided to learners. In the revision process this time in particular Revised syllabus of 'C ' scheme wherever possible additional resource links of platforms such as NPTEL, Swayam are appropriately provided. In an earlier revision of curriculum in the year 2012 and 2016 in Revised scheme 'A' and 'B' respectively, efforts were made to use online contents more appropriately as additional learning materials to enhance learning of students.

In the current revision based on the recommendation of AICTE model curriculum overall credits are reduced to 171, to provide opportunity of self learning to learner. Learners are now getting sufficient time for self learning either through online courses or additional projects for enhancing their knowledge and skill sets.

The Principals/ HoD's/ Faculties of all the institute are required to motivate and encourage learners to use additional online resources available on platforms such as NPTEL/ Swayam. Learners can be advised to take up online courses, on successful completion they are required to submit certification for the same. This will definitely help learners to facilitate their enhanced learning based on their interest.

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Preface By BoS

The outcome based course curriculum for the undergraduate degree in Electrical Engineering in Rev.2019 ‘C’ scheme has been chalked out through the thoughtful discussions and deliberations of academic and industry experts. While devising the syllabus content framework, the correct balance between the fundamental / core topics with appropriate mix of topics from the state of the art technologies in electrical and allied domains is attempted. With the increased Industry-Institute interaction and internship programs, students are encouraged to explore the opportunity to improve communication skills, problem solving skill and good team management. These skills shall surely help them to meet the future challenges in their career.

The new course curriculum will also give ample opportunity to the students to work in cross discipline domains to gain the hands on experience through the project based learning facilitated through the various skill based labs, Mini projects, Course projects , Major projects etc. The increased number of department and institute level electives shall facilitate students with the truly choice based learning and skilling in a particular domains.

On behalf of the Board of Studies (BoS) in Electrical Engineering of the University of Mumbai, we seek the active participation from all the stake holders of the engineering education to meet the set outcomes and objectives for the Undergraduate Program in Electrical Engineering.

Board of Studies in Electrical Engineering

Dr. Sushil S. Thale	**: Chairman**
Dr. B. R. Patil	**: Member**
Dr. S. R. Deore	**: Member**
Dr. B. B. Pimple	**: Member**
Dr. Nandkishor Kinhekar	**: Member**

Semester VI

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract./ Tut.	Theory	Pract.	Total
EEC601	Power System Protection & Switchgear	3	--	3	--	3
EEC602	Microcontroller Applications	3	--	3		3
EEC603	Control System Design	3	--	3	--	3
EEC604	Signals and Systems	3	--	3	--	3
EEDO601X	Department Optional Course – 2	3	--	3	--	3
EEL601	Power System Protection & Switchgear Lab	--	2	--	1	1
EEL602	Microcontroller Applications Lab	--	2	--	1	1
EEL603	Control System Design Lab	--	2	--	1	1
EEL604	SBL-III: Industrial Automation Lab	--	4	--	2	2
EEM601	Mini Project – 2 B	--	4[$]	--	2	2
Total		**15**	**14**	**15**	**07**	**22**

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Prac / Oral	Total
		Internal Assessment			End Sem Exam	Exam. Duration (in Hrs)			
		Test1	Test2	Avg					
EEC601	Power System Protection & Switchgear	20	20	20	80	3	--	--	100
EEC602	Microcontroller Applications	20	20	20	80	3	--	--	100
EEC603	Control System Design	20	20	20	80	3	--	--	100
EEC604	Signals and Systems	20	20	20	80	3	--	--	100
EEDO601X	Department Optional Course – 2	20	20	20	80	3	--	--	100
EEL601	Power System Protection & Switchgear Lab	--	--	--	--	--	25	25	50
EEL602	Microcontroller Applications Lab	--	--	--	--	--	25	25	50
EEL603	Control System Design Lab	--	--	--	--	--	25	--	25
EEL604	SBL-III: Industrial Automation Lab	--	--	--	--	--	25	25	50
EEM601	Mini Project – 2 B	--	--	--	--	--	25	25	50
Total		**--**	**--**	**100**	**400**	**--**	**125**	**100**	**725**

$ indicates work load of Learner (Not Faculty), for Mini Project; **Faculty Load**: 1 hour per week per four groups

Department Optional Courses

Sem. VI: Department Optional Course – 2

EEDO6011: Special Electrical Machine
EEDO6012: Electric Traction
EEDO6013: High Voltage Engineering
EEDO6014: Energy Storage

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEC601	Power System Protection and Switchgear	3	-	3	-	3

Course Code	Course Name	Examination Scheme						
		Theory					Term Work	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)		
		Test 1	Test 2	Avg.				
EEC601	Power System Protection and Switchgear	20	20	20	80	03	-	100

Course Objectives	• To impart basic knowledge of power system protection, substation equipment and protection schemes.
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. To select the appropriate switching/protecting device for substations. 2. To discriminate between the application of circuit breaker and fuses as a protective device. 3. To understand the basic concept of relay, types of relay and their applications in power system. 4. To select the specific protection required for different components of power system according to the type of fault. 5. To apply the specific protection provided for different types of transmission lines.

Module	Contents	Hours
1	Substation Equipment and switching devices **Substation Equipment:** Instrument Transformers: Role of instrument transformers in measuring and protection, difference between measuring and protection CTs, selection of technically suitable instrument transformers; **Switchgear**-Definition, Types, Location of switchgear in typical power system, single line diagram to show the measuring and protection scheme **Switching Devices**- Isolator & Earthing switch (Requirements & definitions, types and construction, Pantograph Isolators, Ratings), Load break switches- Ratings and applications; Contactors- Basic working principle, Terms & Definitions, applications.	03
2	Circuit Breakers and Fuses: **Circuit Breaker:** Arc initiation, arc quenching principles, Re-striking voltage, RRRV, Recovery voltage, Types of Circuit Breakers: For LV application- MCB, MCCB, ELCB, air circuit breakers. For HV application- SF6 circuit breakers, vacuum circuit breakers (working principle, Construction, operating mechanisms, ratings & applications), Mechanical life, Electrical life and testing of circuit breakers. Principle and applications of LV and HV DC circuit breakers **Fuses & their applications**-Introduction, classification, working principle and applications of re-wirable and HRC fuses, Expulsion and drop out fuses, Fusing factor, selection of fuse link and cut off characteristics	10
3	Introduction to Protective relaying: Shunt & Series Faults, causes and Effects of faults, Importance of protective relaying, Protective zones, primary & Back-up protection, Different types of backup protection, desirable qualities of protective relaying, PSM & TSM(Importance, Different types of Time-current characteristics and application), working principle of **Electromagnetic Induction disc Relays,** Thermal, bimetal relays, Frequency relays, under/over voltage relays, DC relays,	09

	Different Principles of protection - Over current & earth fault (non- directional & directional types), differential protection(current and voltage type), distance protection (Working Principle and application of Impedance relay, Causes and remedies of Over reach-under reach, Reactance and Mho relay, Power swing blocking relay).	
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, Protection co-ordination	06
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 - Type and nature of faults, Need for auto-reclosure schemes, Carrier aided distance protection (Directional comparison method), Power Line Carrier Current protection (Phase comparison method). Introduction to the concept of Islanding	06
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), **Numerical Relays**- Introduction, Block diagram of numerical relay, Signal sampling, Anti –Aliasing Filter, Introduction to the concept of Phase Measurement Unit	05

