DEPARTMENT OF APPLIED PHYSICS
UNIVERSITY COLLEGE OF TECHNOLOGY
UNIVERSITY OF CALCUTTA

Regulation for 2 year 4 semester M. Tech. course in Electrical Engineering
w. e. f. the academic year 2021 - 2022

1. Department of Applied Physics, University College of Technology, University of Calcutta shall provide instructions leading towards the 2-year, 4-semester M. Tech. degree in **Electrical Engineering with specializations in I. Smart Grid Systems and II. Advanced Control and Measurement Systems**. The course is of two (2) years duration comprised of four (4) Semesters, each Semester being of six (6) months' duration.
2. A candidate, who has passed the B. Tech./B.E. degree in Electrical Engineering or its equivalent degree from any university or institute approved by All India Council for Technical Education (AICTE), will be eligible to apply for admission to the 4-Semester Master of Technology (M. Tech.) course in **Electrical Engineering** of University of Calcutta. The option for the specialization will be asked from a candidate after the admission to the course.
3. The award of the said M. Tech. Degree in **Electrical Engineering in both specializations** will be conferred to students who are successful in all of the four (4) Semester examinations. End-Semester Examination (ESE) and at least one class test will be held for each theoretical paper in each Semester. End-semester examination will be held for each practical paper in each Semester. The schedule of both theoretical and practical papers and distribution of marks and credit for the said four (4) Semesters are given in course structure.
4. Four (4) lecture hours per week shall be allotted to each theoretical paper of 100 marks and seven (7) practical hours and one (1) tutorial hour per week shall be allotted to practical paper of 100 marks in a laboratory. For Research Methodology and Term Paper leading towards Thesis of 100 marks and Mini Project with Seminar paper of 100 marks, six (6) practical hours and two (2) tutorial hours per week for each paper shall be allotted. For Thesis Phase –I paper of 100 marks, twelve (12) practical hours and four (4) tutorial hours per week shall be allotted. For Thesis Phase – II paper of 100 marks, twenty four (24) practical hours and eight (8) tutorial hours per week shall be allotted.
5. A candidate shall be eligible for appearing at any of the Semester examinations provided, he/she prosecutes a regular course of studies in the Department of Applied Physics maintaining the minimum percentage of attendance as specified by the University.
6. (a) Each theoretical paper of 100 marks shall be comprised of 20 marks for Teacher-Assessment (TA), 10 marks for Class Test (CT) , and 70 marks in End Semester Examination (ESE). TA and CT put together will form the sessional component of the total marks in any theoretical paper.
(b) Teacher-Assessment will be divided ordinarily into three components – attendance, group discussion and performance. Marks for each class test will be awarded by conducting at least one (1) test.
(c) Duration of ESE for each theoretical paper shall be of three (3) hours. For each theoretical paper there shall ordinarily be two (2) internal paper setters. Each theoretical paper shall be examined by the internal examiners.
(d) Each practical paper shall be of 100 marks, out of which 50 marks is assigned for Teacher Assessment (TA) to be assessed by the internal examiner(s) on the basis of performance in the laboratory and records of experiments and 50 marks for ESE. For 50 marks of ESE for each practical paper, an assessment will be made through a representative practical test and viva-voce, which shall ordinarily be made by a board of examiners consisting of at least two (2) members.
7. (a) On the basis of total marks (TA+CT+ESE) secured in each paper, **Grade (G)** and **Grade Point (GP)** shall be awarded to a student.
The equivalence between grades, grade points and the percentage marks is given by:

Percentage (%) of marks	**Grade (G)**	**Grade Point (GP)**
≥ 90	E	10
89 – 80	A	9
79 – 70	B	8
69 – 60	C	7
59 – 50	D	6
< 50	F	0

(b) Each paper shall carry **Credit (C)** according to the number of hours allotted per week and as indicated in the following table:

Paper	No. of hours / week	Credit (C) assigned
Theoretical	1	1
Tutorial	1	0.5*
Practical	1	0.5*

*: For fractional credit, calculation is to be made by rounding off.
(c) In the course structure, the credits assigned to each semester is as follows:

Semester	Credit
1	16
2	20
3	16
4	16
TOTAL	68

(d) In any paper, a candidate securing a grade higher than `F`, that is, Grade Point greater than zero, will be eligible to earn `credit` assigned to that paper. In other words, if a student is unable to secure a grade higher than 'F', that is, grade point greater than zero, he / she fails to earn any 'credit' assigned to that paper.
(e) The performance of a candidate in n^{th} (n = 1,2,3,4) Semester examination, who earns all the credits of that semester, will be assessed by the '**Semester Grade Point Average' (SGPA), 'S_n'** to be computed as:

$$SGPA\,[S_n\,] = \frac{\sum_k [C_k\; GP_k]}{\sum_k C_k}$$

where 'k' denotes the number of papers in a particular semester

and $\sum_k C_k$ denotes the total credits of a particular semester and GP_k is the grade point of k[th] paper.

(f) On completion of the M. Tech. course, the overall performance of a candidate will be assessed by the '**Cumulative Grade Point Average' (CGPA),** to be computed as:

$$CGPA = \frac{\sum_{n=1}^{4} [C_n\; S_n]}{\sum_{n=1}^{4} C_n}$$

where, $C_n = \sum_k c_k$ and $\sum_{n=1}^{4} C_n$ denotes total credits of all the semesters i.e. 68 credits.

8(a) Each candidate shall opt two (2) elective papers of 100 marks each, one in 2[nd] and another in 3[rd] semester, from the list of elective papers to be notified in respective semesters. Such topics of elective papers may be revised from time to time as per recommendation of the Board of PG studies in Applied Physics.

(b) Each candidate shall have to submit a report on Research Methodology and Term Paper leading towards Thesis of 100 marks assigned to him/her under the guidance of a faculty member(s) of the Department during 2[nd] semester examination. He / she has to defend his/her report in an open session. The assessment of this report shall be made by a board of examiners consisting of at least three (3) members.

(c) Each candidate shall have to submit a report on a Mini Project with Seminar work of 100 marks assigned to him/her under the guidance of a faculty member(s) of the Department during 2[nd] semester examination. He / she has to defend his/her seminar report in an open session. The assessment of this report shall be made by a board of examiners consisting of at least three (3) members.

(d) (i) Each candidate shall execute a Thesis assigned to him/her during the 3rd and 4th Semester courses under faculty member(s) of the Department and he/she has to submit a report on the same at least 5 (five) days before the date of examination. The Thesis is divided into two phases. Thesis Phase-I of 100 marks with 12 credit is assigned during 3rd semester while Thesis Phase-II of 100 marks with 16 credit is assigned during 4th semester. The candidate has to present and defend his/her project work in an open session, which shall ordinarily include a panel of internal examiner(s) and at least two (02) external examiners.

Out of the 100 marks assigned to both Thesis Phase-I and Phase-II, 40 marks is earmarked for Sessional work to be assessed by the internal supervisor(s), 60 marks for the presentation of the Thesis and viva voce on the Thesis work. The assessment of the presentation of the Thesis and Thesis viva voce shall be done by a board consisting of at least five (5) examiners of whom ordinarily two (2) shall be external examiners.

(ii) A candidate may also carry out his/her Thesis under joint guidance of faculty member(s) of the Department and a competent person from any industry/academic institution subject to the approval of Departmental Committee. He/she may carry out his/her Thesis Phase-II either in the department or in the concerned industry/academic institute .

9. Candidates appearing in a semester examination shall join classes in the next semester immediately, wherever applicable, after completion of the examination.

10. Candidates of 1[st] to 3[rd] Semester examinations will be allowed to continue in the next semester provided he/she secures at least the following credits respectively and for the 4[th] Semester, he/she has to secure the following credit:

Semester	Minimum Credit to be obtained
1	12
2	16
3	12
4	16

11. A candidate earning less than the credits mentioned in **clause number 10** in any semester will be declared as **'unsuccessful'** candidate in that semester examination. He/she will have to take readmission in the corresponding semester in the next academic session as per CU rules and he/she will be allowed two (2) more such chances to earn the **minimum credit**.

