## INSTITUTE VISION

To be a preferred institution in Engineering Education by achieving excellence in teaching and research and to remain as a source of pride for its commitment to holistic development of individual and society.

## INSTITUTE MISSION

To continuously strive for the overall development of students, educating them in a state-of-the-art-infrastructure, by retaining the best practices, people and inspire them to imbibe real time problem solving skills, leadership qualities, human values and societal commitments, so that they emerge as competent professionals.

## DEPARTMENT VISION

To be the centre of excellence in teaching and learning to produce the competent & socially responsible professionals in the domain of Electrical & Electronics Engineering.

## DEPARTMENT MISSION

To educate students with core knowledge of Electrical and Electronics Engineering by developing problem solving skills, professional skills and social awareness to excel in their career.

## PROGRAM EDUCATIONAL OBJECTIVES (PEO's) :

**Graduates of the program will be able to**

**PEO1:** Possess successful career in Electrical Sciences & apply the knowledge of Mathematics & Engineering fundamentals to analyze & formulate the solution to solve real time problems.

**PEO2:** Excel in Academics, Industry, Entrepreneurship, Administrative Services through lifelong learning.

**PEO3:** Exhibit professional & ethical values, effective communication skills, teamwork, multidisciplinary approach & realize engineering issues in broader social context.

## PROGRAM OUTCOMES (PO's) :

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## PROGRAM SPECIFIC OUTCOMES (PSO's) :

**Graduates will be able to**

**PSO1:** Apply knowledge & competencies to analyze & design Electrical & Electronics Circuits, Controls and Power Systems, Machines & Industrial Drives.

**PSO2:** Use Software/Hardware tools for the design, simulation and analysis of Electrical and Electronics Systems.

## Contents of III-SEM

## 1.0 Student Help Desk

| Sl. No | Coordination Work | Contact Person | |
|---|---|---|---|
| | | Faculty | Instructor |
| 01 | Attestations | Dr. B. V. Madiggond | -- |
| 02 | Exam forms signature, Overall department administration, Counseling/interaction with Parents/Students. | | |
| 03 | Research Centre Coordinator, Academic Coordinator | | |
| 04 | EMS , IEEE, ISTE, Alumni and Website Coordinator | Prof. S. G. Huddar | -- |
| 05 | IA , Internship & IIIC , Hobby Project Coordinator & SC&ST cell Convener | Prof. K. B. Negalur | Shri. S. B. Beelur |
| 06 | EESSA Coordinator | Prof. H. R. Zinage, Prof. O. B. Heddurshetti | -- |
| 07 | Dept. NBA Coordinator, KSCST & Project Coordinator | Prof. M. P. Yanagimath | -- |
| 08 | AICTE/VTU, NIRF, Press Report, News letter Coordinator, Notice Board Coordinator. | Prof. S. S. Birade | Shri. R. S. Bardol |
| 09 | T&P Cell, RoboVidya, GATE Coaching Coordinator, Technical magazine & OBC cell Convener | Prof. P. M. Murari | -- |
| 10 | Library Coordinator | Prof. S. S. Birade | Shri. S. B. Beelur |
| 11 | Dept. Meeting Coordinator, Mentorship Coordinator | Prof. A. U. Neshti | -- |
| 12 | 1st Year Coordinator, Chief Alumni Coordinator | Prof. O. B. Heddurshetti | -- |
| 13 | Dispensary | Dr. Arun G. Bullannavar, Contact No. 9449141549 | |
| **Class Teacher** | | | |
| 14 | 3rd Semester | Prof. P. M. Murari | Shri. S. B. Beelur |
| 15 | 5th Semester | Prof. H. R. Zinage | Shri. V. M. Mutalik |
| 16 | 7th Semester | Prof. M. P. Yanagimath | Shri. R. S. Bardol |

## 2.0 Departmental Resources

Department of Electrical and Electronics Engineering was established in the year 1996 and is housed in a total area of **1339 Sq. Mtrs.**

## 2.1 Faculty Position

| S.N. | Category | No. in position | Average experience |
|---|---|---|---|
| 1 | Teaching faculty | 11 | 14.6 Y |
| 2 | Technical supporting staff | 3 | 23 Y |
| 3 | Helper | 2 | 17 Y |

## 2.2 Major Laboratories

| SL. No. | Name of the laboratory | Area in Sq. Mtrs | Amount Invested (Rs) |
|---|---|---|---|
| 01 | Electronics Lab | 71 | 592669.00 |
| 02 | Operational Amplifier & Linear Integrated Lab | | 119042.00 |
| 03 | Power Electronics Lab | 92 | 781250.00 |
| 04 | Control Systems Lab | | 212755.00 |
| 05 | Power System Simulation Lab | 71 | 1188401.00 |
| 06 | Computer Aided Electrical Drawing Lab | | 650988.43 |
| 07 | Microcontroller Lab / Digital Signal Processing Lab | 72 | 593152.00 |
| 09 | Electrical Machines Lab | 200 | 1463682.00 |
| 10 | Relay & High Voltage Lab | 94 | 1169848.00 |
| 11 | Basic Electrical Engg. Lab | 96 | 38970.00 |
| | **Total** | **696** | **6810757.43** |

## 3.0 Faculty Details

| S.N. | Faculty Name | Designation | Qualification | Area of specialization | Professional membership | Industry Experience (in years) | Teaching Experience (in years) | Contact Nos. |
|---|---|---|---|---|---|---|---|---|
| 01 | Dr. B. V. Madiggond | HOD/Prof. | Ph. D | Power Electronics | LMISTE, YHAI | - | 27 | 9343454993 |
| 02 | Prof. V. B. Dhere | Asst. Prof. | M. Tech, (Ph. D) | Electronics & Telecommunication | LMISTE, IMPARC | 4 | 23 | 9886597573 |
| 03 | Prof. S. D. Hirekodi | Asst. Prof. | M. Tech. | Power Electronics | LMISTE | 1 | 20 | 9480849338 |
| 04 | Prof. H. R. Zinage | Asst. Prof. | M. Tech. | Power System | LMISTE | - | 20 | 9480849335 |
| 05 | Prof. M. P. Yanagimath | Asst. Prof. | M. Tech (Ph. D) | VLSI & ES | LMISTE | 1 | 14.5 | 9341449466 |
| 06 | Prof. O. B. Heddurshetti | Asst. Prof. | M. Tech. | Power Electrics | LMISTE | 1 | 13 | 9448420509 |
| 07 | Prof. A. U. Neshti | Asst. Prof. | M. Tech. | Digital Electronics | ISTE | - | 12 | 9538223362 |
| 08 | Prof. P. M. Murari | Asst. Prof. | M. Tech. | PS & PE | LMISTE | - | 09 | 9739733001 |
| 09 | Prof. S. S. Birade | Asst. Prof. | M. Tech. | VLSI Design & ES | LMISTE | - | 08 | 9945105480 |
| 10 | Prof. K. B. Neglur | Asst. Prof. | M. Tech. | Industrial Electronics | LMISTE | - | 07 | 9886644507 |
| 11 | Prof. S. G. Huddar | Asst. Prof. | M. Tech. | Power System Engg. | LMISTE | - | 07 | 9742066852 |

# 4.0 Institute Academic Calendar

S J P N Trust's
**Hirasugar Institute of Technology, Nidasoshi.**
*Inculcating Values, Promoting Prosperity*
Approved by AICTE, Recognized by Govt. of Karnataka and Affiliated to VTU Belagavi.
Recognized Under Section 2(f) of UGC Act, 1956.
Accredited at ' A' Grade by NAAC, Programmes Accredited by NBA: CSE, ECE, EEE & ME.

IQAC | File I-11 | 2020-21 (Odd) | Rev: 00

**CALENDAR OF EVENTS FOR THE ACADEMIC YEAR 2020-21 (Odd)**

| Date | Events |
|---|---|
| 01-09-2020 | Commencement of III/V/VII Semester Classes |
| 05-09-2020 | Teacher's Day |
| 15-09-2020 | Engineer's Day |
| 02-10-2020 | Gandhi Jayanthi |
| 05-10-2020 to 07-10-2020 | First Internal Assessment for III/V/VII Semester |
| 08-10-2020 | Feedback-I on Teaching-Learning |
| 10-10-2020 | Display of 1st Internal Assessment Marks and Submission of Feedback-I to office. |
| 10-10-2020 | Indoor games/ Health Checkup Camp |
| 17-10-2020 | Blood Donation Camp |
| 27-10-2020 | EDP Activities |
| 01-11-2020 | Kannada Rajyotsava & Commencement of I Semester & Induction Program (Phase - I) |
| 11-11-2020 to 13-11-2020 | Second Internal Assessment for III/V/VII Semester |
| 19-11-2020 | Feedback-II on Teaching-Learning |
| 21-11-2020 | HSIT Quest-2020<br>Display of 2nd Internal Assessment Marks and Submission of Feedback-II to office. |
| 10-12-2020 to 12-12-2020 | Third Internal Assessment for III/V/VII Semester<br>First Internal Assessment for I Semester |
| 14-12-2020 to 16-12-2020 | Lab Internal Assessment of III/V/VII Semester |
| 16-12-2020 | Display of final Internal Assessment Marks |
| 17-12-2020 | Last Working Day of III/V/VII Semester |
| 21-12-2020 to 31-12-2020 | Practical Examination of III/V/VII Semester |
| 04-01-2021 to 23-01-2021 | Theory Examination of III/V/VII Semester |

September-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | | | |

17- Mahalaya Amavasye

October-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |

2-Gandhi Jayanthi
25-Ayudha Pooja
26-Vijayadashami
30-Eid Milad

November-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

14- Narak Chaturdashi,
16-Balipadyami, Deepawali

December-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | 31 | | |

3-Kanakadas Jayanthi, 25-Christmas

January-2021

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | 1 | 2 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |

26-Republic Day

28/8/2020
Dr. B. V. Madiggond
**IQAC Co-ordinator**

28/8/20
Dr. S. C. Kamate
**Principal**

# 5.0 Department Academic Calendar

S J P N Trust's
Hirasugar Institute of Technology, Nidasoshi.
*Inculcating Values, Promoting Prosperity*
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Accredited at ' A' Grade by NAAC, Programmes Accredited by NBA: CSE, ECE, EEE & ME.