Books Recommended:

Text Books:

1. Switchgear & Protection by Sunil.S.Rao, Khanna Publications
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:

1. Fundamentals of protection by Paithanker & Bhide.S.R, P.H.I
2. Static Relays by Madhava Rao, TMH
3. A text book on Power System Engineering by Soni, Gupta, Bhatnagar & Chakraborthi, Dhanpat Rai & Co
4. Protective Relaying by Lewis Blackburn, Thomas.J.Domin
5. Power System Protection by P.M. Anderson, Wiley Interscience
6. Modern Power System Protection – Divyesh Oza, TMH Publication

Website Reference / Video Courses:

1. **NPTEL Course: Power System Protection** By Prof. S.A. Soman, Dept. of Electrical Engineering, IIT Bombay:- Web link- https://nptel.ac.in/courses/108/101/108101039/
2. **NPTEL Course: Power System Protection and Switchgear** By Prof. **Bhaveshkumar Bhalja**, Dept. of Electrical Engg, IIT Roorkee:- Web link- https://nptel.ac.in/courses/108/107/108107167/
3. **NPTEL Course: Power System Protection** By Prof. **Ashok Kumar Pradhan**, Dept. of Electrical Engineering, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105167/

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.

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Tutorial	Theory	Tutorial	Total
EEC602	Microcontroller Applications	3	-	3	-	3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (Hrs.)			
		Test 1	Test 2	Avg.					
EEC602	Microcontroller Applications	20	20	20	80	03	-	-	100

Course Objectives	1. To understand the features and architecture of PIC 18 microcontroller. 2. To introduce assembly programming knowledge for PIC 18 microcontroller. 3. To impart embedded programming knowledge for PIC 18 microcontroller using C. 4. To introduce various applications using microcontroller based system
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. To analyse the difference between microprocessor and microcontroller based systems. 2. To write, debug and execute the software programs for internal peripheral devices of microcontroller. 3. To write, debug and execute the software programs for external peripheral devices for microcontroller based systems. 4. To design and implement the peripheral devices interfacing with microcontroller

Module	Contents	Hours
1.	**Introduction to Microcontroller** Block diagram of generic microcontroller, Microcontroller 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.	05
2.	**PIC18F Programming Model and Instruction Set** PIC18 microcontroller programming model, Bus architecture, 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 *Memory Pointers:* Program ROM and Program Counter (PC), Data ROM and Table Pointer (TBLPTR), File memory and File Select Register (FSR), Stack and Stack Pointer (STKPTR) *PIC 18 internal Architecture:* ALU, EEPROM, RAM, IO Ports, Timer, ADC, Serial port, CCP, Pipelining. (conceptual overview only) *Instructions and Assembly Programs:* Instruction Set, Instruction formats, Addressing modes, Assembler Directives, Assembly programs. (Assembly programs are restricted to basic arithmetic, logical and data transfer operations only)	08
3.	**PIC 18 Support Devices** *Timer Module:* Basic Concept of Timers and counters, Timer Registers, Control Registers, 8 bit and 16 bit operation (only for Timer 0), CCP module (Capture, Compare and PWM), Watch dog Timer. *ADC module:* ADC Features, Block diagram of ADC module, ADC Registers, ADCON0, ADCON1 and ADCON2. *Interrupt Module:* Basic concept of Interrupt, PIC 18 Interrupts, Interrupt versus polling, Interrupt sources, Interrupt vector, Interrupt service routine, Interrupt process, RCON, INTCON, IPR1 and PIE1.	06

4.	**Parallel Ports and Serial Communication** IO PORT Module: Basic concept of I/O interfacing, PORT Registers, TRIS Registers, LAT Registers, Simple input /output peripheral interfacing (switches & LEDs). Serial communication: Basics of serial communication, Data framing, USART module, SPBRG, TXREG, RCREG, TXSTA, RCSTA, PIR1	06
5.	**PIC Programming in C** *IO programming:* Byte size IO, Bit addressable IO. *Timer programming:* Generating delay, generating square wave. (for Timer0 using Interrupt based programming only) *Serial port programming:* Transmit data serially, Receive data serially. (Interrupt based programming only)	06
6.	**Microcontroller Applications** Interfacing matrix keyboard and Seven segments LED display, LCD Interfacing, ADC Interfacing, Traffic signal controller, DC motor interfacing, Stepper motor interfacing, PWM signal generation.	08

Text/Reference Books:-

1. Ramesh Gaonkar, "Fundamentals of Microcontrollers and Applications in Embedded Systems (with the PIC 18 Microcontroller Family)", Penram International publications (Ind) Pvt. Ltd.
2. Ali Mazidi, Rolind D Mckinlay and Danny Causey , "PIC Microcontroller and Embedded Systems", Pearson Education ltd., 2015
3. Robert B. Reese, "Microcontroller from Assembly Language to C using PIC18FXX2", Davinici Engineering press.
4. Han Way Huang, "PIC Microcontroller: An Introduction to Software and Hardware Interfacing", Cengage Learning, 2005.

Website Reference / Video Courses:

1. NPTEL Course: **Microprocessors And Microcontrollers** By Prof. Santanu Chattopadhyay, Dept. of Electrical Engineering, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105102/

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.

ELECTRICAL ENGINEERING SEM-VI						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEC603	Control System Design	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC603	Control System Design	20	20	20	80	3	-	-	100

Course Objectives	1. To establish a quantitative foundation to the design and analysis of Control systems. 2. To impart knowledge and skill on compensator design. 3. To study basics of digital control system and design of digital compensator. 4. To understand the concept of state –space analysis, to design the compensator in time and frequency domain, to design the PID compensator.
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. Define fundamental control system design specifications and basic principles of controller design 2. Understand the basic design of various compensators. 3. Design compensators using root locus techniques. 4. Design modern controllers based on the state space techniques, 5. Recognize the importance of observability and controllability for system design.

Module	Contents	Hours
1.	Introduction to the Compensator: Basic concept of compensator design, its requirement, cascade compensator, feedback compensator, gain compensation, lag, lead and lag-lead compensator, proportional, derivative, integral Compensation, physical realization of compensator with passive and active components, basic block diagrams of a compensated closed loop control system.	03
2.	Design of Compensators using Root Locus Technique: Introduction, improving steady state error by gain compensation, transient response improvement by cascade compensation, improving steady state and transient response.	08
3.	Design of Compensators using Frequency Response Technique (Bode Plot): Introduction, Relation between closed-loop time response parameters of peak time, settling time, and percent overshoot with the open-loop frequency response parameters, transient response improvement by gain adjustment, Lag compensation, Lead compensation, Lag-lead compensation	08
4.	Design of Compensators using State variable approach: Introduction, pole placement topology, controller design by pole placement topology in phase variable form, controllability, controllability matrix, controllability by inspection, alternative approach to controller design, controller design by transformation. Introduction to Observer / estimator, observability, , observability matrix, observability by inspection, observer design by pole placement, alternative approach to Observer design. Steady state error design using integral control	07
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	06
6.	Design of Digital Compensators:	07

	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.	