12. (a) The shortfall in credits, being termed as **'due credit'** (the candidate being unsuccessful in one or more papers) of a semester will have to be earned by the candidate by appearing in the said paper(s) at the examination of the corresponding semester in the next academic session and he/she will have two (2) more such chances to earn his/her **due credit** within the maximum allowable duration of 4 years to complete the course**.**

13. (a) For a candidate, who fails to earn all the '**credit**' of a semester but continues to the next semester by virtue of earning minimum credit **(clause number 10),** it is necessary that, total accumulation of shortfall in credit carried by the candidate, must not exceed 16 (sixteen) at any stage, and in such a case **he/she shall not be allowed to continue the course any further.**

(b) In order to complete the M. Tech. course, a candidate will have to utilize all the allowed chances within four (4) years from the date of first admission. A candidate who fails to earn all the credits of the M. Tech. course within the permissible chances **will not be allowed to continue the course any further**.

(c) If a candidate is unable to appear at any of the theory or practical examination(s), he/she will earn zero (0) credit in that paper(s).

14. The CU syndicate shall publish a list of successful candidates of the M. Tech. examination for each of the Semester examinations.

15. At the end of each Semester examination, a Grade-Sheet showing the Semester performance (Semester Grade-Sheet) indicated by **SGPA** will be issued to the successful students only. However, SGPA will not be calculated for those candidates who fail to earn all the credit in that Semester.

The Semester Grade Sheet should have the following basic information:

Paper	Details of course	Full Marks	Marks obtained	Credit	Grade	Grade Point	SGPA	Remarks

16. (a) A consolidated Grade-Sheet, showing the overall performance in the M. Tech course indicated by **CGPA**, will be issued only to those successful students who have earned 68 (sixty eight) credit in the M. Tech. course.

The consolidated Grade-Sheet shall consist of two components. The first component will contain the information of the 4th Semester itself as follows:

Paper	Details of courses	Full Marks	Marks obtained	Credit	Grade	Grade Point	SGPA	Remarks

And the second component will contain a **summary** of all the semesters having the following basic information:

<table>
<tr><td rowspan="3">Semester</td><td rowspan="3">Total credit</td><td rowspan="3">Credit obtained</td><td rowspan="3">Back credit</td><td rowspan="3">SGPA</td><td rowspan="3">Full marks</td><td rowspan="3">Marks obtained</td><td colspan="2">Cumulative statement</td></tr>
<tr><td>Total credit</td><td>68</td></tr>
<tr><td>CGPA</td><td></td></tr>
<tr><td>4</td><td>16</td><td></td><td></td><td></td><td>100</td><td></td><td rowspan="2">Total Full marks</td><td rowspan="2">1300</td></tr>
<tr><td>3</td><td>16</td><td></td><td></td><td></td><td>200</td><td></td></tr>
<tr><td>2</td><td>20</td><td></td><td></td><td></td><td>600</td><td></td><td>Marks obtained</td><td></td></tr>
<tr><td>1</td><td>16</td><td></td><td></td><td></td><td>400</td><td></td><td>Result</td><td>*</td></tr>
</table>

The asterisks (*) in the last row of the last column will contain the information regarding the final achievement of the candidate in all the examinations. This box will contain only one of the following three information:

'1st Class' / '2nd Class' / 'Failed'.

(b) Candidates securing at least 66 (sixty six) percent of the total marks in M. Tech. Examination (total of semester 1 to semester 4 examinations) shall be placed in the 'First Class' and those securing 50 (fifty) percent marks or more but less than 66 (sixty six) percent marks shall be placed in the 'Second Class'. Candidates securing less than 50 (fifty) percent shall be declared 'Failed'.

17. All exclusions of this regulation, if any, the decision will be taken in the Departmental Committee meeting in consultation with the Controller of Examination, University of Calcutta. The decision taken in the DC meeting will only be applicable subject to the approval of Hon'ble Vice-Chancellor.

18. The Degree of **"Master of Technology in Electrical Engineering with specializations in Smart Grid Systems" OR "Master of Technology in Electrical Engineering with specializations in Advanced Control and Measurement Systems"** from the Department of Applied Physics under the seal of the University shall be awarded to a successful candidate mentioning the grade and class he/she has obtained.

Course structure for 2-Year 4-Semester
M.Tech. Degree in Electrical Engineering with Specializations in I. Smart Grid Systems, II. Advanced Control and Measurement Systems

(w. e. f. the academic year 2021 - 2022)

Paper	Subjects		Periods			Evaluation Scheme				Credits
	Specialization I	Specialization II	L	T	P	TA	CT	ESE	TOTAL	
Semester I										
EE901	Fuzzy Logic & ANN		4	-	-	10	20	70	100	4
EE902	Dynamics of Linear Systems		4	-	-	10	20	70	100	4
EE(I)903 / EE(II)903	Smart Grid Architecture	Nonlinear & Optimal Control	4	-	-	10	20	70	100	4
PR(I)904 / PR(II)904	Advanced Power System Lab1	Advanced Control Lab1	-	-	8	50	-	50	100	4
		Semester-I Total	**12**	**-**	**8**	**80**	**60**	**260**	**400**	**16**
Semester II										
EE1001	Embedded Systems		4	-	-	10	20	70	100	4
EE1002	Electric Vehicles		4	-	-	10	20	70	100	4
EE(I)1003 / EE(II)1003	Smart Grid Security and Reliability	Adaptive and Intelligent Control System	4	-	-	10	20	70	100	4
PE(I)1004 / PE(II)1004	Elective-1	Elective-1	4	-	-	10	20	70	100	4
RE1005	Research Methodology and Term Paper leading towards Thesis		-	-	4	50	-	50	100	2
PR1006	Mini Project with Seminar		-	-	4	50	-	50	100	2
		Semester-II Total	**16**	**-**	**8**	**140**	**80**	**380**	**600**	**20**
Semester III										
PE(I)1101 / PE(II)1101	Elective-2	Elective-2	4	-	-	10	20	70	100	4
PR1102	Thesis Phase – I		-	4	12	50	-	50	100	12
		Semester-III Total	**4**	**4**	**12**	**60**	**20**	**120**	**200**	**16**
Semester IV										
PR1201	Thesis Phase – II		-	8	24	50	-	50	100	16
		Semester-IV Total	**-**	**8**	**24**	**50**	**-**	**50**	**100**	**16**
		Grand Total	**32**	**12**	**52**	**330**	**160**	**810**	**1300**	**68**

Elective Papers:

Elective - I: PE1004:

EL11 : Advanced Engineering Mathematics
EL12 : EHVAC, HVDC Transmission
EL13 : Smart Sensors and Advanced Measurement Techniques
EL14 : Advanced Electrical Machines
EL15 : Advanced Electric Drives
EL16 : Sustainable Power Generation and Supply
EL17 : Power System Harmonics, Quality and Reliability
EL18: Condition Monitoring and Predictive maintenance
EL19 : Microwave principles and Measurements
EL110 : Orthogonal Function Domain based Control Approaches

Elective - II: PE1101:

EL21 : Power Electronics in Grid Integration
EL22 : Robotics and Machine Vision
EL23 : Advanced Digital Signal Processing
EL24 : Converters, Storage and FACTs
EL25 : Power Plant instrumentation
EL26 : High Voltage Engineering
EL27 : Power System Analysis
EL28 : Power System Communication and SCADA
EL29 : Advanced Control Techniques
EL210 : Active Circuits and Systems

Semester I

Theoretical Papers:

EE901: Fuzzy Logic & ANN

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Demonstrate the fundamental concepts of fuzzy set theory and ANN.
CO2	Construct the fuzzy inference models as well as applications.
CO3	To study concepts and techniques for ANN algorithms.
CO4	Synthesize the applicability of fuzzy sets and ANN for intelligent system design.