E&E Engg. Dept | COE | 2020-21 (Odd) | Rev: 00

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
## CALENDAR OF EVENTS FOR THE ACADEMIC YEAR 2020-21 (Odd)

| Date | Events |
|---|---|
| 01-09-2020 | Commencement of III/V/VII Semester Classes |
| 05-09-2020 | Teacher's Day |
| 15-09-2020 | Engineer's Day |
| 18-09-2020 | Webinar |
| 28-09-2020 | Submission of 1st Assignment |
| 02-10-2020 | Gandhi Jayanthi |
| 05-10-2020 to 07-10-2020 | First Internal Assessment for III/V/VII Semester |
| 08-10-2020 | Feedback-I on Teaching-Learning |
| 08-10-2020 | AICTE Activity Point Programme |
| 09-10-2020 | Inauguration of EESSA Activities for AY 2020-21, Welcome function to 3rd Sem Students and Guest Lecture by Alumni |
| 10-10-2020 | Display of 1st Internal Assessment Marks and Submission of Feedback-I to office. |
| 10-10-2020 | Indoor games/ Health Checkup Camp |
| 15-10-2020 | AICTE Activity Point Programme |
| 17-10-2020 | Blood Donation Camp |
| 19-10-2020 | Submission of 2nd Assignment |
| 22-10-2020 | AICTE Activity Point Programme |
| 23-10-2020 | Establishing MoU with Industry/organization |
| 27-10-2020 | EDP Activities |
| 29-10-2020 | AICTE Activity Point Programme |
| 01-11-2020 | Kannada Rajyotsava & Commencement of I Semester & Induction Program (Phase - I) |
| 02-11-2020 | Submission of 3rd Assignment |
| 04-11-2020 to 07-11-2020 | Four days workshop on "PLC and Industrial Automation/MATLAB and Simulink/PCB Designing/ AutoCAD/Transformer Design/Python." |
| 11-11-2020 to 13-11-2020 | Second Internal Assessment for III/V/VII Semester |
| 19-11-2020 | Feedback-II on Teaching-Learning |
| 19-11-2020 | AICTE Activity Point Programme |
| 21-11-2020 | HSIT Quest-2020<br>Display of 2nd Internal Assessment Marks and Submission of Feedback-II to office. |
| 23-11-2020 | Submission of 4th Assignment |
| 26-11-2020 | AICTE Activity Point Programme |
| 27-11-2020 | Mock Press |
| 04-12-2020 | Technical Seminar by industry expert |
| 07-12-2020 | Submission of 5th Assignment |
| 10-12-2020 to 12-12-2020 | Third Internal Assessment for III/V/VII Semester<br>First Internal Assessment for I Semester |
| 14-12-2020 to 16-12-2020 | Lab Internal Assessment of III/V/VII Semester |
| 16-12-2020 | Display of final Internal Assessment Marks |
| 17-12-2020 | Last Working Day of III/V/VII Semester |
| 21-12-2020 to 31-12-2020 | Practical Examination of III/V/VII Semester |
| 04-01-2021 to 23-01-2021 | Theory Examination of III/V/VII Semester |

September-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | | | |

17- Mahalaya Amavasye

October-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |

2-Gandhi Jayanthi,
25-Ayudha Pooja
26-Vijayadashami
30-Eid Milad
31-Valmiki Jayanthi

November-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

14- Narak Chaturdashi,
16-Balipadyami, Deepawali

December-2020

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | 31 | | |

3-Kanakadas Jayanthi, 25-Christmas

January-2021

| S | M | T | W | T | F | S |
|---|---|---|---|---|---|---|
| | | | | | 1 | 2 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |

26-Republic Day

Academic Coordinator | HOD | Principal 29/9/20.

## 5.1 Scheme of Teaching & Examination

**VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI**
**Scheme of Teaching and Examination 2017-2018**
**Choice Based Credit System (CBCS)**

**VII SEMESTER**

| Sl. No | Course Code | Title | Teaching Department | Teaching Hours /Week | | Examination | | | | Credit |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | Practical/ Drawing | Duration in hours | SEE Marks | CIE Marks | Total Marks | |
| 1 | 17EE71 | Power System Analysis – 2(Core) | EEE | 04 | | 03 | 60 | 40 | 100 | 4 |
| 2 | 17EE72 | Power System Protection (Core) | EEE | 04 | | 03 | 60 | 40 | 100 | 4 |
| 3 | 17EE73 | High Voltage Engineering (Core) | EEE | 04 | | 03 | 60 | 40 | 100 | 4 |
| 4 | 17EE74X | Professional Elective – III | EEE | 03 | | 03 | 60 | 40 | 100 | 3 |
| 5 | 17EE75Y | Professional Elective – IV | EEE | 03 | | 03 | 60 | 40 | 100 | 3 |
| 6 | 17EEL76 | Power system Simulation Laboratory | EEE | 01-Hour Instruction 02-Hour Practical | | 03 | 60 | 40 | 100 | 2 |
| 7 | 17EEL77 | Rely and High Voltage Laboratory | EEE | 01-Hour Instruction 02-Hour Practical | | 03 | 60 | 40 | 100 | 2 |
| 8 | 17EEP78 | Project Work Phase–I + Project work Seminar | EEE | | 03 | -- | -- | 100 | 100 | 2 |
| **TOTAL** | | | | **Theory:18 hours Practical and Project: 09 hours** | | **21** | **420** | **380** | **800** | **24** |

| Professional Elective-3 | | Professional Elective-4 | |
|---|---|---|---|
| 17EE741 | Advanced Control Systems | 17EE751 | FACTs and HVDC Transmission |
| 17EE742 | Utilization of Electrical Power | 17EE752 | Testing and Commissioning of Power System Apparatus |
| 17EE743 | Carbon Capture and Storage | 17EE753 | Spacecraft Power Technologies |
| 17EE744 | Power System Planning | 17EE754 | Industrial Heating |

**1. Project Phase – I and Project Seminar:** Comprises of Literature Survey, Problem identification, Objectives and Methodology. CIE marks shall be based on the report covering Literature Survey, Problem identification, Objectives and Methodology and Seminar presentation skill.

| **Subject Title** | **POWER SYSTEM ANALYSIS -2** | | |
|---|---|---|---|
| **Subject Code** | 17EE71 | **CIE Marks** | 40 |
| **Number of Lecture Hrs / Week** | 04 | **SEE Marks** | 60 |
| **Total Number of Lecture Hrs** | 50 | **Exam Hours** | 03 |

| **FACULTY DETAILS:** | | |
|---|---|---|
| **Name:** Prof. Hemalata R Zinage | **Designation:** Asst. Professor | **Experience:**20 |
| **No. of times course taught:-01** | | **Specialization:** Power System |

## 1.0 Prerequisite Subjects:

| Sl. No | Branch | Semester | Subject |
|---|---|---|---|
| 01 | Electrical and Electronics Engineering | I/II | Basic Electrical Engineering |
| 02 | Electrical and Electronics Engineering | III/IV | Electric Power Generation |
| 03 | Electrical and Electronics Engineering | VI | Power system analysis & stability |

## 2.0 Course Objectives

- To explain formulation of network models and bus admittance matrix for solving load flow problems.
- To discuss solution of nonlinear static load flow equations by different numerical techniques and methods to control voltage profile.
- To discuss optimal operation of generators on a bus bar, optimal unit commitment, reliability considerations and optimum generation scheduling.
- To discuss optimal power flow solution, scheduling of hydro-thermal system, power system security and reliability.
- To explain formulation of bus impedance matrix for the use in short circuit studies on power systems and to explain numerical solution of swing equation for multi-machine stability.