Text Books:-

1. Control system engineering by Norman Nise 2nd edition
2. Digital Control Systems by Benjamin C. Kuo,Oxford series 2nd Edition
3. Control Engineering: An Introductory Course by Wilkie J., Johnson M., Katebi R., Palgrave MacMillan.
4. Industrial Control Electronics: Devices, Systems and Applications by Bartelt, Delmar Thomson Learning, 1st edition

Reference Books:-

1. Modern control Engineering by Richard C Dorf, SH Bishop, & Wesley edition, Eighth Edition
2. Linear Control system Analysis and design with MATLAB, by J.J. Azzo, C. H. Houpis, S.N. Sheldon, Marcel Dekkar, ISBN 0824740386
3. Control System Engineering, Shivanagraju s. Devi L., New age International latest edition
4. Control System engineering by Nagrath and Gopal, 5th to latest edition , Wiley Eastern
5. Modern control system engineering by K. Ogata, printice Hall.
6. Automatic control systems, Basic analysis and Design, William A. Wolovich, Oxford
7. Process Control principles and applications, Surekha Bharot, Oxford Higher education

Website Reference / Video Courses:

1. NPTEL Course: **Advanced Linear Continuous Control Systems** By Prof. Yogesh Hote, Dept. of Electrical Engineering, IIT Roorkee:- Web link- https://nptel.ac.in/courses/108/107/108107115/
2. NPTEL Course: Industrial Instrumentation By Prof. Prof. S. Mukhopadhyay and Prof. S.Sen, IIT Kharagpur:- Web link- https://nptel.ac.in/courses/108/105/108105062/

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 questions will be randomly selected from all the modules

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEC604	Signals and Systems	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEC604	Signals and Systems	20	20	20	80	3	-	-	100

Course Objectives	1. To impart knowledge on continuous and discrete time signals. 2. To understand the basic properties of signals & systems 3. To know the methods of characterization of LTI systems in time domain 4. To analyze discrete time signals and system in the Fourier and Z transform domain 5. Understand the design of various types of digital filters and implement them using various implementation structures
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. Discriminate continuous and discrete time signals and systems. 2. Understand the transformation of discrete time signal to Z domain. 3. Analyse frequency response of systems using Z domain. 4. Design, implementation, analysis and comparison of digital filters for processing of discrete time signals

Module	Contents	Hours
1.	Introduction- Classification of Signals and Systems: Definitions of signal and system. Standard signals- Step, Ramp, Pulse, impulse, Real and complex exponentials and Sinusoids, Classification of signals – Continuous time (CT) and Discrete Time (DT) signals, Periodic & Aperiodic signals, Deterministic & Random signals, Even and odd, Energy & Power signals, Classification of systems- Linear/ Non-Linear, Time-Variant/Invariant , Causal /Anti causal, stable/unstable, Memory/ Memory less System (static and dynamic), Sampling Theorem (Derivation is not Required). Basic operations on signals-Folding, Scaling and Time shifting). Convolution in DT domain (Matrix Method only)	07
2.	Z-Transform Z-Transform of bilateral signal, Definition of ROC, Properties of ROC, Properties of Z-transform, Inverse Z-Transform (only partial fraction).	05
3.	Frequency Response & Fourier Series 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 & without initial Conditions), Zero input, zero state and Total Response of the system, Magnitude and phase response (only Analytical Method). , Introduction to Fourier Series: Representation of continuous time Periodic Signals, convergence of the Fourier Series, Properties of continuous time Fourier Series, Fourier Series representation of discrete time periodic signals, Properties of discrete time Fourier Series	10
4.	Discrete and Fast Fourier Transform DTFT, DFT & IDFT (Only Matrix Method), Properties of DFT, DIT FFT Algorithm (Radix-2)	06
5.	Design of FIR System	06

	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	05

Text Books:-

1. Salivahan S.," Digital Signal Processing", TMH Publication,2012
2. Oppenhein & Schafer," Discrete Time Signal Processing," PHI Publication 1989.
3. Haykin S and Van Veen B," Signal and System", Wiley Publication, 2nd Ed.
4. Linder D.K.," Introduction to Signal & System," McGraw Hill International, 1999.

Reference Books:-.

1. Proakis & Manolakis," Digital Signal Processing", PHI Publication, 1995.
2. Mitra S.K.," Digital Signal Processing," TMH Publication, 2001.
3. Digital Signal Processing: A Practitioner's Approach, Kaluri V. Rangarao, Ranjan K. Malli November 2006, John Wiley.
4. Li Tan,"Digital Signal Processing, Fundamental & Application", Elsevier Publisher, Academic Press
5. DSP – A Practical Approach – Emmanuel C. Ifeacher, Barrie. W. Jervis, 2 ed., Pearson Education

Website Reference / Video Courses:

1. NPTEL Course: Principles of Signals And Systems By Prof. Ravindra Arora, Dept. of Electrical Engineering, IIT Kanpur:- Web link- https://nptel.ac.in/courses/108/104/108104100/
2. NPTEL Course: Signals And Systems By Prof. Kushal K. Shah, Dept. of Electrical Engineering, IISER Bhopal :- Web link- https://nptel.ac.in/courses/108/106/108106163/

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Theory Examination:

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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 questions will be randomly selected from all the modules

ELECTRICAL ENGINEERING SEM-VI						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO6011	Special Electrical Machines	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO6011	Special Electrical Machines	20	20	20	80	3	-	-	100

Course Objectives	• To impart knowledge on special electrical machines and its control
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To exemplify the working of Stepper motor and its control 2. To demonstrate the functioning of SRM motor and its control 3. To illustrate the working of BLDC motor and its control 4. To illustrate the operational features of PMSM motor and its control 5. To illustrate the operational features of Synchronous reluctance motor and its control 6. To illustrate the working of Linear motors

Module	Contents	Hours
1	Stepper motor and its Control: Features, construction, application and working of Stepper motor Characteristics – Open Loop and Closed Loop Control – Control Strategies -Power Converter Circuit –DSP/ Microcontroller based Control	07
2	Switched reluctance Motor and its Control: Features, construction, application and working of Switched Reluctance motor; Open Loop and Closed Loop Control- Control Strategies - Power Converter Circuit –DSP/ Microcontroller based Control – Sensor less control	07
3	Brushless DC Machines and its control: Brushless DC Machines Construction and working principle, Equivalent magnetic circuit, Type of converter and speed control, Comparison between the axial and radial permanent magnet motors, Applications. Characteristics – Open Loop and Closed Loop Control – Control Strategies - Power Converter Circuit –DSP/ Microcontroller based Control	07
4	Permanent Magnet Synchronous Machine and its control: Features, construction , application and working of PMSM, Characteristics – Open Loop and Closed Loop Control – Control Strategies - Power Converter Circuit –DSP/ Microcontroller based Control	07
5.	Synchronous Reluctance Motor and its control Construction, Working, Phasor Diagram, Torque Equation, Control - Direct Axis Current Control, Fast Torque Response Control, Advantages	06
6.	Linear Induction Machine Construction, Types, Working, Feature, Thrust Equation, Equivalent circuit, Characteristics, Control, Application	05

Books Recommended:

Text Books:

1. E. G. Janardanan — Special Electrical Machine PHI, publication
2. G. K. Dubey- Fundamentals of Electrical Drives, CRC press 2002 - Technology & Engineering
3. K. Venkataratnam- Special Electric Machines, Universities Press, Apr-2009 - Technology & Engineering

Reference Books:

1. D. C. Hanselman — Brushless Permanent-Magnet Motor Design—Eman Press LLC
2. R. Krishnan, SWITCHED RELUCTANCE MOTOR DRIVES Modeling, Simulation, Analysis, Design, and Applications, CRC Press.
3. M. Ramamoorty, O. Chandra Sekhar—Electrical Machines - PHI publication
4. R Krishnan — Permanent Magnet Synchronous and Brushless DC Motor Drives—CRC press

Website Reference / Video Courses:

1. NPTEL Course: **Advanced Electric Drives** By Dr. S.P. Das, Department of Electrical Engineering, IIT Kanpur:- Web link- https://nptel.ac.in/courses/108/104/108104011/
2. NPTEL Course: **Fundamentals of Electric Drives** By Dr. S.P. Das, Department of Electrical Engineering, IIT Kanpur:- Web link- https://nptel.ac.in/courses/108/104/108104140/

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 questions will be randomly selected from all the modules

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO6012	Electric Traction	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO6012	Electric Traction	20	20	20	80	3	-	-	100

Course Objectives	• To impart knowledge of principles of electrical traction • To explore various electrical subsystems of traction • To increase the awareness of latest developments in electric traction systems
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To illustrate the basics as well as the state of the art of electrical traction systems and subsystems. 2. To understand traction mechanics and different factors contributing to the traction. 3. To illustrate and analyse the performance of various traction motors and drives 4. To explain the traction power Supply arrangement and its protection aspects. 5. To understand the design requirements of the overhead equipments 6. To demonstrate the functioning of railway signaling system

Module	Contents	Hours
1	Introduction to Electric Traction: Requirements of Ideal Traction Systems, the Indian Scenario of Electric traction, Present day State of art Electric traction as a Viable Transport Strategy, Advantages of Electric Traction over other systems of traction, Ideal choice of traction system, Power supply systems for Electric Traction, DC systems, Single phase ac system and three phase ac systems, Kando systems, Latest Developments in 3phase with special reference to locomotives, EMUs and Metro stock, Role of Battery banks in Traction, types and maintenance.	04
2.	Traction Mechanics: Types of services, Speed-Time Curve, Trapezoidal, Quadrilateral Speed-Time Curve, Mechanics of train movement, Different Speed - time characteristics for train movement, Requirement of tractive effort and tractive effort produced, Train resistance, Power output and energy output from driving axles, Specific energy consumption & Factors affecting SEC, Adhesion & Coefficient of adhesion, Concept of Weight Transfer and weight transfer due to torque exerted by Traction motor, Influence of Electrical parts on Co-efficient of adhesion, wheel slip detection device (Numericals)	08
3.	Traction motor and Drives: Type of traction motor best suited for traction duties, Available motor characteristics and their suitability for traction duties, speed control methods, Braking methods, special Emphasis and techniques of regenerative braking, Optimization of design and construction features for improved power to weight ratio, Power Factor and Harmonics, Tractive Effort and Drive Ratings, Important Features of Traction Drives, conventional DC and AC Traction drives, Semiconductor/IGBT based Converter Controlled Drives, DC Traction using Chopper Controlled Drives, AC Traction employing Poly-phase motors, Traction control of DC locomotives and EMU's, Traction control system of AC locomotives, Control gear, PWM control of induction motors, Power & Auxiliary circuit equipment (Other than traction	10

	motors), Linear Induction motors, introduction to Maglev Technology.	
4.	**Power Supply Arrangement and Protection:** Traction substation, spacing and location of Traction substations, Major equipment at traction substation, selection and sizing of major equipment like transformer and Switchgear, Types of protection provided for Transformer and overhead lines, surge protection, maximum demand and load sharing between substations, sectionalizing paralleling post and feeder posts, Booster transformers, Return Conductor, 2X25KV AC system, controlling/monitoring, Railway SCADA systems, Train lighting and Air-conditioning	07
5.	**Overhead Equipment and Track circuits:** Design requirement of catenary wire, contact wire, Dropper, Height, span length, Automatic weight tensioning, section insulator, overlap, Different techniques of current collection (overhead and underground systems), neutral section, overhead crossing of power lines, Protection.	05
6.	**Railway Signaling:** Block Section Concept, AC/DC Track Circuits, Interlocking Principle, Train speed and signaling, Solid state Interlocking, Automatic Warning Systems, CAB signaling, Signaling level crossing. Permissible limit of EMI and EMC, Permissible capacitively-coupled current, Coupling between circuits, conductive coupling, Electrostatic induction.	05

Textbook and Reference Books

1. Modern Electric traction by H.Partab:
2. Electric Traction – Motive Power and Energie Supply by Andreas Steimel, Oldenbourg Industrieverlag GmbH, 2008
3. Electrical Railway Transportation Systems by Morris Brenna, Federica Foiadelli and Dario Zaninelli, IEEE Press and Wiley, 2018
4. Power Electronics and Electric Drives for Traction Applications Edited by Gonzalo Abad, Wiley, 2017

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 questions will be randomly selected from all the modules.

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credit Assigned		
		Theory	Practical	Theory	Practical	Total
EEDO6013	High Voltage Engineering	3	-	3		3

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term work	Pract. & Oral	Oral	
		Test 1	Test 2	Avg					
EEDO6013	High Voltage Engineering	20	20	20	80	-	-	-	100

Course Objectives	1. To understand various breakdown processes in solid, liquid and gaseous insulating materials. 2. To impart the knowledge of Generation of high voltage DC, AC and Impulse voltages and currents. 3. To impart the knowledge of Testing and Measurement of high voltage DC, AC and Impulse voltages and currents. 4. To understand the design and layout of H V Laboratories
Course outcomes	Upon successful completion of this course, the learner will be able: 1. To know the fundamentals properties of the materials and their failure mechanisms to get appropriate and optimal design. 2. To explain and calculate the generation and measurement of High DC, AC and Impulse voltages and currents. 3. To understand testing of High voltage power apparatus. 4. To illustrate the major requirements in design of HV Laboratories.

Module	Contents	Hours
1	Electrostatic Fields, Their Control and Estimation: • Electric field Stress, its control and Estimation, Numerical methods – Finite difference, Finite Element and Charge simulation method for estimation of Electric Field. Surge voltage, their distribution and control	04
2	Conduction and Breakdown in Air and Other Gaseous Dielectrics: • Gases as insulating media, Collision Processes, Ionization process in gas, Townsend's Theory, current growth equation in presence of primary and secondary ionization processes, Townsend's criterion for breakdown in electronegative gases, Limitation of Townsend's theory, Panchen's law, Breakdown in non-uniform fields and corona discharges. • Streamer mechanism of breakdown, Post-breakdown phenomenon and application. • Practical considerations in using gas for insulation purposes. (Numerical on Townsend's theory and Paschen's law)	07
3	Breakdown in Liquid and Solid Dielectrics: • Liquid Dielectrics, Conduction and breakdown in pure liquids, Conduction and breakdown in commercial liquids: Suspended Particle Theory, Cavitations and bubble Theory. • Solid dielectrics used in practice, Intrinsic, Electro-mechanical and Thermal breakdown, Breakdown of solid dielectrics in practice, due to chemical, electrochemical deterioration, treeing, tracking, Internal discharges. • Breakdown of composite insulation, Application of insulating materials in electrical power apparatus, electronic equipment's.	06