Module1: Fuzzy Sets: Classical sets and fuzzy sets, fuzzy sets and probability, fuzzy numbers, operations and properties, membership functions and its types.
Module2: Fuzzy inference mechanism, fuzzy rule base and reasoning – linguistic variables, concept of approximate reasoning. Engineering examples.
Module3: Artificial Neural Network (ANN): Neuron model – Biological neuron, artificial neuron, activation function, mathematical model.
Module4: ANN architecture – feed-forward network, single layer and multi layer, Learning mechanism in ANN.

References:

1. J M Zurada , "An Introduction to ANN", Jaico Publishing House.
2. Simon Haykins, "Neural Networks", Prentice Hall.
3. Timothy Ross, "Fuzzy Logic with Engg.Applications", McGraw. Hill.
4. Bart Kosko, "Fuzzy Thinking", Flamingo Books.
5. George J. Klir and Bo Yuan, "Fuzzy Sets and Fuzzy Logic: Theory and Applications", Pearson, 1995.
6. Jyh-Shing Roger Jang, Chuen-Tsai. Sun, Eiji Mizutani, "Neuro Fuzzy and Soft Computing", Pearson Education India; 1st edition, 2015.

EE902: Dynamics of Linear Systems

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Remembering the concept of state space and state models
CO2	Analysis of discrete-time systems using state variable technique
CO3	Design of the state observers
CO4	Describe the concepts of Linear-quadratic regulator and Kalman filter

Module1: State space analysis: Concept of state space and state models, state transition matrix for time varying system, similarity transformation, special cases of determining the state transition matrix.
Module2: State-space representation of discrete-time systems, solving the discrete-time state equation.
Module3: Controllability and observability concepts and criterion. Pole placement method, concept of full-order and reduced order state observer, conditions for state observation.
Module4: Linear-quadratic regulator (LQR), linear-quadratic Gaussian (LQG), Kalman filter and its variants.

References:

1. K. Ogata, "Modern Control Engineering" Fifth Edition,. Prentice Hall Inc.
2. Benjamin C. Kuo "Automatic Control Systems" Seventh Edition, PHI
3. K. Ogata, "System-Dynamics" Fourth Edition, Pearson Education, Inc.
4. Norman S. Nise "Control System Engineering" Sixth Edition, John Wiley & Sons, Inc
5. Ogata K., "Discrete-Time Control Systems", Prentice Hall, Englewood Cliffs, N.J.
6. Dorf R C & Bishop R.H.: Modern Control System ; Addison – Wisley
7. Nagrath I. J. and Gopal M., "Control Systems Engineering", Third Edition, New Age Int. Ltd.
8. Madan Gopal, Control Systems , Principles & Application , 2/e ,TMH

EE(I)903: Smart Grid Architecture

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Explain the architecture of smart grid and their basic operations
CO2	Analyse and differentiate the operational aspects of smart grid components and communications
CO3	Estimate and evaluate the various operating conditions with AMI schemes
CO4	Formulate the design aspects of integration of renewable energy resources.

Module1: Introduction – Comparison of Power grid with Smart grid, General View of the Smart Grid Market Drivers, Stakeholders. Functions of Smart Grid Components.
Module2: Smart Grid Communications Protocols: Communication Protocols – RS 232, RS 485, SCADA, ZigBee/PLC, CRC., HAN, NAN, WAN, Smart Meter: need, construction and operation. Advanced metering infrastructure.

Module3: Introduction of renewable energy integration, Demand Side Integration: Need for DSI, Demand Response, Demand side management, Components of DSI, Concept of energy efficient load, consumers participation in DSI.
Module 4: Phasor Measurement Unit (PMU), Smart Meters, Wide area monitoring systems (WAMS).

References:

1. J. Ekanayake, K. Liyanage, J. Wu, A. Yokoyama, N. Jenkins - "Smart Grid Technology and Applications" Wiley publication, 2012
2. James Momoh, "Smart Grid Fundamentals of Design and Analysis" IEEE press, Wiley publication, 2012
3. D.P. Bernardon, V.J.Garcia, Smart Operation for Power Distribution Systems concepts and Applications" Springer Publication
4. Momoh, James A. Smart grid: fundamentals of design and analysis. Vol. 63. John Wiley & Sons, 2012.
5. Gottschalk, Marion, Mathias Uslar, and Christina Delfs. The Use Case and Smart Grid Architecture Model Approach: The IEC 62559-2 Use Case Template and the SGAM Applied in Various Domains. Springer, 2017

EE(II)903: Nonlinear and Optimal Control

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Demonstrate the fundamental concepts of nonlinear dynamical systems and optimal control theory.
CO2	Construct the tools for mathematical analysis as well as applications.
CO3	To study concepts and techniques for stability analysis.
CO4	Synthesize the optimal control design of nonlinear systems.

Module1: Nonlinear system: Methods for analysis and design of nonlinear control systems, linearization, Describing function analysis, stability of limit cycles, Phase plane analysis, singular points.
Module2: Lyapunov stability theorem, Krasovskii's theorem, Lyapunov based design.
Module3: Optimal control: Integral performance index, Euler equation, state function of Pontryagin, basic and general optimal control problem, Pontryagin's maximum principle.
Module4: Time-optimal control/ Bang- Bang control, External control application, Quadratic Performance Index, Parameter optimization problem, Matrix-Ricaati equation.

References:

1. H. K. Khalil, "Nonlinear systems", 3rd edition, Prentice Hall, 2001.
2. J. J. E. Slotine and W. Li, "Applied nonlinear systems", Prentice Hall, 1991.
3. A. Nijemjer and A. van der schaft, "Nonlinear dynamical control systems", Springer, 1989.
4. M. Vidyasagar, "Nonlinear Systems Analysis, Society for Industrial and Applied Mathematics", 2002.
5. S. Strogatz, "Nonlinear Dynamics and Chaos", Westview Press, 2001.
6. M. Athans and P. L. Falb, "Optimal Control: An Introduction to the Theory and Its Applications", Dover Books on Engineering, 2006
7. D. S. Naidu, "Optimal Control Systems", CRC Press, 2002.
8. D. Liberzon, "Calculus Of Variations and Optimal Control Theory: A Concise Introduction", Princeton University Press, Dec 2011.
9. Frank L. Lewis, Draguna Vrabie, Vassilis L. Syrmos, Optimal Control, 3rd Edition, Wiley, 2012.

Practical Papers:

EE(I)904: Adv. Power System Lab

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Understand the various simulation tools related to power system operation, control and design
CO2	Apply the fundamental knowledge to various power system healthy and faulty conditions
CO3	Demonstrate and analyse the development and operation of few control systems to different abnormal conditions
CO4	Synthesize the hardware for power system transients.

List of Experiment
1. Design and simulation of power system faults using RTDS, ETAP/Digsilent/ Matlab
2. Design and simulation of different length of transmission line parameters RTDS, ETAP/ Digsilent/ Matlab
3. Design and simulation of distance protection system using RTDS, ETAP/ Digsilent/ Matlab
4. Design and simulation of FACTs system with RTDS, ETAP/ Digsilent/ Matlab
5. Design and simulation of SPV system interface with power grid RTDS, ETAP/ Digsilent/ Matlab
6. Design and simulation of Hardware-in-loop testing of inverters with the grid RTDS
7. Hardware simulation of 400 kV ac transmission system.
8. 400 kV HVDC transmission system.
9. Test bed operation of microgrid, load flow control of DFIG and PV inverters.

References: Reference manuals for (PSCAD, RSCAD, ETAP, Digsilent, Matlab), SG Test Bed

EE(II)904: Adv. Control Lab

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Model a control system given its parameters.
CO2	Design gains of the controllers like PI,PID in a given control system.
CO3	Design gains of the controllers like State Feedback Controller a given control system.
CO4	Study different practical systems using various control scheme.