## 3.0 Course Outcomes

Having successfully completed this course, the student will be able to

| | Course Outcome | RBT Level | POs |
|---|---|---|---|
| C 401.1 | Develop network matrices and models for solving load flow problems. | L4 | 1,2,3,5,8, 9,10 |
| C401.2 | Discuss steady state power flow analysis of power systems using numerical iterative techniques. | L4 | 1,2,3, 1,2,3,5,8, |
| C401.3 | Demonstrate the knowledge of optimal operation of generators on a bus bar, optimal unit commitment | L4 | 1,2,3,5,8, 9,10 |
| C 401.4 | Discuss optimal scheduling for hydro-thermal system, power system security and reliability. | L4 | 1,2,3,5,8, 9,10 |
| C401.5 | Analyze short circuit faults in power system networks using bus impedance matrix and Perform numerical solution of swing equation for multi-machine stability | L4 | 1,2,3,5,8, 9,10 |

## 4.0 Course Content

| **Module-1** | **Teaching Hours** |
|---|---|
| **Load Flow Studies:** Introduction, Network Model Formulation, Formation of $Y_{bus}$ by Singular Transformation, Load Flow Problem, Gauss-Seidel Method. ■ | **10** |
| **Revised Bloom's Taxonomy Level** $L_1$ – Remembering, $L_2$ – Understanding, $L_3$ – Applying $L_4$ – Analysing | . |
| **Module-2** | |
| **Load Flow Studies (continued):** Newton-Raphson Method, Decoupled Load Flow Methods, Comparison of Load Flow Methods, Control of Voltage Profile. ■ | **10** |
| **Revised Bloom's Taxonomy Level** $L_1$ – Remembering, $L_2$ – Understanding, $L_3$ – Applying $L_4$ – Analysing | . |
| **Module-3** | |
| **Optimal System Operation:** Introduction, Optimal Operation of Generators on a Bus Bar, Optimal Unit Commitment, Reliability Considerations, Optimum Generation Scheduling. ■ | **10** |
| **Revised Bloom's Taxonomy Level** $L_1$ – Remembering, $L_2$ – Understanding, $L_3$ – Applying $L_4$ – Analysing | . |
| **Module-4** | |
| **Optimal System Operation (continued):** Optimal Load Flow Solution, Optimal Scheduling of Hydrothermal System, Power System Security, Maintenance Scheduling, Power System Reliability. ■ | **10** |
| **Revised Bloom's Taxonomy Level** $L_1$ – Remembering, $L_2$ – Understanding, $L_3$ – Applying $L_4$ – Analysing. | |
| **Module-5** | |
| **Symmetrical Fault Analysis:** Algorithm for Short Circuit Studies, $Z_{bus}$ Formulation. **Power System Stability:** Numerical Solution of Swing Equation, Multimachine Stability. ■ | **10** |
| **Revised Bloom's Taxonomy Level** $L_1$ – Remembering, $L_2$ – Understanding, $L_3$ – Applying $L_4$ – Analysing | . |

## 5.0 Relevance to future subjects

| Sl No | Semester | Subject | Topics |
|---|---|---|---|
| 1 | VIII | PSOC | ALL |

## 6.0 Relevance to Real World

| SL.No | Real World Mapping |
|---|---|
| 01 | Power system operation |
| 02 | Carryout load flow analysis |
| 03 | Power system stability studies |

## 7.0 Gap Analysis and Mitigation

| Sl. No | Delivery Type | Details |
|---|---|---|
| 01 | Visit to power plant | Power system operation study |

## 8.0 Books Used and Recommended to Students

| **Text Books** |
|---|
| 1 Modern Power System Analysis D. P. Kothari McGraw Hill 4th Edition, 2011 |
| **Reference Books** |
| 1. Stag, G. W., and EI-Abiad, A. H., "Computer Methods in Power System Analysis", McGraw Hill International Student Edition. 1968 |
| 2. .Pai, M. A., "Computer techniques in Power System Analysis", TMH, 2nd edition, 2006. |

| |
|---|
| 4.Hadi Saadat,"power system analysis"<br>McGraw Hill 2nd Edition, 2002 |
| **Additional Study material & e-Books** |
| 1. http://pdfstuff4u.com/ebook.php?id=1071881<br>2. http://sjbit.edu.in |

## 9.0 Relevant Websites (Reputed Universities and Others) for Notes/Animation/Videos Recommended

| **Website and Internet Contents References** |
|---|
| 1) ieeexplore.ieee.org/document/152452/<br>2) https://engineering.purdue.edu/jump/8cb309<br>*3)nptel.iitg.ernet.in* |

## 10.0 Magazines/Journals Used and Recommended to Students

| Sl.No | Magazines/Journals | website |
|---|---|---|
| 1 | Society of energy engineers and managers | www.energyprofesionals.in |
| 2 | IEEE Explore | ***ieeexplore.ieee.org/xpl/RecentIssue*** |
| 3 | Journal *of Modern* Power Systems *and Clean Energy* | ***www.springer.com*** |

## 11.0 Examination Note

**Scheme of Evaluation for CIE (40 Marks)**

Internal Assessment test will be done in the same pattern as that of the main examination.

**Internal Assessment: 30 Marks**

**Assignment: 10 Marks**

**SCHEME OF EXAMINATION: 100 Marks, scaled down to 60 in VTU result sheet.**

The question paper will have ten questions.

- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of three sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module.

## 12.0 Course Delivery Plan

| UNIT No. | Lecture No. | Content of Lecture | % of Portion |
|---|---|---|---|
| I | 1. | **Load Flow Studies:** Introduction | 20 |
| | 2. | Network Model Formulation | |
| | 3. | Formation of $Y_{bus}$ by Singular Transformation, | |
| | 4. | Numerical problems | |
| | 5. | Numerical problems | |
| | 6. | Load Flow Problem | |
| | 7. | Gauss-Seidel Method | |
| | 8. | Numerical problems | |
| | 9. | Numerical problems | |

| | | | |
|---|---|---|---|
| | 10. | Numerical problems | |
| **II** | 11. | **Load Flow Studies (continued):** Newton-Raphson Method, | **20** |
| | 12. | Newton-Raphson Method | |
| | 13. | Flow chart of Newton-Raphson Method | |
| | 14. | Numerical problems | |
| | 15. | Decoupled Load Flow Methods | |
| | 16. | Flow chart Decoupled Load Flow Methods, | |
| | 17. | Comparison of Load Flow Methods | |
| | 18. | Control of Voltage Profile | |
| | 19. | Types of Control of Voltage Profile | |
| | 20. | Types of Control of Voltage Profile | |
| **III** | 21. | **Optimal System Operation :** Introduction, Performance curves | **20** |
| | 22. | Optimal Operation of Generators on a Bus Bar | |
| | 23. | Optimal Unit Commitment | |
| | 24. | Optimal Unit Commitment | |
| | 25. | Reliability Considerations | |
| | 26. | Reliability Considerations | |
| | 27. | Optimum Generation Scheduling | |
| | 28. | Optimum Generation Scheduling | |
| | 29. | Numerical problems | |
| | 30. | Numerical problems | |
| **IV** | 31. | **Optimal System Operation (continued):** Optimal Load Flow Solution, | **20** |
| | 32. | Optimal Load Flow Solution, | |
| | 33. | Optimal Scheduling of Hydrothermal System, | |
| | 34. | Optimal Scheduling of Hydrothermal System, | |
| | 35. | Power System Security | |
| | 36. | Power System Security | |
| | 37. | Maintenance Scheduling | |
| | 38. | Power System Reliability | |
| | 39. | Power System Reliability | |
| | 40. | Power System Reliability | |
| **V** | 41. | **Symmetrical Fault Analysis:** Algorithm for Short Circuit Studies | |
| | 42. | Algorithm for Short Circuit Studies | |
| | 43. | $Z_{bus}$ Formulation | |
| | 44. | $Z_{bus}$ Formulation | |
| | 45. | Numerical on $Z_{bus}$ Formulation | |
| | 46. | **Power System Stability:** Numerical Solution of Swing Equation | |
| | 47. | Numerical Solution of Swing Equation | |
| | 48. | Multimachine Stability | |
| | 49. | Multimachine Stability | |
| | 50. | Multimachine Stability | |

## 13.0 Assignments

| Sl.No. | Title | Outcome expected | Allied study | Week No. | Individual / Group activity | Reference: book/website /Paper |
|---|---|---|---|---|---|---|
| 1 | Assignment1: University Questions on network topology | Students study the Topics and write the Answers. Get practice | Module 1 of the syllabus | 3 | Individual Activity. | Book 1 of the Text book list. Website of the |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | to solve university questions. | | | | Reference list |
| 2 | Assignment 2: University Questions on energy economic analysis | Students study the Topics and write the Answers. Get practice to solve university questions. | Module 2 of the syllabus | 5 | Individual Activity. | Book 1 of the Text book list. Website of the Reference list |
| 3 | Assignment 3: University Questions on energy auditing | Students study the Topics and write the Answers. Get practice to solve university questions. | Module 3 of the syllabus | 7 | Individual Activity. | Book 1 of the reference list. Website of the Reference list |
| 4 | Assignment 4: University Questions on electrical system optimization | Students study the Topics and write the Answers. Get practice to solve university questions. | Module 4 of the syllabus | 8 | Individual Activity. | Book 1 of the reference list. Website of the Reference list |
| 5 | Assignment 5: University Questions on power factor correction & location of capacitors, energy efficient motors | Students study the Topics and write the Answers. Get practice to solve university questions. | Module 5 of the syllabus | 9 | Individual Activity. | Book 5 of the reference list. Website of the Reference list |

## 14.0 QUESTION BANK

**Module -1**

Explain the formation of $Y_{Bus}$ by method of inspection.

Explain the formation of $Y_{Bus}$ by method of singular transformation.