4	**Generation & Measurement of High Voltage and Currents:** • Generation of high voltage and currents: Generation of high DC voltages by rectifier, Voltage doublers and multiplier circuits. • Electrostatic machines, Generation of high AC voltage – Cascading of transformers, series and parallel Resonance transformer (system), Tesla coil. • Generation of impulse voltages and currents-Impulse voltage definition, wave front and wave tail time, Multistage impulse generator, Modified Marx circuit, Tripping and control of conventional impulse generators, Introduction to Generation of high impulse current, (Design of Marx Generators circuits- numerical can be taken). • Generation of switching surges. (Numerical based on impulse generation, high DC voltage generation, optimum number of stages)	08
5	**Measurement of High Voltages and Currents:** • High ohmic series resistance with micro-ammeter., HVAC and impulse voltage-Resistance and capacitance voltage dividers, Sphere gap for measurement of High DC, AC and impulse voltages, Capacitance Voltage Transformer • Measurement of High DC, AC and impulse currents	06
6	**High Voltage Testing of Electrical Power Apparatus and H V Laboratories Layouts:** • Non-destructive testing of dielectric materials, DC resistivity measurement, Dielectric and loss factor measurement, Partial discharge measurement. • Testing of insulators and bushing, Power capacitors and cables testing, testing of surge diverters. • High Voltage laboratory–design, planning and layout. - Size and dimensions of the equipment and their layout, Classification of HV laboratory, Earthing and Shielding of H.V. laboratories, its importance.	08

Textbooks:

1. C. L. Wadhwa, “High Voltage Engineering”, New Age International Publishers Ltd.
2. M. S. Naidu, V. Kamaraju, “High Voltage Engineering”, Tata McGraw Hill Publication Co. Ltd. New Delhi

Reference books:

1. E. Kuffel, W. S. Zaengl, J. Kuffel, “High Voltage Engineering Fundamentals”, Newnes Publication
2. Prof. D. V. Razevig Translated from Russian by Dr. M. P. Chourasia, “High Voltage Engineering”, Khanna Publishers, New Delhi
3. Ravindra Arora, Wolf Gang Mosch, “High Voltage Insulation Engineering”, New Age International Publishers Ltd. Wiley Estern Ltd.
4. High Voltage Engineering Theory and Practice by M. Khalifa Marcel Dekker Inc. New York and Basel.
5. Subir Ray, “An Introduction to High Voltage Engineering” PHI Pvt. Ltd. New Delhi

Website Reference / Video Courses:

1. **NPTEL Course: High Voltage Engineering** By Prof. Aditya K. Jagannatham, Dept. of Electrical Engineering, IIT Kanpur:- Web link- **https://nptel.ac.in/courses/108/104/108104048/**

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 questions will be randomly selected from all the modules

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEDO6014	Energy Storage	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		3	--	3		3

Course code	Course Name	Examination Scheme							
		Theory					Term Work	Pract/ Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEDO6014	Energy Storage	20	20	20	80	3	-	-	100

Course Objectives	• To explore the various energy storage technologies and their major applications • To increase awareness of ES suitability and capacity calculation for any given applications
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To illustrate the importance of energy storage systems in Power systems and other application domains 2. To illustrate the operational features of various energy storage technologies 3. To understand the principles and types of thermal, mechanical, electrochemical and electrical energy storage systems. 4. To compare and contrast different types of Energy storage systems 5. To illustrate the hybridization of various ES technology to improve the performance 6. To calculate the capacity of ES system for various application requirements,

Module	Contents	Hours
1.	Introduction to Energy Storage systems and components: Historical Perspective, Storage Needs, Variations in Energy Demand, Interruptions in Energy Supply, Demand for Portable Energy, Environmental and sustainability issues; Necessity of energy storage, different types of energy storage, mechanical, chemical, electrical, electrochemical, biological, magnetic, electromagnetic, thermal, comparison of energy storage technologies;	07
2.	Thermal Energy Storage: Principles and applications, Latent heat, sensible heat storage. Molten salt, Solar pond, seasonal thermal energy storage, Ice storage; Energy and exergy analysis of thermal energy storage.	05
3.	Mechanical Energy Storage: Potential Energy Storage, Energy Storage in Pressurized Gas, Compressed air energy storage (CAES), Flywheel, Applications	04
4.	Electrochemical Energy Storage: Parameters to be considered, Cyclic behaviour, equivalent circuit of electrochemical cell, self-discharge, Battery technologies: Flow battery, Rechargeable battery, Lead-acid, Nickel-Metal hydride, Lithium Ion; Battery system model, parameters; emerging trends in batteries. Fuel Cell: types, comparison and applications.	07
5.	Electrical Energy Storage: Pumped hydro storage system, Energy Storage in Capacitors, Comparative Magnitudes of Energy Storage, Transient behaviour of a Capacitor, Super-capacitor, series connection of super capacitors, charge balancing of super capacitors; Superconducting magnetic energy storage (SMES), Applications	06

6.	**Design, Sizing and Applications of Energy Storage**: Design considerations for sizing of different types of energy storage systems for various applications, case studies; Renewable energy storage- Battery sizing for stand-alone applications; Small scale application-Portable storage systems; (Numerical) E-mobility storage applications- Electric vehicles (EVs), batteries, super-capacitors and fuel cells, future technologies. Electric vehicle: V2X, G2V and V2G modes of operation. Hybrid Energy storage systems: configurations and applications. Energy Storage - Charging methodologies, SoC, SoH, SoS estimation techniques.	10

Textbook:

1. Robert Huggins, Fundamentals, Materials and Applications Second Edition, Springer, 2016
2. Dincer I., and Rosen M. A. (2011); Thermal Energy Storage: Systems and Applications,Wiley
3. Leo J.M.J. Blomen and Michael N. Mugerwa, "Fuel Cell System", New York, Plenum Press, 1993.
4. Ahmed Faheem Zobaa, Energy storage – Technologies and Applications, InTech Publication 2013.
5. Jiuchun Jiang and Caiping Zhang, Fundamentals and Applications of Lithium-Ion Batteries In Electric Drive Vehicles, Wiley, 2015
6. K.T. Chau, Energy Systems for Electric and Hybrid Vehicles, IET, UK, 2016
7. M. Broussely and G. Pistoia, Industrial Applications of Batteries From Cars to Aerospace and Energy Storage, Elsevier, 2007.

Reference books

1. S. Kalaiselvam and R. Parameshwaran , Thermal Energy Storage Technologies for Sustainability Systems Design, Academic Press, 2014
2. Trevor M. Letcher, Storing Energy with Special Reference to Renewable Energy Source, Elsevier, 2016.
3. Frank S. Barnes and Jonah G. Levine, Large Energy Storage Systems Handbook, CRC Press, 2011
4. Aiping Yu, Victor Chabot, and Jiujun Zhang, Electrochemical Super-capacitors For Energy Storage And Delivery Fundamentals And Applications, CRC Press, 2013.
5. Younghyun Kim and Naehyuck Chang, Design and Management of Energy-Efficient Hybrid Electrical Energy Storage Systems, Springer, 2014

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 questions will be randomly selected from all the modules.