List of experiment

1. Design and simulation of Linearised models using a simulation software.
2. Simulation and analysis of State space models for continuous time and discrete time systems using simulation software.
3. Design and Simulation of LTI models of Feedback Control System using simulation software.
4. Simulation and analysis of Digital Control System using simulation software.
5. Simulation and Stability analysis of control system with common non-linearities using simulation software.
6. Design and simulate a PID controller for 2^{nd} order LTI system.
7. Design and simulate a state feedback controller for 2^{nd} order LTI system.
8. Experiment on Position Control System using a Two Link Manipulator test bed.
9. Experiment on Velocity Control System using a DC Servo Motor test bed.
10. Experiment on Temperature Control Systems using a Bend Type Thermal Air Heater System along with disturbances.

Semester II

Theoretical Papers:

EE1001: Embedded Systems and applications

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Explain basic architecture of embedded controllers with features of various embedded peripherals
CO2	Differentiate the constructional and operational features of CPU architecture of embedded controllers
CO3	Develop firmware for various applications using assembly or middleware programming languages
CO4	Design embedded controller systems to solve real world problems

Module 1: General Concepts:
Embedded systems defined; Princeton and Harvard architecture; Peripheral interfaces; Timer and serial communication architecture; synchronous and asynchronous bus protocols; handling of interrupts.
Module 2: 8051 Microcontroller architecture:
8051 functional block diagram, memory map; pin functions; timer and UART operations; interrupts of 8051; introduction to assembly level programming.
Moule 3: PIC microcontrollers:
Pic-16 series microcontrollers: Block diagram, pin functions, memory map; power down modes; Use of digital IO, Timers, interrupt handling, serial interface, ADCs, SPI and I2C bus handling; Introduction to embedded C-programming.

Module 4: Applications of embedded systems:
Interfacing of ADCs, DACs, LEDS, Relays using 8051 and PIC series microcontrollers; microcontroller based DAQ system development; Use of PWM generation for power control, interfacing to wireless transceivers.

Reference Books:

1. Microcontrollers in Practice: M. Mitescu and I. Susnea (Springer)
2. Analog Interfacing to Embedded Microprocessor Systems: Stuart R. Ball
3. The 8051 Microcontroller: 3rd Ed: K. Ayala (Thomson Delmer learning)
4. The 8051 Microcontroller and Embedded Systems Using Assembly and C language: Mazidi, Mazidi & Mckinlay
5. Designing Embedded Systems with PIC Microcontrollers: Principles and applications: Tim Wilmshurst (Newnes)
6. Programming 8-bit PIC Microcontrollers in C: With Interactive Hardware Simulation: Martin P. Bates (Newnes)

EE1002: Electric Vehicles

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Explain the basic operation of Electrical vehicles and environmental issues
CO2	Differentiate the various drive systems along with their power resources
CO3	Conclude about the impact on power system for charging and discharging along with energy management schemes
CO4	Design the aerodynamics and energy consideration with various modeling for EV systems

Module 1: Introduction to Electric Vehicle, Evolution in Electric vehicles, EV architecture, Environmental issues.
Module 2: Electric drives - Electrical machines used in EVs, Power electronics converters and controllers for various motor drives, Drive Controller design.
Module 3: Energy Source and power system - Various types of energy sources for different types of EVs, Battery modelling, Charging and discharging of EVs, impact on power system due to charging and discharging, Energy Management System.

Module 4: EV Modelling- Introduction, Tractive effort, vehicle acceleration modelling, Aerodynamics and energy considerations

References:

1. Larminie, James, and John Lowry, "Electric Vehicle Technology Explained" John Wiley and Sons, 2012
2. Emadi, A. (Ed.), Miller, J., Ehsani, M., "Vehicular Electric Power Systems" Boca Raton, CRC Press, 2003
3. Sheldon S. Williamson, "Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles", Springer, 2013
4. Chris Mi, Abul Masrur& David Wenzhong Gao, "Hybrid electric Vehicle- Principles & Applications with Practical Properties", Wiley, 2011.
5. Iqbal Husain, " Electric and Hybrid Vehicle Design Fundamentals" Boca Raton, CRC Press, 2003

EE(I)1003: Smart Grid Security and Reliability

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Understand and interpret the security and protection system of smart grid
CO2	Assessment of different security and contingent conditions under different running aspects
CO3	Justify the reliability issues of the grid with different stability issues for with grid standards and codes.
CO4	Formulate for assessment of security, generation scheduling, transmission scheduling

Module 1: SG protection system**,** System Security: Definition, Operating limits, Power angle limits, Steady state, dynamic and transient stability, Credible contingencies, contingency Analysis.

Module 2: Security assessment using ac power flow model, Performance Index concept, introduction to System Restoration methods

Module3: Introduction to Grid Standards and Grid Code, System Reliability: States of power system, Difference with stability Transfer Capability, Reliability Margin and assessment.

Module 4: Generation scheduling, transmission scheduling, **L**oad forecasting,

References:

1. Roy Billinton, R.N. Allan, "Reliability Evaluation of Engineering Systems"
2. C. Andersson, "Power System Security Assessment"
3. A. Chakraborty, S. Halder, "Power System Analysis: Operation and Control"
4. Flick, Tony, and Justin Morehouse. Securing the smart grid: next generation power grid security. Elsevier, 2010.
5. Berger, Lars T., and Krzysztof Iniewski. Smart grid applications, communications, and security. John Wiley & Sons, 2012.
6. Momoh, James A. Smart grid: fundamentals of design and analysis. Vol. 63. John Wiley & Sons, 2012.
7. Ekanayake, Janaka B., Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, and Akihiko Yokoyama. Smart grid: technology and applications. John Wiley & Sons, 2012.

EE(II)1003: Adaptive and Intelligent Control

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Demonstrate the fundamental concepts of adaptive control theory.
CO2	Construct the model reference control scheme for linear and nonlinear systems.
CO3	Study concepts of intelligent control approach via fuzzy logic.
CO4	Synthesize the fuzzy control design of nonlinear systems.

Module1: Adaptive control (Classical approach): Adaptive control concept, self-tuning regulator.

Module2: Model reference adaptive control, design of adaptive control law from Lyapunov stability concept.

Module3: Concept of Intelligent Control, Fuzzy Logic Control: Need for fuzzy control, Mamdani and Takagi-Sugeno models, fuzzy PD and fuzzy PI controller design concept, application.

Module4: Adaptive fuzzy controller design from Lyapunov stability concept. Stochastic optimization in fuzzy controller design.

References:

1. H. K. Khalil, "Nonlinear Systems", 3rd edition, Prentice Hall, 2002.
2. S. Sastry and M. Bodson, "Adaptive Control", Prentice-Hall, 1989.
3. K. S. Narendra and A. M. Annaswamy, "Stable Adaptive Systems", Prentice-Hall, 1989.
4. J.J.E. Slotine, and W. Li, "Applied Nonlinear Control", Prentice-Hall, 1991.
5. P. Ioannou& B. Fidan, "Adaptive Control Tutorial", SIAM, Philadelpia, PA, 2006.
6. Karl Johan Astrom & Bjorn Wittenmark, "Adaptive Control", Pearson, 1994.
7. Dimiter Driankov, Hans Hellendoorn, & Michael Reinfrank, "An Introduction to Fuzzy Control", Springer, 1993.
8. Li Xin Wang, "A Course in Fuzzy Systems and Control", Prentice Hall, 1997.
9. Jan Jantzen, "Foundations of Fuzzy Control", John Wiley & Sons, 2007.

PE(I)1004 / PE(II)1004: Elective – I:

Practical Papers:

RE1005: Research Methodology and Term Paper leading towards Thesis

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Understand the general overview of basic methodologies for doing research work.
CO2	Realise the current state of work of the research works based on the allocated thesis work
CO3	Demonstrate the technical aspects of various research works on the basis of allocated thesis work.
CO4	Analyse and design the methodologies to execute the thesis work

References:

1. Nayak, Jayanta Kumar, and Priyanka Singh. Fundamentals of Research Methodology Problems and Prospects. SSDN Publishers & Distributors, 2021.
2. Laplante, Phillip A. Technical Writing: A Practical Guide for Engineers, Scientists, and Nontechnical Professionals. CRC Press, 2018.
3. Basu, B. N. Technical writing. PHI Learning Pvt. Ltd., 2007.