1. What are different types of buses considered during power system load flow analysis.
2. Explain G-S load flow solution procedure for a system having both PV & PQ buses. Derive the associated algorithmic expressions used for determining the unknown variables.
3. With the help of flow chart, explain the procedure of fast decoupled load flow analysis.
4. With the help of flow chart explain G-S method Of load flow analysis
5. What are the advantages of $Y_{Bus}$ based power flow analysis

.

6. The following is the system data for a load flow solution:

| Bus code | Admittance |
|---|---|
| 1-2 | 2.0 -j8.0 |
| 1-3 | 1.0 – j3.0 |
| 2-3 | 0.6 – j2.0 |
| 2-4 | 1.0 –j4.0 |
| 3-4 | 2.0 –j8.0 |

The schedule of active and reactive power is

| Bus code | P | Q | V | Remarks |
|---|---|---|---|---|
| 1 | - | - | 1.05+j0.0 | Slack |
| 2 | 0.5 | 0.2 | 1.0+j0.0 | PQ |
| 3 | 0.4 | 0.3 | 1.0+j0.0 | PQ |
| 4 | 0.3 | 0.1 | 1.0+j0.0 | PQ |

Determine the voltage at the end of first iteration Using 1)Gauss – Seidal 2)N-R method.
Take acceleration factor = 1.4

7. What is the need for acceleration factor?
8. What is Q-limit of generator?

**Module -2**

1. **1.** Explain the significance of Jacobian matrix of N-R LF analysis.
2. With the help of flow chart explain N-R method Of load flow analysis
3. Compare different method of load flow solution procedure in respect of the following.

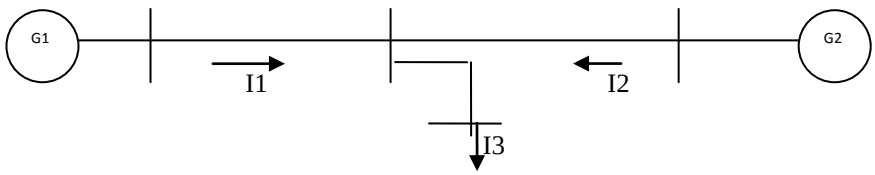
I) Time per iteration

ii) Total solution time
iii) Acceleration of convergence of iterative solution
iv) Adaptability for power system calculations

4. What are all the approximations made in fast decoupled load flow solution?
5. What is voltage stability problem in power system? Explain with suitable figure and illustrations, how does it depend upon temperature and power factor?
6. Clearly distinguish between the angle stability and voltage stability of a power system
7. Describe the various factors affecting the voltage stability and voltage collapse.
8. What is voltage instability? Explain the phenomenon of voltage collapse with relevant PV and QV diagrams.
9. What is voltage collapse? Explain with PV and QV characteristics of loads

**Module -3**

1 Explain with reference to economic operation of electric power system, the equal incremental cost criterion. Comment on the same, if the filtration way to include the effect of transmission line losses also.
2 What are transmission line loss coefficients? Obtain the general expression $B_{mn}$ with usual notations.
3. Explain in brief penalty factors & loss co-efficient. Derive the relevant expression.
4. For the system shown in figure, obtain the loss co-efficient. Assume $I_1$ & $I_2$ are in phase.




**Module -4**

1. Explain problem formulation, solution procedure & algorithm for hydrothermal coordination.
2. Explain the modes of failures of a system.
3. Explain the generating system and its performance,
4. Derive the expression of reliability index.
5. Discuss reliability measure for N- unit system
6. What are cumulative probability outages- Recursive Relation
7. What is loss of load probability?
8. Define system security and explain major functions involved in the system security.
9. Explain the importance of security assessment in the power system. What are the constraints and how these constraints differ from the normal operating constraints?
10. Distinguish between the normal operating constraints and security constraints of a power system.
11. What are the factors which affect the power system security?
12. Explain the contingency analysis with the help of flow chart.
13. Explain the role of sensitivity factors in the contingency analysis.
14. Explain the contingency analysis using sensitivity factors with the help of flow chart

**Module-5**

1. Derive the swing equation in the form
$d^2 / dt^2 = \Pi f / H (Pm-Pe)$
2. Explain the simplified representation of synchronous machine for transient stability studies. Why its detailed representation of synchronous machine is also necessary for stability studies?
3. Explain clearly the representation of load for transient stability studies.
4. Explain how the network performs equation used for load flow analysis can be applied to describe the performance of the network during a transient period.
5. Starting from the pair of equations representing a swing equation, explain the modified Eulers method of obtaining swing curie.
6. With the help of flow diagram, explain the method of finding the transient stability of a given power system based on Runga-Kutta method.
7. Explain step by step method for the numerical analysis of swing equation.

8. Explain Milne's predictor-corrector method for transient stability studies.
9. Explain the Z BUS building algorithm.

## 15.0 UNIVERSITY RESULTS

| Examination | S+ | S | A | B | C | D | E | F | % Passing |
|---|---|---|---|---|---|---|---|---|---|
| Jan2020 | 1 | 6 | 15 | 15 | 6 | 7 | 6 | 1 | 98.24 |

| Prepared by | Checked by | | |
|---|---|---|---|
| Prof. Hemalata R Zinage | Prof. Hemalata R Zinage | HOD | Principal |

| **Subject Title** | **POWER SYSTEM PROTECTION** | | |
|---|---|---|---|
| **Subject Code** | 17EE72 | **CIE Marks** | 40 |
| **Number of Lecture Hrs / Week** | 04 | **SEE Marks** | 60 |
| **Total Number of Lecture Hrs** | 50 | **Exam Hours** | 03 |
| | | | **CREDITS – 04** |

| **FACULTY DETAILS:** | | |
|---|---|---|
| **Name:** Prof.Mahesh P. Yanagimath | **Designation:** Asst.Professor | **Experience:**14.5 |
| **No. of times course taught:**02 | | **Specialization:** VLSI and Embedded System |

## 1.0 Prerequisite Subjects:

| Sl. No | Branch | Semester | Subject |
|---|---|---|---|
| 01 | Electrical & Electronics Engineering | I/II | BEE |
| 02 | Electrical & Electronics Engineering | III | T&G |

## 2.0 Course Objectives

The subject aims to provide the student with:

1. To discuss performance of protective relays, components of protection scheme and relay terminology.
2. To explain relay construction and operating principles.
3. To explain Overcurrent protection using electromagnetic and static relays and Overcurrent protective schemes.
4. To discuss types of electromagnetic and static distance relays, effect of arc resistance, power swings, line length and source impedance on performance of distance relays.
5. To discuss pilot protection; wire pilot relaying and carrier pilot relaying.
6. To discuss construction, operating principles and performance of various differential relays for differential protection.
7. To discuss protection of generators, motors, Transformer and Bus Zone Protection.
8. To explain the principle of circuit interruption and different types of circuit breakers.
9. To describe the construction and operating principle of different types of fuses and to give the definitions of different terminologies related to a fuse.
10. To discuss protection Against Overvoltages and Gas Insulated Substation (GIS)

## 3.0 Course Outcomes

At the end of the course the student will be able to:

| | Course Outcome | RBT Level | POs |
|---|---|---|---|
| C402.1 | Discuss performance of protective relays, components of protection scheme. | $L_1$,$L_2$, $L_3$,$L_4$ | PO1,PO2,PO3, PO8,PO10,PO12 |
| C402.2 | Explain the working of distance relays and the effects of arc resistance, power swings, line length and source impedance on performance of distance relays. | $L_1$,$L_2$, $L_3$,$L_4$ | PO1,PO2,PO3, PO8,PO10,PO12 |
| C402.3 | Discuss various Pilot protection schemes, protection of generators, motors, Transformers and construction, operating principles, performance of differential relays for differential protection. | $L_2$,$L_3$,$L_4$, $L_5$ | PO1,PO2,PO3, PO8, PO10,PO12 |
| C402.4 | Explain the principle of circuit interruption in different types of circuit breakers. | $L_1$,$L_2$,$L_3$,$L_4$ | PO1,PO2,PO3, PO8,PO10,PO12 |
| C402.5 | Describe the construction and operating principle of different types of fuses and modern trends in power system protection. | $L_1$,$L_2$,$L_3$,$L_4$ | PO1,PO2,PO3, PO8,PO10,PO12 |
| | **Total Hours of instruction** | **50** | |

## 4.0 Course Content

**MODULE-1**

**Introduction to Power System Protection:** Need for protective schemes, Nature and Cause of Faults, Types of Fault, Effects of Faults, Fault Statistics, Zones of Protection, Primary and Backup Protection, Essential Qualities of Protection, Performance of Protective Relaying, Classification of Protective Relays, Automatic Reclosing, Current Transformers for protection, Voltage Transformers for Protection.

**Relay Construction and Operating Principles:** Introduction, Electromechanical Relays, Static Relays – Merits and Demerits of Static Relays, Numerical Relays, Comparison between Electromechanical Relays and Numerical Relays.

**Overcurrent Protection:** Introduction, Time – current Characteristics, Current Setting, Time Setting. **10 Hours**

**MODULE-2**

**Overcurrent Protection (continued):** Overcurrent Protective Schemes, Reverse Power or Directional Relay, Protection of Parallel Feeders, Protection of Ring Mains, Earth Fault and Phase Fault Protection, Combined Earth Fault and Phase Fault Protective Scheme, Phase Fault Protective Scheme, Directional Earth Fault Relay, Static Overcurrent Relays, Numerical Overcurrent Relays.