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credit Assigned		
		Theory	Practical	Theory	Practical	Total
EEL601	Power System Protection And Switchgear Lab	-	2	-	1	1

Course Code	Course Name	Examination Scheme							Total
		Theory				TW/Practical/Oral			
		Internal Assessment			End Sem. Exam	Term work	Pract. & Oral	Oral	
		Test 1	Test 2	Avg					
EEL601	Power System Protection And Switchgear Lab	-	-	-	-	25	--	25	50

Course Objectives	• To introduce the concept of different protection schemes
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To understand the working principle of various protective devices like Circuit breakers, fuses, switches and contactors. 2. To understand the concept of various over current protection scheme and its applications in power system. 3. To understand different protection schemes of transformer and Induction motor. 4. To understand protection schemes of transmission line.

Syllabus: Same as that of Course EEC601-Power System Protection and Switchgear

Suggested List of Laboratory Experiments: Minimum six experiments need to be performed.

1. Demonstration of working parts of different Fuses and Contactor.
2. Demonstration of working parts of MCB, MCCB, RCCB & Circuit breakers.
3. To perform overcurrent protection using Induction Disc relay by setting different TSM and plot time vs current characteristics.
4. To perform overvoltage protection using Induction Disc relay by setting different TSM and plot time vs current characteristics.
5. Demonstration of different protection schemes like protection against overload, locked rotor, single phasing of 3 phase Induction motor.
6. Demonstration of differential protection of 3 phase transformer.
7. Demonstration of Directional Over-current protection relay.
8. To perform simulation of Numerical Based relay.
9. To perform simulation of distance protection in transmission line.

- Any other experiment based on syllabus, which will help students to understand topics/concept.
- It is desirable to arrange the Visit to a substation and a report preparation.

Industry Visit: Students' visit to be arranged to the nearby industry involved in design/ manufacturing/ processing in the following electrical engineering domains: Electrical Switchgears / Electrical Substation / Electrical Machines / Traction Locomotives / HV Equipments / Energy Storage . All students shall submit visit report in appropriate format as a part of the submission for EEL601.

Note: Students and teachers are encouraged to use the virtual labs whose links are as given below The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct online experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

Term work shall consist of minimum six experiments. The distribution of marks shall be as follows:

Experiments Performance	: 10 marks
Journal	: 05 marks
Industrial Visit Report	: 05 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 of EEC601-Power System Protection and Switchgear

ELECTRICAL ENGINEERING SEM-VI						
Course Code	Course Name	Teaching Scheme (Contact Hours)		Credit Assigned		
		Theory	Practical	Theory	Practical	Total
EEL602	**Microcontroller Applications Lab**	**-**	**2**	**-**	**1**	**1**

Course Code	Course Name	Examination Scheme							Total
		Theory				Practical			
		Internal Assessment			End Sem. Exam	Term work	Pract. & Oral	Oral	
		Test 1	Test 2	Avg					
EEL602	**Microcontroller Applications Lab**	-	-	-	-	**25**	**25**	**-**	**50**

Course Objectives	1. To impart the Assembly language programming knowledge of PIC 18 microcontroller. 2. To impart the Embedded C programming knowledge of PIC 18 microcontroller
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. To write, debug and execute Assembly language based programs. 2. To write, debug and execute embedded language based programs. 3. To design and implement the interfacing of internal peripheral devices. 4. To design and implement the interfacing of external peripheral devices.

Syllabus: Same as that of Course EEC602 Microcontroller Applications

Suggested List of Laboratory Experiments: Minimum four from Group (A) and four from Group (B), in all minimum eight experiments need to be performed.

(A) Assembly Language Programming:

1. To perform Addition, subtraction
2. To perform Multiplication and Division
3. To perform Logical operations (AND, OR, X-OR, NOT)
4. To sort Even and Odd numbers
5. To sort Negative and Positive numbers
6. To Find Largest Number
7. To Find Largest Number
8. To copy source array to destination array (Table related process)
9. To Toggle the bits of Port.

(B) Embedded C Language Programming:

1. Timer programming to Generate square wave
2. Timer programming to Generate time delay
3. Timer programming to Generate the PWM pattern
4. ADC programming to perform Analog to digital conversion
5. Serial communication programming for serial data transfer
6. IO port programming to interface simple switches and 7-segment LED Display
7. IO port programming to interface Liquid Crystal Display (LCD)
8. Stepper Motor interfacing
9. DC Motor interfacing
10. Traffic Signal programming

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

Note: Students and teachers are encouraged to use the virtual labs whose links are as given below The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct online experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

Term work:

The term work shall consist of minimum 08 experiments based on PIC 18F microcontroller using assembly and embedded C language and minimum 02 assignments. The distribution of marks shall be as follows:

Experiments Performance	: 10 marks
Journal (Experiment and Assignments)	: 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 of EEC602-Microcontroller Applications

ELECTRICAL ENGINEERING - SEMESTER-VI						
Course code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEL603	Control System Design Lab	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	2		1	1

Subject code	Subject Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEL603	Control Systems Design Lab	---	---	---	---	--	25	-	25

Course Objectives	1. To enable the students to strengthen their understanding of the design and analysis of control systems through practical exercises 2. Use of modern software tools to analyze and simulate the performance of realistic system models and to design control systems to satisfy various performance specifications.
Course Outcomes	Upon successful completion of this course, the learner will be able to 1. Implement various types of compensators and control algorithms using simulation platforms 2. Apply root-locus & Bode Plot techniques to analyze and design control systems. 3. Able to design digital controllers, assess their design through the constraint specifications

Syllabus: Same as EEC603: Control System Design

Suggested List of Laboratory Experiments: Minimum eight experiments need to be performed.

1. To draw the frequency response characteristic of a given lag- lead compensating network.
2. To study the effect of P, PI, PD and PID controller on step response of a feedback control system (Using control engineering trainer/process control simulator). Verify the same by simulation.
3. Design of a Lead compensator using Root-locus method
4. Design of a lag compensator using Root-locus method
5. Design of a lead-lag compensator using Root-locus method
6. Design of a lead compensator using bode plot method
7. Design of a lag compensator using bode plot method
8. Design of a lead-lag compensator using bode plot method
9. Obtain transfer function of a given system from state variable model and vice versa. State variable analysis of a physical system - obtain step response for the system by simulation
10. State variable analysis using simulation tools. To obtain step response and initial condition response for a single input, two output system in state variable form by simulation.
11. Familiarization with digital control system toolbox
12. Determination of z-transform, inverse z-transform & pole zero map of discrete systems to study step response of a discrete time system and effect of sampling time on system response
13. To explore the Properties of Digital Control Systems. Convert continuous time system to discrete system and vice versa. Root Locus of Digital control system on z-plane

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

Note: Students and teachers are encouraged to use the virtual labs whose links are as given below The remote-access to Labs in various disciplines of Science and Engineering is available. Students can conduct online

experiments which would help them in learning basic and advanced concepts through remote experimentation.

Virtual Lab Website Reference

1. http://vlab.co.in/broad-area-electrical-engineering
2. http://vlab.co.in/broad-area-electronics-and-communications

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.