PR1006: Mini Project with Seminar

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Describe the basic realization of the working mini project in details
CO2	Explain the basic techniques associated with the mini project work through seminar presentation
CO3	Elaborate the techniques and working of the project through hardware or simulation as applicable
CO4	Construct the design aspects for betterment through analysis of the results

Semester III

Theoretical Papers:

PE(I)1101 / PE(II)1101: Elective – II

Practical Papers:

PR1102: Thesis Phase – I

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Adopt the techniques to execute the part of the thesis work.
CO2	Design and simulate the part of the thesis work
CO3	Analyse and compare the results obtained through the simulation
CO4	Investigate the associated problems and discover their mitigation techniques

Semester IV

Practical Papers:

PR1201: Thesis Phase – II

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Design and simulate the total part of the thesis work	
CO2	Apply the mitigation techniques to solve the problems of the first part of the thesis work.	
CO3	Justify the results obtained by analyzing and comparing the methods utilised	
CO4	Construct and organize the project work for practical implementation	

Elective Papers - I : PE1004

EL11: Advanced Engineering Mathematics

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Construct the mathematical solution methods for nonlinear differential and integral equations.
CO2	Investigate aspects of Fourier transform.
CO3	Conceptualize the idea of linear algebra.
CO4	Synthesize and plasticize the concept of higher mathematics.

Module1: Nonlinear differential equations: graphical and analytical methods of solutions; Perturbation and variation of parameter methods; Ritz and Galerkin method; Riccati, vander Pol, Duffing.Matheu equations; Approximate solution of integral equations.

Module2: Nonlinear integral equation; Operation research and quality control: Estimation of parameters, testing of hypothesis, decisions; Quality control, acceptance, sampling, non-parametric tests, fitting of straight lines; operational research.

Module3: Fourier Transform: Fourier integrals and its interpretation, Fourier transformation, Frequency spectrum,

Module4: Linear transformation of vector spaces; sum and scalar multiplication, product, polynomial and invertible transformations; matrix representation of linear transformation; Solution of linear equations; Eigen values and eigen vectors, matrix polynomial; Cayley-Hamilton theorem and its application; computation of matrix functions. Canonical representations: Jordan and rational canonical form; bilinear, quadratic and Hermitian forms, positive and negative definite and semi definite form, Sylvester's criteria.

References:

1. Dominic Jordan & Peter Smith, "Nonlinear Ordinary Differential Equations: An Introduction for Scientists and Engineers", Oxford Texts in Applied and Engineering Mathematics, Oxford University Press; 4th edition, 2007.
2. Russell L. Herman, "An Introduction to Fourier Analysis", Chapman and Hall/CRC; 1st edition, 2016.
3. Gilbert Strang, "Introduction to Linear Algebra", Fifth Edition, 2016.

EL12: EHVAC, HVDC Transmission

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Describe EHVAC, HVDC transmission mechanisms, their need and limitations
CO2	Explain the need for adopting compensation schemes
CO3	Explain the stability aspects, the fault occurrence aspects and the necessary protection aspects.
CO4	Design the basic parameters of accessories for EHVAC and HVDC system equipment

Module1: EHVAC Transmission; Choice of working voltage and line length, common operating problems of uncompensated EHVAC transmission lines, Need for compensation.

Module2: Voltage Stability in Power Transmission: Controls and Improvements. Technical problems in EHVAC system,

Module3: HVDC Transmission: Advantages, principles, terminal equipment, necessity of control of a DC link, power reversal of DC link.

Module4: CSC and VSC Transmission. Harmonics and filters, Fault and protection schemes in HVDC systems.

References:

1. Begamudre, Rakosh Das. Extra high voltage AC transmission engineering. New Age International, 2006.
2. Naidu, Motukuru S., and M. KAMARAJU NAIDU. High voltage engineering. Tata McGraw-Hill Education, 2013.
3. Padiyar, K. R. HVDC power transmission systems: technology and system interactions. New Age International, 1990.
4. Eremia, Mircea, Chen-Ching Liu, and Abdel-Aty Edris, eds. Advanced solutions in power systems: HVDC, FACTS, and Artificial Intelligence. John Wiley & Sons, 2016.

EL13: Smart Sensors and Advanced Measurement Techniques

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Describe the necessity of signal conditioning of signals from various sensors
CO2	Explain the schemes for transmission of signals using various standards and protocols
CO3	Analyze the working of various intelligent schemes to adopt smartness in these sensors
CO4	Design advanced measurement systems using sensors for various applications

Module 1: Signal conditioning of sensor signal; noise and interference minimization, shielding and grounding; cabling techniques; plug-in data acquisition boards; Introduction to virtual instrumentation.

Module 2: Intelligent sensors: Features and types; self-adaptive, cogent, self-validating sensors, soft sensors: functional features; linearization of smart sensors; temperature and offset compensation techniques; self and auto-calibration.

Module 3: Communication with smart sensors: IEEE 1451 standards; Bus protocols for RS-422 and RS-485, IEEE 488; energy harvesting strategies.

Module 4: concept of wireless sensor networks; sensor node configurations; interfaces to wireless sensor nodes; different topologies of sensor networks; routing strategies; IEEE 802.15.4 and ZigBee standard; application of sensor network: case studies;

Reference:

1. Practical Data Acquisition for Instrumentation and Control Systems: John Park, Steve Mackay. Elsevier Newnes
2. PC Based Instrumentation Concepts and Practice: M. Mathivanan (PHI)
3. Intelligent Instrumentation, principles and Practice: Manvendra Bhuyan (CRC Press)
4. Understanding smart sensors: Randy Frank (Artech House)
5. Protocols and Architectures for Wireless Sensor Networks-H. Karl, A. Willing (2007, Wiley)

EL14: Advanced Electrical Machines

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Remembering the operating principle of electrical machines	

CO2	Applying the generalized theory of electrical machines	
CO3	Analysis of dynamics of electrical machines	
CO4	Study the stability analysis of electrical machines	

Module 1: Review of conventional electrical machines: Transformer, DC machine, Polyphase induction machine and Synchronous machines.

Module 2 : Generalized theory of electrical machines: Rotational frame; Holonomic and non holonomic reference frame, quasi holonomic reference frame. Impedance matrix, torque matrix, rotational matrix, flux and current density matrices. Modeling and analysis of different electrical machines. Analysis of machines in Clarke, Park and dqo planes.

Module 3: Dynamics of electrical machines: Need for study of machine dynamics. Dynamics of DC machine – open loop and closed loop model and its responses, speed control of separately exited DC motor.

Module 4: Dynamics of synchronous machines – Parallel operation of alternators, swing equation of single machine connected to infinite bus and its stability considerations in light of Lyapunov stability theory.

References:

1. E. Fitzgerald and C. Kingsley, "Electric Machinery", New York, McGraw Hill Education.
2. M. G. Say, "Performance and design of AC machines", CBS Publishers.
3. C.I. Hubert, "Electric Machines: Theory, Operating Applications and Control", Pearson
4. F. Puchstein and T.C. Lloyd, "Alternating Current Machines", John Wiley & Sons, Inc.
5. V. Richardson, "Rotating electric machinery and transformer technology", Prentice-Hall Inc.
6. L. Kosow, "Electric Machinery & Transformers", PHI
7. A.S. Langsdorf, "Alternating current machines", McGraw Hill Education, 1984.
8. G. S. Brosan and J. T. Hayden "Advanced Electrical Power and Machines"

EL15: Advanced Electric Drives

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Describe the basic aspects of DC drive control and operation
CO2	Explain various advanced control mechanisms for AC motor drives
CO3	Analyze the drive controllers for special machines and differentiate them with other drives
CO4	Design the drive to solve real applications

Module 1: Drive Concept: Different machine and load characteristics, four quadrant operation, DC machine speed control: State feedback control and sliding mode control of separately excited dc machine, modeling and control of separately excited dc machine in field weakening region and discontinuous converter conduction mode, control of dc series motor.