**Distance Protection:** Introduction, Impedance Relay, Reactance Relay, Mho Relay, Angle Impedance Relay, Effect of Arc Resistance on the Performance of Distance Relays, Reach of Distance Relays. Effect of Power Surges (Power Swings) on Performance of Distance Relays, Effect of Line Length and Source Impedance on Performance of Distance Relays.

**10 Hours**

**MODULE-3**

**Pilot Relaying Schemes:** Introduction, Wire Pilot Protection, Carrier Current Protection **Differential Protection**: Introduction, Differential Relays, Simple Differential Protection, Percentage or Biased Differential Relay, Differential Protection of 3 Phase Circuits, Balanced (Opposed) Voltage Differential Protection.

**Rotating Machines Protection:** Introduction, Protection of Generators. **Transformer and Buszone Protection:** Introduction, Transformer Protection, Buszone Protection, Frame Leakage Protection. **10 Hours**

**MODULE-4**

Circuit Breakers: Introduction, Fault Clearing Time of a Circuit Breaker, Arc Voltage, Arc Interruption, Restriking Voltage and Recovery Voltage, Current Chopping, Interruption of Capacitive Current, Classification of Circuit Breakers, Air – Break Circuit Breakers, Oil Circuit Breakers, Air – Blast Circuit Breakers, SF6 Circuit Breakers, Vacuum Circuit Breakers, High Voltage Direct Current Circuit Breakers, Rating of Circuit Breakers, Testing of Circuit Breakers.

**10 Hours**

**MODULE-5**

**Fuses:** Introductions, Definitions, Fuse Characteristics, Types of Fuses, Applications of HRC Fuses, Selection of Fuses, Discrimination.

**Protection against Overvoltages:** Causes of Overvoltages, Lightning phenomena, Wave Shape of Voltage due to Lightning, Over Voltage due to Lightning, Klydonograph and Magnetic Link, Protection of Transmission Lines against Direct Lightning Strokes, Protection of Stations and Sub – Stations from Direct Strokes, Protection against Travelling Waves, Insulation Coordination, Basic Impulse Insulation Level (BIL).

**Modern Trends in Power System Protection:** Introduction, gas insulated substation/switchgear (GIS). **10 Hours**

## 5.0 Relevance to future subjects

| Sl No | Semester | Subject | Topics |
|---|---|---|---|
| 01 | VIII | Project work | Student come to know Protection of faults in final year projects |
| 02 | VII | Testing & commissioning of electrical equipments | Study of Relays & Different types of faults. |

## 6.0 Relevance to Real World

| SL.No | Real World Mapping |
|---|---|
| 01 | Student understands the usage of fuses & circuit breakers in home & industrial applications. |
| 02 | Use of different types of relays & circuit breakers in substations & receiving stations & power generating stations. |

## 7.0 Gap Analysis and Mitigation

| Sl. No | Delivery Type | Details |
|---|---|---|
| 01 | Practical approach | Visiting the substations & generating stations to see use of protective devices. |
| 02 | NPTEL | Working of restricted earth fault relay & pole discrepancy relay. |
| 03 | Mi power tool | Simulation of relay coordination |

## 8.0 Books Used and Recommended to Students

**Text Books**

1. Power System Protection and Switchgear Badri Ram, D.N. Vishwakarma McGraw Hill 2nd Edition.
2. Power System Protection and Switchgear BhuvaneshOza et al McGraw Hill 1st Edition, 2010.

**Reference Books**

1. Protection and Switchgear Bhavesh et al Oxford 1st Edition, 2011.
2. Power System Switchgear and Protection N. Veerappan S.R. Krishnamurthy S.Chand 1st Edition, 2009.
3. Fundamentals of Power System Protection Y.G.Paithankar S.R. Bhide PHI 1st Edition, 2009.

**Additional Study material & e-Books**

1. "Switchgear & Protection", by U.A. Bakshi & M.V.bakshi.
2. www.NPTEL.com

## 9.0 Relevant Websites (Reputed Universities and Others) for Notes / Animation/Videos Recommended

**Website and Internet Contents References**

1) Electrical4u.com
2) http://books.google.co.in/books
3) http://www.vlab.co.in/
4) https://www.accessengineeringlibrary.com
5) WWW.NPTEL.com

## 10.0 Magazines/Journals Used and Recommended to Students

| Sl.No | Magazines/Journals | website |
|---|---|---|
| 1 | Electrical construction & maintenance magazine | ecmweb.com |
| 2 | IEEE industry applications Magazine | ieeexplore.ieee.org |

## 11.0 Examination Note

**Scheme of Evaluation for CIE (40 Marks)**
Internal Assessment test will be done in the same pattern as that of the main examination.
**Internal Assessment: 30 Marks**
**Assignment: 10 Marks**

**SCHEME OF EXAMINATION:**
The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of three sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module.

## 12.0 Course Delivery Plan

| Module No | Lecture No. | Content of Lecture | % of Portion |
|---|---|---|---|
| | 1 | **Introduction to Power System Protection:** Need for protective schemes, Nature and Cause of Faults, | 20% |
| | 2 | Types of Fault, Effects of Faults, Fault Statistics, | |
| | 3 | Zones of Protection, Primary and Backup Protection, | |
| | 4 | Essential Qualities of Protection, Performance of Protective Relaying, | |
| | 5 | Classification of Protective Relays, Automatic Reclosing. | |
| | 6 | Current Transformers for protection, Voltage Transformers for Protection. | |
| | 7 | **Relay Construction and Operating Principles:** Introduction, Electromechanical Relays, | |
| | 8 | Static Relays – Merits and Demerits of Static Relays | |
| | 9 | Numerical Relays, Comparison between Electromechanical Relays and Numerical Relays. | |
| | 10 | **Over current Protection:** Introduction, Time – current Characteristics, Current Setting, Time Setting. | |
| **2** | 11 | Over current Protective Schemes, Reverse Power or Directional Relay. | 20% |
| | 12 | Protection of Parallel Feeders, Protection of Ring Mains. | |
| | 13 | Earth Fault and Phase Fault Protection, Combined Earth Fault and Phase | |
| | 14 | Phase Fault Protective Scheme, Directional Earth Fault Relay. | |
| | 15 | Static Over current Relays, Numerical Over current Relays. | |
| | 16 | **Distance Protection:** Introduction, Impedance Relay. | |
| | 17 | Reactance Relay, Mho Relay. | |
| | 18 | Angle Impedance Relay, Effect of Arc Resistance on the Performance of Distance Relays. | |
| | 19 | Reach of Distance Relays. Effect of Power Surges on Performance of Distance Relays. | |
| | 20 | Effect of Line Length and Source Impedance on Performance of Distance Relays. | |
| **3** | 21 | **Pilot Relaying Schemes:** Introduction, Wire Pilot Protection, Carrier Current Protection. | 20% |
| | 22 | **Differential Protection**: Introduction, Differential Relays. | |
| | 23 | Simple Differential Protection, Percentage or Biased Differential Relay, | |
| | 24 | Differential Protection of 3 Phase Circuits | |
| | 25 | Balanced (Opposed) Voltage Differential Protection. | |

| | | | |
|---|---|---|---|
| | 26 | **Rotating Machines Protection:** Introduction. | |
| | 27 | Protection of Generators | |
| | 28 | **Transformer and Buszone Protection:** Introduction, Transformer Protection | |
| | 29 | Buszone Protection | |
| | 30 | Frame Leakage Protection | |
| **4** | 31 | **Circuit Breakers:** Introduction, Fault Clearing Time of a Circuit Breaker | 20% |
| | 32 | Arc Voltage, Arc Interruption, Restriking Voltage and Recovery Voltage, | |
| | 33 | Current Chopping, Interruption of Capacitive Current, | |
| | 34 | Classification of Circuit Breakers, | |
| | 35 | Air – Break Circuit Breakers, Oil Circuit Breakers | |
| | 36 | Air – Blast Circuit Breakers, SF6 Circuit Breakers, | |
| | 37 | Vacuum Circuit Breakers, | |
| | 38 | High Voltage Direct Current Circuit Breakers | |
| | 39 | Rating of Circuit Breakers, | |
| | 40 | Testing of Circuit Breakers | |
| **5** | 41 | **Fuses:** Introductions, Definitions, Fuse Characteristics, Types of Fuses, | 20% |
| | 42 | Applications of HRC Fuses, Selection of Fuses, Discrimination. | |
| | 43 | **Protection against Over voltages:** Causes of Over voltages, Lightning phenomena. | |
| | 44 | Wave Shape of Voltage due to Lightning, Over Voltage due to Lightning. | |
| | 45 | Klydonograph and Magnetic Link, Protection of Transmission Lines against | |
| | 46 | Protection of Stations and Sub – Stations from Direct Strokes. | |
| | 47 | Protection against Travelling Waves, Insulation Coordination. | |
| | 48 | Basic Impulse Insulation Level (BIL). | |
| | 49 | **Modern Trends in Power System Protection:** Introduction. | |
| | 50 | Gas insulated substation/switchgear (GIS). | |