ELECTRICAL ENGINEERING- SEM-VI						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEL604	SBL-III: Industrial Automation Lab	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		-	4		2	2

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEL604	SBL-III: Industrial Automation Lab	--	--	--	--	--	25	25	50

Course Objectives	1. Develop necessary acquaintance with components and subsystems used in industrial automation 2. Develop the necessary skillset to integrate, monitor, maintain such systems
Course Outcomes	Upon successful completion of this course, the learner will be able: 1. To comprehend with various components and subsystems used in industrial automation 2. To understand the integration of components and sub-systems. 3. To interface the microcontroller / PLC with external devices/ sensors/ actuators. 4. To interface the microcontroller / PLC with control circuits. 5. To design /implement / integrate such systems for any given applications

Section A:

Lab contents shall be covered through some of the following ways:

1) Class room discussions / Expert Lectures
2) Visiting various industries involving such facilities to illustrate industrial automation
3) Multiple day webinar specifically organized to cover such contents
4) In-house facility for demonstration of Industrial automation
5) Hands-on Workshop
6) Exhibitions showcasing these technologies
7) Using virtual Instrumentation platform
8) Using Virtual Lab platform (Virtual Labs (vlab.co.in)

Contents:

1) Components and subsystems used in Industrial automation:

Controllers: Computers, Distributed Control Systems (DCS), Programmable Logic Controllers (PLC), Embedded Controllers.

Operator Interfaces (HMI)-Text based, Graphical, Touchscreens.

Sensors-Analog & Digital; Encoders, Proximity sensor, Ultrasonic Sensors, Photoelectric Sensors; Limit Switches

Actuators-Pneumatic, Hydraulic, Electric; Motors- AC, DC, Linear, Servo and Stepper motor.

Mechanisms and Machine Elements- Cam Driven Systems, ratchets and pawl, gears; Linkages and coupling; Conveyors- Belt, Roller, Chain, Vibrating, Pneumatic.

Motion Profile- trapezoidal velocity motion, S-curve velocity motion, Multi-axis motion

hardware and software platforms for Distributed Control System, DCS Functional Block Diagram, and Sequential Flow Charts

Software- Design and Analysis software, PLC programming, SCADA

2) Industry 4.0:

Conceptual Framework- Main Concepts and Components of Industry 4.0; Technology Roadmap for Industry 4.0; Technologies and Applications: Data Analytics in Manufacturing, Role of IoT, Robotics in the era of Industry 4.0, Additive Manufacturing, 3D printing; Augmented Reality

3) Real life Applications:
   a) Agriculture/ farm produce-sorting and grading system
   b) Automated / Robotic Assembly line
   c) Temperature Control in Process Industries
   d) Cyclic Operation of Traffic Lights
   e) Conveyor System for an Assortment of Objects
   f) Automatically filling of two tanks with liquid
   g) Automated warehouse management system
   h) Automated bottle filling plant
   i) Automated packaging system

4) Industrial Safety Practices:
   General Workplace Safety rules and procedures, recommended safety practices, Personal Protective Equipments (PPE), Industrial safety Acts and regulations

Section B:

Based on the insights received with the coverage of syllabus contents specified in section A, the students should carry out detailed study of at least six different applications listed below (maximum two from any group is desirable). They should have hands-on experience with each of these applications. Wherever possible software development / coding should be done by students.

Group 1: Pneumatic and Hydraulic based Industrial Automation systems:
   a) Electro-Pneumatic System for Pickup and Lay Down of Plastic Containers
   b) Design and assembly of Pneumatic / Hydraulic circuit and wiring of control interface for a particular application
   c) Application with different types of Pneumatic / Hydraulic valves and actuators
   (Any other application which incorporates Pneumatic and Hydraulic components)

Group 2: Drives and Control- Industrial Automation systems
   a) Linear Motion Control System
   b) PLC based Motion Control System
   c) VFD control of Motor
   d) HMI interface based Control
   e) Conveyor belt system
   f) Sorting and grading System for Agriculture Applications
   g) Home automation system with Web Server
   h) Lift control System (Demo)
   (Any other application which incorporates (Drives / Control)

Group 3: Use of IoT in following Applications
   a) Smart Agriculture,
   b) Smart City,
   c) Smart Life—Wearable Technologies,
   d) Smart Health
   e) Smart Grid
   (Any other application which incorporates IoT)

Group 4: Other Applications: Based on PLC/ Embedded micro-controller
   a) To wire up hardware, write and implement ladder programs for the following controls.
      i. Lamp control for various situations.
         a. Staircase control, hospital etc.
         b. Traffic light control.
      ii. Water level control using level sensors

iiii. Logic implementation for Bottle Filling Application

b) Tune PID controller for heat exchanger using DCS
(Any other suitable application)

Note: For each of the experiment carried out, students should prepare a detailed report, clearly specifying following:

[1] Technical description and specification of the system
[2] Drawing/ schematic/ block diagram for system visualization
[3] Components used and their specs
[4] Interconnectivity between the components
[5] Working principle
[6] Software tools used
[7] Program code (if any) developed
[8] Observations
[9] Photographs of the system

Books Recommended:

1. Industrial Automation Hands-On, by Frank Lamb, McGraw-Hill, 2013
2. Industrial Motion Control- Motor Selection, Drives, Controller Tuning, Applications, by Hakan Gürocak Wiley, 2016
3. Industry 4.0: Managing The Digital Transformation, by Alp Ustundag and Emre Cevikcan, Springer, 2018
4. Introduction to Industrial Automation, by Stamatios Manesis and George Nikolakopoulos, CRC Press, 2018

Term Work:

Term work shall consist of minimum requirement as given in the syllabus. The distribution of marks for term work shall be as follows:

Laboratory Performance : 15 marks
Journal : 05 marks
Attendance : 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 experiments carried out in EEL604-SBL-III- Industrial Automation Lab

ELECTRICAL ENGINEERING - SEMESTER-V						
Course Code	Course Name	Teaching scheme (Contact Hours)		Credits Assigned		
EEM601	Mini Project – 2B	Theory	Pract./Tut.	Theory	Pract./Tut.	Total
		--	4$	--	2	2

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Oral	Total
		Internal Assessment			End Sem. Exam	Exam Duration (in Hrs)			
		Test 1	Test 2	Avg					
EEM601	Mini Project – 2B	--	--	--	--	--	25	25	25

$ indicates work load of Learner (Not Faculty)

Course Objectives	1. To design and develop a moderately complex electrical/electronic/digital circuit with practical applications. 2. To understand basic concepts of circuit design while developing the project. 3. To enable the students to gain hands-on experience independently proposing and implementing the project and thus acquire the necessary confidence to deal with complex electrical/electronic/digital systems.
Course Outcomes	Upon successful completion of this course, the learner will be able to: 1. Identify problems based on societal /research needs. 2. Apply Knowledge and skill to solve societal problems in a group. 3. Develop interpersonal skills to work as member of a group or leader. 4. Draw the proper inferences from available results through theoretical/ experimental/ simulations. 5. Analyse the impact of solutions in societal and environmental context for sustainable development. 6. Use standard norms of engineering practices 7. Excel in written and oral communication. 8. Demonstrate capabilities of self-learning in a group, which leads to life-long learning. 9. Demonstrate project management principles during project work

A. Mini Project -Topic Selection and Approval

1. The group may be of maximum **FOUR (04)** students.
2. Students should propose project ideas & finalize the project idea in consultation with guide/ HOD. Students should select a problem which addresses some basic home, office or other real life applications. The mini project must have hardware part. The software part is optional.
3. Students should identify different components/ devices, instruments, simulation/emulations software tools required for the project.
4. Students should submit implementation plan in the form of Gantt/ PERT/ CPM chart, which will cover weekly activity of project.
5. A Log Book to be prepared by each group to record the work progress in terms of milestones per week by students. Weekly comment, remarks to be put by guiding faculty.