Module 2: Induction machine drive: Review of variable frequency operation of three phase symmetrical induction machine, 12 pulse / 18 pulse inverter, scalar control methods (constant volts/Hz and air gap flux control), vector control of induction machine, methods of flux sensing/estimation, PWM control.

Module 3: Traction drives: important features of traction drive, conventional ac and dc drives, diesel electric traction, ac traction, dc traction.

Module 4: Special machines drive: Speed control of BLDC machine, SRM, PMSM, linear induction motor.

References:

1. N. Mohan, "Power Electronics – converters, Application and Design".
2. M. Rashid, "Power Electronics - Circuits, Devices and Applications"
3. G. K. Dube, "Fundamental of Electrical Drive"
4. W. Leonhard, "Control of Electric Drives", Springer Science & Business Media, 2001.
5. P.C. Sen, "Thyristor Dc Drives", John Wiley, NY.
6. B.K. Bose, "Modern Power Electronics and AC Drives", PHI.

EL16: Sustainable Power Generation and Supply

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Understand various sustainable power resources
CO2	Discriminate their basic characteristics
CO3	Explain the operational aspects and development aspects
CO4	Formulate the various generation and operation characteristics

Module 1: Different forms of sustainable power sources**:** Solar, biogas, wind, tidal, geothermal, Basic bio-conversion, Fuel cells, mechanism, mechanism of generation of electricity and their supply to the grid.

Module 2: Wind and tidal energy generation**;** turbine parameters and optimum operation, Ocean thermal energy conversion, Geothermal energy- hot springs and steam injection, power plant based on Wind, Tidal, OTEC and geothermal springs.

Module 3: Energy from the sun: Fundamentals of the technology, increase of efficiency, study of nano-structures, limitation of photo voltaics efficiency.

Module 4: Different Direct energy conversion methods: Fusion energy, Controlled fusion of hydrogen, helium etc. Energy release rates, present status and problems, future possibilities. Intergration aspects of these energies into the grid.

References:

1. Randolph, John, and Gilbert M. Masters. Energy for sustainability: Technology, planning, policy. Island Press, 2008.
2. Khan, B. H. Non-conventional energy resources. Tata McGraw-Hill Education, 2006.
3. Chauhan, D. S. Non-Conventional Energy Resources. New Age International, 2006.
4. Fahrenbruch, Alan, and Richard Bube. Fundamentals of solar cells: photovoltaic solar energy conversion. Elsevier, 2012.

EL17: Power System Harmonics, Quality and Reliability

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Describe about the power system harmonics, quality and reliability
CO2	Analyse the reasons of degradation in quality and resources of harmonics generation
CO3	Discriminate the normal and restructured power system
CO4	Formulate the various disturbances, harmonics and quality issues

Module 1: Power system disturbances: types, definitions, Harmonics: sources, analysis, effects, computation of harmonic flows, reduction of harmonics, passive and active filters, their controls and uses.
Module 2: Power system Quality: Different factors, definitions, measurements techniques, effects on power system operation and control.
Module 3: Power system Restructuring: Need of restructuring, basis of restructuring, Distributed Generation, Co-generation, importance of power quality in restructured environment.
Module 4: Power system reliability: Its necessity, basic principles, different techniques to improve reliability.

References:

1. Arrillaga, Jos, and Neville R. Watson. Power system harmonics. John Wiley & Sons, 2004.
2. Zobaa, Ahmed F., Shady Aleem, and Murat Erhan Balci, eds. Power system harmonics: analysis, effects and mitigation solutions for power quality improvement. BoD–Books on Demand, 2018.
3. Elmakias, David, ed. New computational methods in power system reliability. Vol. 111. Springer Science & Business Media, 2008.
4. Chowdhury, Ali, and Don Koval. Power distribution system reliability: practical methods and applications. Vol. 48. John Wiley & Sons, 2011.

EL18: Condition Monitoring and Predictive maintenance

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Describe the general aspects of condition monitoring techniques
CO2	Explain the condition monitoring schemes adopted for electrical machines
CO3	Analyse different operating conditions for estimation of parameters for predictive and preventive maintenance
CO4	Develop schemes with various AI techniques for CBM and predictive maintenance

Module 1: Condition monitoring and diagnostic engineering: objective, instrumentation and data acquisition systems for vibration, current, voltage, lubrication, temperature of electrical equipment, advanced non-destructive measurements using ultrasonic and eddy current techniques.

Module 2: Condition monitoring of rotating electrical machines: stator, rotor and winding faults, insulation ageing, mechanical faults, bearing faults, shaft alignment faults, crawling in induction motor;

Module 3: Condition monitoring of transformers and high voltage equipment: winding frequency analysis and dissolved gas analysis; discharge monitoring, electrical capacitance tomography, condition-based maintenance (CBM), Predictive and preventive maintenance.

Module 4: Signal processing tools and AI techniques methods condition monitoring: FFT, DWT, HT, current signature analysis for induction machine fault detection; Feature extraction and minimization techniques, pattern classifier applications: Fuzzy logic and Neural network, remaining useful life prediction.

References:

1. Condition Monitoring of Rotating Electrical Machines: P. Tavner (IEE Press)
2. An Introduction to Predictive Maintenance: K. Keith Mobley (Butterworth Heinimann)
3. Induction Motor Fault Diagnosis Approach through Current Signature Analysis: S. Karmakar *et. al.* (Springer)
4. Condition Monitoring and Assessment of Power Transformers Using Computational Intelligence- W. H. Tang Q. H. Wu (Springer-Verlag London)
5. Non destructive testing: B.Hull and V. John (Macmillan Education)

EL19: Microwave principles and Measurements

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Explain the basic operational aspects of microwave generation and its propagation
CO2	Describe communication and measurement schemes using microwave principle
CO3	Explain the working principle of microwave generation and the microwave accessories
CO4	Design some measurement scheme using microwave principle

Module1: Microwave technique of communication; Microwave generator; Klystron, Magnetron, and Travelling wave tube.
Module2: Cavity: Natural modes of oscillation in rectangular and cylindrical cavity, Condition of maximum amplification; Maser and parametric amplifiers.
Module3: Microwave accessories: Antenna Characteristics, Dipole antenna, Radiation pattern, Directivity, Gain, linear Array.
Module4: Microwave measurements, Power, VSWR Impedance, Wave length, Q of resonance cavity, Dielectric constant measurement.

References:

1. The RF and Microwave Handbook, Mike Golio (CRC Press)
2. Electromagnetic Shielding, S. Celozzi, R. Araneo, G. Lovat (Wiley-IEEE Press)
3. Microwave Devices and Circuits, Samuel Y. Liao, Prentice Hall

EL110: Orthogonal Function Domain based Control Approaches

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Demonstrate the fundamental concepts of orthogonal function.
CO2	Analysis of control system via different orthogonal function.
CO3	Study concepts and techniques for stability analysis continuous control systems.
CO4	Synthesize the optimal control design of continuous control systems.

Module1: Piecewise constant orthogonal function; comparison with sine -cosine function, mean squared error; Walsh and block pulse function, operational matrices for integration, differentiation; time scaling.
Module2: Control system analysis in Walsh and block pulse domain, Correlation and convolution.
Module3: Control system identification using block pulse functions.
Module4: Triangular functions, hybrid function concept. Application in control system analysis and controller design.

References:

1. Anish Deb, Gautam Sarkar & Anindita Sengupta, "Triangular Orthogonal Functions for the Analysis of Continuous Time Systems", Anthem Press, First edition, 2011.
2. K B Datta & B M Mohan, "Orthogonal Functions in Systems and Control", World Scientific, 1995.