## 13.0 Assignments, Pop Quiz, Mini Project, Seminars

| Sl. No. | Title | Outcome expected | Allied study | Week No. | Individual / Group activity | Reference: book/website /Paper |
|---|---|---|---|---|---|---|
| 1 | Assignment 1: Introduction to power system protection | Students study the Topics and write the Answers. Get practice to solve university questions. | Unit 1 of the syllabus | 2 | Individual Activity. Written solution is expected. | Book 1 of the reference list. Website of the Reference list |
| 2 | Assignment 2: Over current & Distance protection | Students study the Topics and write the Answers. Get practice to solve university questions. | Unit 2 of the syllabus | 4 | Individual Activity. Written solution is expected. | Book 1 of the reference list. Website of the Reference list |
| 3 | Assignment 3: Pilot relaying schemes & rotating machine, Transformer & Buszone protection. | Students study the Topics and write the Answers. Get practice to solve university questions. | Unit 3,4 of the syllabus | 6 | Individual Activity. Written solution is expected. | Book 1 of the reference list. Website of the Reference list |
| 4 | Assignment 4: Circuit breakers | Students study the Topics and write the Answers. Get practice to solve university questions. | Unit 3,4 of the syllabus | 8 | Individual Activity. Written solution is expected. | Book 1 of the reference list. Website of the Reference list |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | Assignment 5: Fuses, Protection against overvoltage's Modern trends in power system protection. | Students study the Topics and write the Answers. Get practice to solve university questions. | Unit 5 of the syllabus | 10 | Individual Activity. Written solution is expected. | Book 1 of the reference list. Website of the Reference list |

## 14.0 QUESTION BANK

**Module No. 1:**

1. Explain need of protection schemes?
2. Mention different types of faults?
3. With neat sketch explain primary and backup protection?
4. Explain the classification of protective relays?
5. Mention merits and demerits of static relays?
6. Compare electromechanical and Numerical relays?
7. With a neat diagram, explain zones of protection in a power system.
8. Explain the various methods of back up protection.
9. Briefly explain essential qualities of protective relay.
10. Draw the schematic diagram of Numerical relay and briefly describe its various components.

**Module No. 2:**

1. Explain over current protective schemes?
2. With neat sketch explain the operation of Directional relay?
3. Explain the protection of parallel feeders & Ring mains?
4. Explain earth fault and phase fault protection?
5. Explain the operation of static over current relay?
6. With neat sketch explain the operation of impedance relay?
7. With neat sketch explain the operation of reactance relay & Mho relay?
8. Explain the effect of arc resistance on the performance of Distance relays?
9. Explain the effect of power surges on performance of Distance relays?
10. Mention effect of source impedance & line length on performance of distance relays?
11. With neat sketch, explain Directional overcurrent relay.
12. With a neat circuit diagram, explain Directional over current relay.

**Module No. 3**

1. Explain carrier current protection?
2. With neat sketch explain the operation of differential relay?
3. With neat diagram explain the operation of percentage or biased differential relay?
4. Explain differential protection of 3 phase circuits?
5. Explain the operation of balanced voltage differential protection?
6. Explain the protection of Generators?
7. Explain transformer protection?
8. Explain buszone protection?
9. Explain the term Pilot with reference to power line protection.
10. Describe the balanced(opposed) voltage differential protection scheme.
11. With a neat diagram. Explain the working of Buchholz relay.

**Module No. 4**

1. Explain the basic principle of operation of Circuit breaker?
2. Explain arc interruption in circuit breaker?
3. Define restriking & recovery voltage?
4. With neat sketch explain interruption of capacitive current?
5. With neat sketch the operation of fallowing circuit breakers?

*Course Plan 2020-21 Odd – Semester 7 th*
*Electrical & Electronics Engineering*

- Air-break circuit breaker
- Oil circuit breaker
- Air-blast circuit breaker
- SF6 circuit breaker
- Vacuum circuit breaker
- High voltage direct current circuit breaker

6. Explain the ratings of circuit breaker?
7. Explain various methods of testing of circuit breakers?
8. Explain how interruption of capacitive current takes place in AC circuit breaker.
9. With a neat sketch, explain the construction and working of Non-Puffer type of SF6 Circuit breaker.
10. With the help of Schematic diagram, explain the working of short circuit test plant.

**Module No. 5**

1. Mention different types of fuses?
2. With neat sketch explain the operation of HRC fuse?
3. With neat sketch explain the construction & working of Liquid fuse?
4. Explain the procedure for selection of fuses and define discrimination?
5. Mention the causes of over voltages?
6. Explain the lightning phenomena?
7. Explain the protection of transmission lines against direct lightning strokes?
8. Explain the protection of substations from direct strokes?
9. Explain the basic Impulse insulation level?
10. Explain about Gas insulated substation?
11. Define the fusing factor and Fuse.
12. With a neat sketch, explain the working of Klydonograph.
13. What are the various components of a GIS? Briefly describe their functions.

| Prepared by | Checked by | | |
|---|---|---|---|
| | HRZinage 27/08/2020 | 27/8 | |
| Prof. Mahesh P.Yanagimath | Prof. H.R.Zinage | HOD | Principal |





Page 7

| **Subject Title** | **HIGH VOLTAGE ENGINEERING** | | |
|---|---|---|---|
| **Subject Code** | **17EE73** | **CIE Marks** | 40 |
| **Number of Lecture Hrs / Week** | 04 | **SEE Marks** | 60 |
| **Total Number of Lecture Hrs** | 50 | **Exam Hours** | 03 |
| | | **CREDITS – 04** | |

| **FACULTY DETAILS:** | | |
|---|---|---|
| **Name:** Prof. O. B. Heddurshetti | **Designation:** Asst.Professor | **Experience:** 14 years |
| **No. of times course taught:** 01 | **Specialization:** Power Electronics | |

## 1.0 Prerequisite Subjects:

| Sl. No | Branch | Semester | Subject |
|---|---|---|---|
| 01 | Electrical and Electronics Engineering | I/II | Basic Electrical Engineering |
| 02 | Electrical and Electronics Engineering | III | Electrical and Electronics Measurements |
| 03 | Electrical and Electronics Engineering | III | Transformers and Generators |
| 04 | Electrical and Electronics Engineering | V | Transmission and Distribution |
| 05 | Electrical and Electronics Engineering | V | Electrical Engineering Materials |
| 06 | Electrical and Electronics Engineering | VII | Power System Protection |

## 2.0 Course Objectives

- To discuss conduction and breakdown in gases, liquid dielectrics.
- To discuss breakdown in solid dielectrics.
- To discuss generation of high voltages and currents and their measurement.
- To discuss overvoltage phenomenon and insulation coordination in electric power systems.
- To discuss non-destructive testing of materials and electric apparatus.
- To discuss high-voltage testing of electric apparatus

## 3.0 Course Outcomes

Having successfully completed this course, the student will be able to

| | Course Outcome | RBT level | POs |
|---|---|---|---|
| C403.1 | Examine conduction and breakdown phenomenon in gases, liquid and solid dielectrics. | L1,L2,L3,L4 | 1,2,3,8,12 |
| C403.2 | Illustrate various techniques of generation of different forms of high voltages and currents. | L1,L2,L3,L4 | 1,2,3,8,12 |
| C403.3 | Outline measurement techniques for high voltages and currents. | L1,L2,L3,L4 | 1,2,3,8,12 |
| C403.4 | Analyze overvoltage phenomenon and insulation coordination in electric power systems. | L1,L2,L3,L4 | 1,2,3,8,12 |
| C403.5 | Illustrate non-destructive testing of materials and electric apparatus and high-voltage testing of electric apparatus. | L1,L2,L3,L4 | 1,2,3,8,12 |
| **Total Hours of instruction** | | **50** | |

## 4.0 Course Content

**Module-1**
**Conduction and Breakdown in Gases:** Gases as Insulating Media, Collision Process, Ionization Processes, Townsend's Current Growth Equation, Current Growth in the Presence of Secondary Processes, Townsend's Criterion for Breakdown, Experimental Determination of Coefficients α and γ, Breakdown in Electronegative Gases, Time Lags for Breakdown, Streamer Theory of Breakdown in Gases, Paschen's Law, Breakdown in Non-Uniform Fields and Corona Discharges.
**Conduction and Breakdown in Liquid Dielectrics:** Liquids as Insulators, Pure Liquids and Commercial Liquids, Conduction and Breakdown in Pure Liquids, Conduction and Breakdown in Commercial Liquids. **Breakdown in Solid Dielectrics:** Introduction, Intrinsic Breakdown, Electromechanical Breakdown, Thermal Breakdown. 10Hours
**Revised Bloom's Taxonomy Level:** $L_1$ – Remembering, $L_2$ – Understanding

**Module-2**
**Generation of High Voltages and Currents:** Generation of High Direct Current Voltages, Generation of High Alternating Voltages, Generation of Impulse Voltages, Generation of Impulse Currents, Tripping and Control of Impulse Generators. 10Hours
**Revised Bloom's Taxonomy Level:** $L_1$ – Remembering, $L_2$ – Understanding $L_3$ – Applying