B. Mini Project –Execution

i. Design and Fabrication

a. Initial fabrication of the project by students can be done using standard devices/material/software tools to verify the circuit functionalities Initial project fabrication and testing is expected to be done by soldering/assembling on general purpose PCB/ Bakelite boards or suitable platforms required for the electrical/electronic/digital components. Discourage the use of breadboards.
b. If essential, use of a simulation/ emulation software tools to test and verify the performance of the circuit should be encouraged.
c. Students should prepare the proper drawings (electrical/ mechanical), schematics/ layouts of the project.
d. For final implementation of the circuit, preparation of PCB (if any required) using suitable CAD tools and fabricating the same in the lab is expected.

ii. Devices/ Components/ Systems to be Used:

Students are encouraged to use passive components like resistors, capacitors, inductors etc. If any specialize inductor is not readily available, the fabrication of the same in the lab should be encouraged. Other components like: Transistors, diodes, voltage regulators, logic gates, Op-amps, general purpose microcontroller, DC motors/ AC motors, sensors, actuators, relays etc. (Students may add more components as per the requirement of project).

iii. Testing and analysis of the Project

Students should test the circuit using suitable laboratory equipments like power supply, multi-meter, CRO, DSO etc. In case of any debugging requirement, students should record the problems faced during the testing and solutions sought after for the fault in the circuit.

All the testing results must be well documented in the final project report verifying the functionalities of the propose project.

iv. Use of Reference Material/Literature :

Students are advised to refer Application Notes, research publications & data sheets of various electrical/electronic/digital devices from Texas Instruments, Microchips, International Rectifiers, ST Microelectronics, Philips, NXP and many other manufacturers.

C. Project Report Format:

Mini Project **report** should include circuit diagram, operation, application, design details, testing, waveforms (if applicable) references, simulation results and final prepared PCB image, conclusion, etc. Project report should include report of all above steps listed in (2) and the conclusion.

Note:-

It is expected that the department should organise some of the guidance expert lectures / video lectures/ courses/ webinars/ workshops etc. for the students at the appropriate timing during the Mini Project practical slots on following topics:

1) Understanding passive components viz. resistors, capacitors and inductors from practical point of view: types/ varieties, device packages, applications and cost.
2) Understanding semiconductor components viz. diodes, BJT and JFET/MOSFETs from practical point of view: types/ varieties, device packages, applications and cost.
3) Design principles of simple electrical / electronic circuits with some examples.
4) Selection of switches and circuit protection components.
5) Selection and sizing of wires and conductors.
6) Soldering Practice.
7) Heat-sinking and Enclosure design concepts
8) Overall workmanship while working on the project fabrication.
9) Use of different software tools for design and development of circuits

11) Use of standard as well as some of the advanced laboratory equipments needed for testing of such projects

Application Domains:

List of key application domains from where students are encouraged to derive Mini Projects topics:

1) Smart Agriculture solutions
2) Power converter applications in various Applications
3) IoT based applications in power systems
4) AI/ML applications in disaster management
5) Renewable Energy
6) Energy Conservation
7) Energy Storage
8) Battery Charging and Protection
9) Fire Safety
10) Electrical System Protection
11) Lighting Control
12) Wireless Power Transfer
13) Electrical Components Testing
14) Electrical Parameters Measurement
15) Non-conventional Electricity Generation
16) Laboratory Equipments
17) E-Mobility / Electric Vehicles
18) Video Surveillance Systems
19) Robotics for Hazardous applications
20) Waste Management System
21) Smart City Solutions
22) Smart Classrooms and learning Solutions
23) Design of Electrical Equipment
24) PLC based automation system
25) Power system Monitoring System (EMS)

It is every much expected that the complexity of the Mini Project 2A/ 2B should be increased compared to the selection of projects during Mini Project 1A/1B. Also based on the subjects learned in Sem. III and Sem. IV the broader area inclusive of the concepts learned must be selected. Students can identify the mini project topics either from above suggested domains or any other relevant electrical engineering domains. The inter-disciplinary nature of the project is also desirable.

Guidelines for Assessment of Mini Project:

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
  - Marks awarded by guide/supervisor based on log book : 10
  - Marks awarded by review committee : 10
  - Quality of Project report : 05

Review/progress monitoring committee may consider following points for assessment based on either one year or half year project as mentioned in general guidelines.

One-year Mini Project:

- In first semester entire theoretical solution shall be ready, including components/system selection and cost analysis. Two reviews will be conducted based on presentation given by students group.
  - First shall be for finalization of problem
  - Second shall be on finalization of proposed solution of problem.
- In second semester expected work shall be procurement of components /systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
  - First review is based on readiness of building working prototype to be conducted.
  - Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.

Half-year Mini Project:

- In this case in one semester students' group shall complete project in all aspects including,
  - Identification of need/problem
  - Proposed final solution
  - Procurement of components/systems
  - Building prototype and testing
- Two reviews will be conducted for continuous assessment,
  - First shall be for finalization of problem and proposed solution
  - Second shall be for implementation and testing of solution.

Assessment criteria of Mini Project.

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

- In one year, project, first semester evaluation may be based on first six criteria's and remaining may be used for second semester evaluation of performance of students in mini project.
- In case of half year project all criteria's in generic may be considered for evaluation of performance of students in mini project.

Guidelines for Assessment of Mini Project Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organizations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions

Oral Examination: Mini Project shall be assessed during oral examination based on following points:

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact
4. Full functioning of working model as per stated requirements
5. Effective use of skill sets

6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication

Reference Books:

1. P. Horowitz and W. Hill, "The Art of Electronics", 3rd Edition, Cambridge University Press, 2015
2. R. S. Khandpur, "Printed Circuit Board", McGraw-Hill Education; 1st edition, 2005.
3. Simon Monk, "Hacking Electronic: Learning Arduino and Raspberry Pi", McGraw-Hill Education TAB; 2 edition (September 28, 2017).
4. Matthew Scarpino, Designing Circuit Boards with EAGLE: Make High-Quality PCBs at Low Cost, 1st Edition Prentice Hall.
5. P. Horowitz and W. Hill, The Art of Electronics, 3 Edition, Cambridge University Press.
6. Archambeault and D. James, PCB Design for Real-World EMI Control, Springer Publications
7. Mitzner, Kraig, "Complete PCB design using OrCAD Capture and PCB", Elsevier, 2009
8. Peter Dalmaris, "Kicad Like a Pro", Tech exploration
9. Charles Platt, "Encyclopedia of Electronic Components – Vol-1: Power, electromagnetism, and discrete semiconductors. ", Maker Media, 2012
10. Charles Platt, "Encyclopedia of Electronic Components – Vol-2: Integrated circuits, light sources, sound sources, heat sources, and high frequency sources. ", Maker Media, 2015

Suggested Software tools:

1. LTspice:https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html#
2. Eagle : https://www.autodesk.in/products/eagle/overview
3. OrCAD: https://www.orcad.com/
4. Multisim : https://www.multisim.com/
5. Webbench: http://www.ti.com/design-resources/design-tools-simulation/webench-power-designer.html
6. Tinkercad : https://www.tinkercad.com/
7. Raspbian OS: https://www.raspberrypi.org/downloads
8. Arduino IDE: https://www.arduino.cc/en/main/software

Online Repository:

1. https://www.electronicsforu.com
2. https://circuitdigest.com
3. https://www.electronicshub.org
4. Github