Elective Papers – II : PE1101

EL21: Power Electronics in Grid Integration

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Understand the basics of power electronics converters with various control strategies
CO2	Analyse grid integration and corresponding stability assessment techniques
CO3	Estimate the grid integration issues with respect to availability of storage and other energy resources
CO4	Formulate different load flow schemes towards contingency studies

Module1: Inverters and converter: Stand alone mode, Parallel mode of operations, Grid interface mode of operation.
Module2: Renewable Energy and Storage, Renewable Energy Resources, Storage Technologies, Grid integration issues of renewable energy sources, Induction Generators /other special machines.
Module3: Stability Analysis Tools for Smart Grid: Voltage Stability Assessment Techniques, angle stability assessment in smart grid, approach of smart grid to State Estimation, Energy management in smart grid.
Module 4: Different Load flow techniques for smart grid design, contingencies studies for smart grid.

References:

1. Yazdani, Amirnaser, and Reza Iravani. Voltage-sourced converters in power systems. Vol. 39. Hoboken, NJ, USA: John Wiley & Sons, 2010.
2. Bose, Bimal K. "Power electronics and AC drives." Englewood Cliffs (1986).
3. Luo, Fang Lin, and Ye Hong. Renewable energy systems: advanced conversion technologies and applications. Crc Press, 2017.
4. Zhong, Qing-Chang, and Tomas Hornik. Control of power inverters in renewable energy and smart grid integration. Vol. 97. John Wiley & Sons, 2012.

EL22: Robotics and Machine Vision

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Construct the mathematical methods for modeling and control of robotic manipulator.
CO2	Investigate and scrutinize the Mobile Robots and its control aspects.
CO3	Employ the concept of image processing.
CO4	Synthesize the machine vision concept using image processing.

Module1: Introduction to Robotics: Industrial Manipulator, Robot arm kinematics and dynamics, planning of manipulator trajectory, Elementary steps for robot arm design. Control of robot arm, Force and Impedance Control. Mobile Robot:
Module2: Wheeled and legged robots, trajectory planning, locomotion, SLAM.
Module3: Machine Vision and Visual feedback: Image Segmentation and description, Image segmentation and description of 3D structure, Recognition.

Module4: Vision based autonomous operation of industrial manipulators and walking robots (path and locomotion planning).

References:

1. Mark W. Spong, Seth Huchinson and M. Vidyasagar, "Robot Modeling and Control", John Wiley and Sons, Inc., 2005.
2. John J. Craig, “Introduction to Robotics: Mechanics & Control”, 3rd Edition, Prentice Hall, 2004.
3. Richard Murray, A. Lee, S. Sastry, “A Mathematical Introduction to Robotic Manipulation”, CRC Press, 1994.
4. Rafael Gonzalez & Richard Woods, “Digital Image Processing”, Pearson, 2017.
5. Rafael Gonzalez, Richard Woods & Steven L. Eddins, “Digital Image Processing using MATLAB”, Pearson, 2017.
6. Ramesh Jain, Rangachar Kasturi, Brian G. Schunck, “Machine Vision”, McGraw-Hill, 1995.
7. Milan Sonka, Vaclav Hlavac & Roger Boyle, “Image Processing, Analysis, and Machine Vision”, Cengage Learning, 2015.

EL23: Advanced Digital Signal Processing

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Describe the transformation schemes for continuous signal into discrete time signal
CO2	Explain the working of optimal and adaptive filters in discrete domain
CO3	Analyse processed signal with component analysis and signal decomposition techniques
CO4	Design advanced DSP system to solve real world problems

Module1: Discrete time signals in transform domain; Z transform; correlation, convolution and spectral methods, Discrete Fourier Transform (DFT), IIR and FIR filters.

Module2: Optimal and Adaptive filters; Wiener filter; Time-frequency analysis: Wavelet transform;

Module3: Multivariate signal processing: Principal component and independent component analysis

Module4: Signal decomposition techniques: empirical mode decomposition; Applications of DSP in fault detection, data compression.

References:

1. DIGITAL FILTERS: Principles and Applications with MATLAB: Fred J. Taylor (IEEE Press)
2. Digital Signal Processing - Computer Based Approach - Sanjit K. Mitra (Mc Graw Hill)
3. Scientist and Engineer's Guide to Digital Signal Processing- Steven W. Smith (California Publishing)
4. Digital Signal Processing: Principles, Algorithms and Applications: John G. Proakis, Dimitris K Manolakis (Prentice Hall)

EL24: Converters, Storage and FACTs

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Understand basics of operation of converters, storage and FACTs devices
CO2	Analyse the synchronization aspects in various control frames of VSC system for autonomous operation
CO3	Estimate the various storage requirements by analyzing their individual characteristics
CO4	Formulate the design aspects in respects of Converters’ synchronization and storage and FACTs controllers

Module1: Converters: Introduction to voltage source inverters, analysis of 1-phase, square - wave voltage Source inverter, 3-phase voltage source inverter with square wave output, 3-phase pulse width modulated (PWM) inverter. Sine PWM and its realization, other popular PWM techniques. Current source inverter Load-commutated current source inverter.

Module2: Synchronization with grid: Grid-Imposed Frequency VSC System; Structure of Grid-Imposed Frequency VSC System, control in α - β- frame; control in d - q- frame; Phase-Locked Loop (PLL); real and reactive power control. Controlled-Frequency VSC System, voltage control, autonomous operation.

Module3: Storage: Introduction to energy storage for power systems: Role of energy storage systems, applications. Overview of energy storage technologies: Thermal, Mechanical, Chemical, Electrochemical, Electrical. Efficiency of energy storage systems. Electrical energy storage: Batteries, Super capacitors, Superconducting Magnetic Energy Storage (SMES), charging methodologies, SoC, SoH estimation techniques.

Module4: FACTS: Definition, concepts, classification, Types of Compensation. Static Shunt Compensators, Static Series Compensators, Static Voltage and Phase angle Regulator, UPFC, IPFC.

References:

1. Yazdani, Amirnaser, and Reza Iravani. Voltage-sourced converters in power systems. Vol. 39. Hoboken, NJ, USA: John Wiley & Sons, 2010.
2. Bose, Bimal K. "Power electronics and AC drives." Englewood Cliffs (1986).
3. A.G.Ter-Gazarian, “Energy Storage for Power Systems”, Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN - 978-1-84919-219-4), 2011.
4. Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt,” Energy Storage in Power Systems” Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016.
5. A. R. Pendse, “Energy Storage Science and Technology”, SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN - 13:9789380090122), 2011.

6. Hingorani, Narain G., and Laszlo Gyugyi. Understanding FACTS: concepts and technology of flexible AC transmission systems. IEEE press, 2000.

EL25: Power Plant instrumentation

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Describe the required instrumentation in a power plant operation with flow diagram
CO2	Explain the working of instrumentations for application specific measurement and control
CO3	Explain the working of the communication system required for centralized measurement and control
CO4	Analyse the working of DCS system along with its all accessories, HMI and FCS

Module 1: Power plant process flow diagram; important components; steam and water circuits; Fuel, air and Flue gas circuits;
Module 2: Condensate section PI diagram and instrumentation scheme; Coal section instrumentation; Burner management systems; outlet temperature control;
Module 3: Boiler Drum instrumentation; Boiler feedwater control and instrumentation scheme; steam temperature control; pollution control; equipment for nuclear reactor control and instrumentation.
Module 4: SCADA system; DCS based power plant control: configuration of DCS, components, FCS, layout of operator interface, MIMIC diagrams.