**Module-3**
**Measurement of High Voltages and Currents:** Measurement of High Direct Current Voltages, Measurement of High AC and Impulse Voltages, Measurement of High Currents – Direct, Alternating and Impulse, Cathode Ray Oscillographs for Impulse Voltage and Current Measurements. 10Hours
**Revised Bloom's Taxonomy Level:** $L_1$ – Remembering, $L_2$ – Understanding $L_3$ – Applying

**Module-4**
**Overvoltage Phenomenon and Insulation Coordination in Electric Power Systems:**
National Causes for Overvoltages - Lightning Phenomenon, Overvoltage due to Switching Surges, System Faults and Other Abnormal, Principles of Insulation Coordination on High Voltage and Extra High Voltage Power Systems.
**Revised Bloom's Taxonomy Level:** $L_1$ – Remembering, $L_2$ – Understanding 10Hours

**Module-5**
**Non-Destructive Testing of Materials and Electrical Apparatus:** Introduction, Measurement of Dielectric Constant and Loss Factor, Partial Discharge Measurements.
**High Voltage Testing of Electrical Apparatus:** Testing of Insulators and Bushings, Testing of Isolators and Circuit Breakers, Testing of Cables, Testing of Transformers, Testing of Surge Arrestors, Radio Interference Measurements, Testing of HVDC Valves and Equipment. 10Hours
**Revised Bloom's Taxonomy Level:** $L_1$ – Remembering, $L_2$ – Understanding

## 5.0 Relevance to future subjects

| Sl No | Semester | Subject | Topics |
|---|---|---|---|
| 1 | VII | Testing and Commissioning of Power System Apparatus | Switchgear and Protective Devices |

## 6.0 Relevance to Real World

| SL.No | Real World Mapping |
|---|---|
| 01 | Electric breakdown in gases, liquid and solid dielectrics. |
| 02 | High voltage AC, DC and impulse generation in power research laboratory for testing. |
| 03 | High voltage and current measurements in research laboratory for testing. |
| 04 | Overvoltage Phenomenon and Insulation Coordination in Electric Power Systems. |
| 05 | Non-destructive test techniques in high voltage engineering. High voltage tests on power system apparatus and switchgear such as circuit breakers, insulators, transformers and cables in site and research laboratory. |

## 7.0 Gap Analysis and Mitigation

| Sl. No | Delivery Type | Details |
|---|---|---|
| 01 | Practical Assignment | Practical assignments will be given to the students to study electric breakdown in gases, liquids and solid dielectrics and generation and measurement of different forms of high voltages in laboratory and testing of high voltage power system apparatus and switchgears. |
| 02 | Power point presentation | Topic related to High voltage engineering subject. |

## 8.0 Books Used and Recommended to Students

| **Text Books** |
|---|
| 1. **High Voltage Engineering** by M.S.Naidu and Kamaraju- 5th Edition, McGraw Hill. 2013. |
| **Reference Books** |
| 1**. High Voltage Engineering Fundamentals** by E.Kuffel and W.S. Zaengl, 2nd Edition, Newnes 2000.<br>2. **High Voltage Engineering** by C.L.Wadhwa, New Age International Private limited, 3rd Edition 2012.<br>3. **High-Voltage Test and Measuring Techniques** by Wolfgang Hauschild & Eberhard Lemke, Springer 1st Edn.2014.<br>4. **High Voltage Engineering by** Farouk A.M. Rizk , CRC Press ,1st Edition2014 . |
| **Additional Study material & e-Books** |
| 1. High Volatge test and measuring techniques: Springer<br>2. High voltage and electrical insulation engineering by Ravindra Arora |

## 9.0 Relevant Websites (Reputed Universities and Others) for Notes/Animation/Videos Recommended

| **Website and Internet Contents References** |
|---|
| 1) www.nptelviodes.in<br>2)www.freevideolectures.com |

## 10.0 Magazines/Journals Used and Recommended to Students

| Sl.No | Magazines/Journals | website |
|---|---|---|
| 1 | IET Digital library | ***www.digital-library.theiet.org/content/journals/hve*** |
| 2 | High Voltage Engineering | **www.oriprobe.com/journals/gdyjs.html** |
| 3 | IEEE Electrical Insulation engineering | ***http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=57*** |

## 11.0 Examination Note

**Scheme of Evaluation for CIE (40 Marks)**

Internal Assessment test will be done in the same pattern as that of the main examination.

**Internal Assessment: 30 Marks**

**Assignment: 10 Marks**

**SCHEME OF EXAMINATION:**

The question paper will have ten questions.

- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of three sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module.

## 12.0 Course Delivery Plan

| Module No. | Lecture No. | Content of Lecture | % of Portion |
|---|---|---|---|
| 2 | 1 | HV transformer, Need for cascade connection and working of transformers units connected in cascade. | 20% |
| | 2 | Resonant Transformers. Tesla coil. | |
| | 3 | HV DC- voltage doubler circuits | |
| | 4 | Voltage Multiplier circuits: Cock croft- Walton type high voltage DC set | |
| | 5 | Calculation of high voltage regulation and ripple | |
| | 6 | Optimum number of stages for minimum voltage drop. | |
| | 7 | Introduction to standard lightning and switching impulse voltages, Analysis of single stage impulse generator-expression for Output impulse voltage | |
| | 8 | Multistage impulse generator- working of Marx impulse generator, Rating of impulse generator, Components of multistage impulse generator | |
| | 9 | Generation of switching impulse voltage, Generation of high impulse current | |
| | 10 | Tripping and Control of Impulse Generators. | |
| 3 | 11 | Series resistance micro ammeter for HV DC measurements | 20% |
| | 12 | Generating voltmeter- Principle, construction | |
| | 13 | Standard sphere gap measurements of HV AC, HV DC and impulse voltages | |
| | 14 | Factors affecting the measurements | |
| | 15 | Electrostatic voltmeter-principle, construction | |
| | 16 | Chubb and Fortescue method for HV AC measurement | |
| | 17 | Resistance potential dividers | |
| | 18 | Capacitance dividers, Mixed RC potential dividers | |
| | 19 | Measurement of High Currents – Direct, Alternating and Impulse | |
| | 20 | Cathode Ray Oscillographs for Impulse Voltage and Current Measurements. | |
| 1 | 21 | Gases as Insulating Media, Collision Process | 20% |
| | 22 | Ionization processes | |
| | 23 | Townsend's Current Growth Equation, Current Growth in the Presence of Secondary Processes, Townsend's Criterion for Breakdown. | |
| | 24 | Experimental Determination of Coefficients of $\alpha$ and $\gamma$, Breakdown in Electronegative Gases, Time Lags for Breakdown. | |
| | 25 | Streamer Theory of Breakdown in Gases. | |
| | 26 | Paschen's Law, Breakdown in Non-Uniform Fields and Corona Discharges. | |
| | 27 | Liquids as Insulators, Pure Liquids and Commercial Liquids, Conduction and Breakdown in Pure Liquids. | |
| | 28 | Conduction and Breakdown in Commercial Liquids | |
| | 29 | Breakdown in Solid Dielectrics: Introduction, Intrinsic Breakdown, | |
| | 30 | Electromechanical Breakdown, Thermal Breakdown. | |
| 4 | 31 | Natural Causes for Over voltages | 20% |
| | 32 | Lightning Phenomenon | |
| | 33 | Overvoltage due to Switching Surges | |
| | 34 | Switching over voltages in EHV and UHV systems | |
| | 35 | System Faults and Other Abnormal conditions | |
| | 36 | Protection of Transmission lines against overvoltages. | |
| | 37 | Principles of Insulation Coordination: Surge Arresters | |
| | 38 | Protection of lines with Surge Arresters. | |
| | 39 | Insulation Coordination in EHV and UHV Systems | |
| 5 | 40 | Measurement of Dielectric Constant and Loss Factor: Introduction | 20% |
| | 41 | HV Schering Bridge | |
| | 42 | Transformer ratio arm bridges | |
| | 43 | Detectors in Dielectric Measurements | |
| | 44 | Partial Discharge Measurements: Introduction | |

| | | | |
|---|---|---|---|
| | 45 | Discharge detection using Straight Detectors and Balanced Detection method | |
| | 46 | Testing of Insulators and Bushings | |
| | 47 | Tests on isolators, circuit breakers | |
| | 48 | Tests on cables, Tests on transformers | |
| | 49 | Testing of Surge Arrestors, Radio Interference Measurements | |
| | 50 | Testing of HVDC Valves and Equipment | |

## 13.0 Assignments

| Sl. No. | Title | Outcome expected | Allied study | Week No. | Individual / Group activity | Reference: book/website /Paper |
|---|---|---|---|---|---|---|
| 1 | Assignment 1: Questions on Generation of High voltages and Currents. | Students will be able to explain different techniques of high voltage AC, DC and Impulse generation and solve examples. | Module 2 of the syllabus | 5 | Individual Activity. | Books 1, 2 & 3 of the book list |
| 2 | Assignment 2: Questions on Measurement of high voltages and currents | Students will be able to explain different techniques of high voltage and current measurements and solve examples. | Module 3 of the syllabus | 7 | Individual Activity. | Books 1, 2 & 3 of the book list. |
| 3 | Assignment 3: Questions on conduction and breakdown in gases, liquid and solid dielectrics. | Students will be able to explain breakdown theories in different dielectrics, Paschen's law, Time lags of breakdown | Module 1 of the syllabus | 10 | Individual Activity. | Books 1, 2 & 3 of the book list. |
| 4 | Assignment 4: Questions on Overvoltage Phenomenon and Insulation Coordination in Electric Power Systems | Students will be able to explain Overvoltage Phenomenon and Insulation Coordination in Electric Power Systems | Module 4 of the syllabus | 12 | Individual Activity. | Books 1, 2 & 3 of the book list |
| 5 | Assignment 5: Questions on non-destructive Testing of materials and HV testing of electrical apparatus | Students will be able to explain Non-destructive test techniques and testing of Transformer, Insulator, CB Cables and Surge Arrestors | Module 5 of the syllabus | 16 | Individual Activity. | Books 1, 2 & 3 of the book list |