References:
1. Power Plant Engineering: A.K. Raja, A.P. Srivastava and M. Dwivedi (New Age International)
2. Power-plant control and instrumentation: The control of boilers and HRSG systems: David Lindsley (IEE Press)
3. Maintenance of Process Instrumentation in Nuclear Power Plants: H. M. Hashemian (Springer)
4. Power Plant Engineering: Black and Veatch (Springer)

EL26: High Voltage Engineering

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Understand the effects of high voltage through partial discharge and breakdown of insulators
CO2	Analyse the electric field distribution
CO3	Illustrate the measurement principles for measuring equipment for high voltage systems
CO4	Organize the microprocessor based measuring techniques for surge currents and voltages

Module 1: Different types of breakdown in solid and liquids, Partial discharge and its measurement techniques. Basic Equations of Electric field analysis.
Module 2: Electric Field Analysis by Finite Difference Method – in 2D and Axi-Symmetric Systems with equal and unequal nodal distances,
Module 3: Measurement of High Voltages, Electrostatic Voltmeters, Compensated ac and impulse peak voltmeters, Different types of voltage dividers and their characteristics.
Module 4: Surge current and voltage recorders, Surge crest ammeter and Klydanograph. High Voltage Schering Bridge. Microprocessor based measurement techniques.

References:
1. K.R.Padiyar, “HVDC Power Transmission Systems”, New Age International Publishers, 2011.
2. J.Arrillaga, “High Voltage Direct Current Transmission”, Peter Peregrinus Ltd., 1983.
3. M.S.Naidu and V. Kamaraju, “High Voltage Engineering”, McGraw Hill Education, 2013.
4. C.L.Wadhwa, “High Voltage Engineering”, New Age International Publishers, 2007.
5. Kuffel, John, and Peter Kuffel. High voltage engineering fundamentals. Elsevier, 2000.
6. Ryan, Hugh McLaren, ed. High voltage engineering and testing. No. 32. Iet, 2001.

EL27: Power System Analysis

Course Outcomes:
At the end of this course, students will demonstrate the ability to

CO1	Explain and interpret different kinds of the fault currents.
CO2	Analyse the characteristics of transmission lines with smith chart aspects
CO3	Differentiate various operating conditions with demands and power flow measurements
CO4	Synthesis the power system design aspects for healthy and faulty conditions with variable tariff structure.

Module 1: Symmetrical fault: fault current calculations using computer in n-bus system, Asymmetrical fault: introduction to symmetrical components, sequence networks for generators, transformer and transmission line, Computer aided calculations; Application of fault analysis in power system co-ordination.
Module 2: Reflection in transmission line: reflection co-efficient, standing wave and traveling wave, standing wave ratio Smith transmission line chart: its origin and applications.
Module 3: Power system Tariff: its need and structure, Availability Based Tariff (ABT), its background, need, basic principle, areas of use and achievements in restructured power system.

Module 4: Power system measurement: energy: active, reactive and apparent, Demand and maximum demand, trivector meter, digital metering, SMART Metering.

References:

1. Saadat, Hadi. Power system analysis. Vol. 2. McGraw-hill, 1999.
2. Grainger, John J. Power system analysis. McGraw-Hill, 1999.
3. Glover, J. Duncan, Mulukutla S. Sarma, and Thomas Overbye. Power system analysis & design, SI version. Cengage Learning, 2012.
4. Anderson, Paul M., and Aziz A. Fouad. Power system control and stability. John Wiley & Sons, 2008.
5. J. Arrillaga, and C. P. Arnold. Computer Analysis of Power Systems. John Wiley & Sons, 1990.
6. Watson, Neville, Jos Arrillaga, and J. Arrillaga. Power systems electromagnetic transients simulation. Vol. 39. Iet, 2003.
7. Stevenson Jr, William, and John Grainger. Power system analysis. McGraw-Hill Education, 1994.

EL28: Power System Communication and SCADA

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Understand the various communication standard related to modern power system
CO2	Interpret SCADA communication in power system automation
CO3	Analyse and compare various network topology used in smart distribution system
CO4	Evaluate and organize SCADA application in plant and power system automation

Module 1: Power System communication: Evolution of power system communication, Power line communication, Optical Fiber Communication, Computer Communication Technology: Types Of Communication Interface, Types Of Networking Channels, Parallel and serial communication Interface, Communication Mode,

Module 2: Synchronization And Timing In Communication, Standard Interface, Software Protocol, ASCII Protocol, HART Protocol, Manufacturer Specific Protocol, Network Topology, Open System Interconnection (OSI) Network Model,

Module 3: Device Bus and Process Bus Network, Controller Area Network (CAN), Device net, Control net, Ethernet, Proprietory Network, Smart Distributed System.

Module 4: Distributed Control System, Supervisory Control and SCADA systems: server-client and server-server communication, SCADA application in plant automation and power system.

References:

1. Mini S. Thomas, Power System SCADA and Smart Grids
2. Tanenbaum, Computer Networks
3. E. Kabalci, Y. Kabalci, Smart Grid and Their Communication Systems

EL29: Advanced Control Techniques

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Construct the mathematical methods for tuning the controller.
CO2	Investigate the MIMO systems and its control aspects.
CO3	Employ the concept of adaptive control for tackling the nonlinearities, uncertainties and external disturbances.
CO4	Synthesize and conceptualize the idea of Kalman filter and its applications.

Module1: Idea of 'good control', Controller performance index, Different tuning methods and their comparative study, Advanced tuning techniques.

Module2: Idea of MIMO systems, Tuning of MIMO systems, Relative gain array, Optimizing control. Special control techniques- Selective control, Override control, Limit control, Idea of Statistical process control. Self-tuning control-Deterministic self-tuning regulators, Stochastic and predictive self-tuning regulators.

Module3: Adaptive control- what is adaptive control, properties of adaptive systems, stochastic adaptive control, auto-tuning, gain scheduling.

Module4: Kalman Filter, Square root Kalman filter. Non-linear system optimization, Gradient optimization techniques, steepest ascent and decent in parameter plane.

References:

1. H. K. Khalil, "Nonlinear Systems", 3rd edition, Prentice Hall, 2002.
2. S. Sastry and M. Bodson, "Adaptive Control", Prentice-Hall, 1989.
3. K. S. Narendra and A. M. Annaswamy, "Stable Adaptive Systems", Prentice-Hall, 1989.
4. J.J.E. Slotine, and W. Li, "Applied Nonlinear Control", Prentice-Hall, 1991.
5. P. Ioannou& B. Fidan, "Adaptive Control Tutorial", SIAM, Philadelpia, PA, 2006.
6. Karl Johan Astrom & Bjorn Wittenmark, "Adaptive Control", Pearson, 1994.

EL210: Active Circuits and Systems

Course Outcomes:

At the end of this course, students will demonstrate the ability to

CO1	Describe various types of active circuits and active systems
CO2	Explain the operational insights of timing and counting circuits for various schemes
CO3	Analyse the linearity and non-linearity aspects of active circuits and systems

CO4	Design various parameters of active circuits for various filter development

Module1: Special operational amplifiers: high voltage/high current, chopper and chopper stabilized amplifiers, instrumentation amplifier, isolation amplifier.

Module2: Nonlinear function circuits: limiter, log/anti-log, multiplier/divider, peak detector, comparator, true RMS/DC converter, square wave oscillators.

Module3: Timing and counting circuits: digital counters, shift register, analog and digital timers, frequency counters. Sinusoidal and relaxation oscillators: phase shift, ring, Wien-bridge, tuned, quadrature oscillator, crystal oscillator and clock circuits, voltage controlled oscillators – sine, square and triangle, frequency synthesizers. Frequency-to-voltage converters: Diode pump integrator, frequency and RPM transducers. Phase and phase /frequency comparators – analog and digital.

Module4: Active filters: types, filter approximations – Butterworth and chebyshev, filter realisations, frequency and impedance scaling, filter transformations, sensitivity, switched capacitor circuit

References:

1. David Johns & Kenneth Martin, “Analog Integrated Circuit Design”, John Wiley & Sons, 1996.
2. Meyer Gray, Hurst & Lewis, “Analysis and Design of Analog Integrated Circuits”, Wiley; 5th edition, 2009.
3. Millman & Halkias, “Electronic Devices and Circuits”, McGraw Hill Education 1967.
4. S.A. Pactitis, “Active Filters: Theory and Design”, CRC Press, 2019.