## 14.0 QUESTION BANK

**Module 1:**

1. What is ionization?Explain the different types of primary and secondary ionization processes of a gaseous insulation subjected to high voltage.
2. Explain Townsend's theory of gaseous breakdown. Derive the equations for the current growth and the Townsend's criterion for breakdown.
3. Explain in detail the streamer mechanism of breakdown in gases.
4. Explain briefly formative time lag and statistical time lag.
5. What are electronegative gaes? Why the breakdown strength of these gases higher is compared to that of other gases?
6. What is Paschen's law? How do you account for the minimum voltage for breakdown under a given 'pxd' condition?
7. Briefly explain "Cavitation and Bubble theory" in the context of liquid dielectric breakdown.
8. Discuss the electrical properties that determine the dielectric performance of liquid dielectrics?
9. What is "Stressed oil volume theory" and how does it explain breakdown in large volume of commercial dielectrics?
10. Explain the different mechanisms by which breakdown occurs in solid dielectrics in practice.
11. Explain the terms dielectric strength,electric field intensity and electron negativity related to breakdown process of gases.
12. Explain thermal breakdown in solid dielectrics and how it is more significant than other breakdown mechanisms.
13. Define Townsend's first and second ionization coefficients.Explain the Townsend's criterion for breakdown.
14. Explain the various factors which deteriorate the strength of dielectric materials used in various electrical equipments
15. Explain any two theories that explain breakdown in commercial liquid dielectrics.

**Module 2:**

1. Explain with diagrams, different types of rectifier circuits for producing high voltages.
2. Explain with circuit diagram, the working of simple voltage doubler circuit for generation of D.C high voltage.
3. Explain the different schemes for cascade connection of transformers for producing very high a.c. voltages.
4. load Why is a Cockcroft-Walton circuit preferred for voltage multiplier circuits? Explain its working with a schematic diagram.
5. Explain Cock Croft Walton voltage Multiplier circuit with neat circuit diagram. Show input and output wave form with certain.
6. Explain the no-load operation of a CockCroft- Walton voltage Multiplier circuit.
7. Derive expressions for ripple and voltage drop in cascaded voltage multiplier circuit.
8. State the chief advantages of resonant transformers.
9. What is tesla coil?How are damped high frequency oscillations obtained from a Tesla coil.
10. What is the principle of operation of a resonant transformers?How is it advantageous over the cascade connected transformers?

11. Define the front and tail times of an impulse wave. What are the tolerances allowed as per specification?
12. Give the different circuits that produce impulse waves, explain clearly their merits and demerits.
13. How will you specify impulse generator? Describe the working of a multistage Marx impulse generator with a neat sketch. How is the basic arrangement modified to accommodate the wave time control?
14. Explain the different methods of producing switching impulses in the test laboratories.
15. Outline the method of tripping a multistage impulse generator using three electrode gap arrangements.
16. What is trigatron gap?Explain its function and operation.
17. Define an impulse wave and show that the output voltage of impulse generation circuit is double exponential in nature.
18. Give the general equation of a standard impulse wave and explain the wave shape giving the percentage tolerances allowed for front, tail and the peak.
19. Discuss the components of a multistage impulse generator of less than 1MV.

**Module 3:**

1. Explain the working principle of series capacitor peak voltmeter based on Chubb-Fortesque method.
2. Briefly explain factors influencing spark over voltage of sphere gap.
3. Write a short note on MIX- RC potential dividers.
4. Explain the principle of measurement of high AC voltage using sphere gap & discuss the effect of atmosphere condition for its calibration.
5. Describe the construction & working of Electrostatic voltmeter. State its advantages & limitations.
6. Write a short note on the resistance dividers.
7. Draw a neat schematic diagram of generating voltmeter & explain its operation & discuss its applications.
8. Which are the four main sources of errors in the measurements of impulse voltages with potential dividers?
9. Explain the Chubb- Fortesque method for peak voltage measurement. Bring out the sources that contribute to the errors in the measurement.
10. Explain the importance of Sphere gap in Measurement of high voltages and high currents.
11. How Capacitance Potential Dividers are used for the impulse voltage measurements.

**Module 4:**

1. Explain the different theories of charge formation in clouds.
2. What are the mechanisms by which lighting strokes develop and induce overvoltages on overhead power lines
3. Give the mathematical models for lighting discharges and explain them
4. What are the causes for switching and power frequency overvoltages? How are they controlled in power systems
5. What are the different methods employed for lightning protection of overhead lines?
6. What is a surge arrester? Explain its function as a shunt protective device.
7. What is meant by insulation co-ordination? How are are the protective devices Chosen for optimal insulation level in a power system?
8. Explain the different aspects of insulation design and insulation co-ordination

**Module 5:**

1. What are partial discharges & how are they detected under power frequency operating conditions?
2. Discuss the method of balanced detection for locating partial discharges in electrical equipment.
3. Explain the method of measurement of capacitance and tan ∂ using H.V. Schering bride.
4. Why partial discharge tests are performed on H.V. cables? Describe partial discharge testing of cables.
5. Write a short note on Transformer ratio Arm Bridge.
6. Explain the method of measuring dielectric loss at power frequency using high voltage Schering Bridge.
7. Explain the partial discharge diction using straight detectors.
8. Define the following i) Disruptive discharge voltage ii) withstand voltage iii) 50% flash over voltage. iv)Creeping distance.
9. Explain the method of impulse testing of high voltage transformers. What is the procedure adopted for locating the failure.
10. Name and explain in brief different tests that are carried out on high voltage insulators.
11. What are the different power frequency tests done on insulators? Mention the procedure for testing.
12. Mention the different electrical tests done on isolators and circuit breakers.
13. Why is synthetic testing advantageous over the other testing methods for short circuit tests? Give the layout for synthetic testing.
14. What is the significance of impulse tests? Briefly explain the impulse testing of insulators.

| Prepared by | Checked by | | |
|---|---|---|---|
| Prof.O.B.Heddurshetti | Prof. S.D.Hirekodi | HOD | Principal |

| **Subject Title** | **POWER SYSTEM PLANNING (Professional Elective)** | | |
|---|---|---|---|
| **Subject Code** | 17EE744 | **CIE Marks** | 40 |
| **Number of Lecture Hrs / Week** | 04 | **SEE Marks** | 60 |
| **Total Number of Lecture Hrs** | 40 | **Exam Hours** | 03 |
| **Credits-03** | | | |

| **FACULTY DETAILS:** | | |
|---|---|---|
| **Name:** Prof. Pramod Murari | **Designation:** Asst.Professor | **Experience:** 09 Years |
| **No. of times course taught(including present):** 02 | **Specialization:** Power Systems & Power Electronics | |

## 1.0 Prerequisite Subjects:

| Sl. No | Branch | Semester | Subject |
|---|---|---|---|
| 01 | Electrical and Electronics Engg | IV | PGE |
| 02 | Electrical and Electronics Engg | IV | TD |

## 2.0 Course Objectives

- To discuss primary components of power system planning namely load furcating, evaluation of energy resources, provisions of electricity Act and Energy Conservation Act.
- To explain planning methodology for optimum power system expansion, various types of generation, transmission and distribution
- To explain forecasting of anticipated future load requirements of both demand and energy by deterministic and statistical techniques using forecasting tools.
- To discuss methods to mobilize resources to meet the investment requirement for the power sector
- To perform economic appraisal to allocate the resources efficiently and take proper investment decisions
- To discuss expansion of power generation and planning for system energy in the country
- To discuss evaluation of operating states of transmission system, their associated contingencies and determination of the stability of the system for worst case conditions
- To discuss principles of distribution planning, supply rules, network development and the system studies
- To discuss reliability criteria for generation, transmission, distribution and reliability evaluation and analysis.
- To discuss grid reliability, voltage disturbances and their remedies.
- To discuss planning and implementation of electric –utility activities designed to influence consumer uses of electricity.
- To discuss market principles and the norms framed by CERC for online trading and exchange in the interstate power market of stability of a simple system.

## 3.0 Course Outcomes

Having successfully completed this course, the student will be able to,

| Course Code | Course Outcome | RBT Level | POs |
|---|---|---|---|
| C407.1 | Explain power system planning principles, planning process, different demand forecasting techniques. | L1,L2 | 1,2,6,8, 12 |
| C407.2 | Explain private participation, financial analysis, economic characteristics, clean coal technologies. | L1,L2,L3, L4 | 1,2,6,8, 12 |
| C407.3 | Explain criteria for transmission planning in power system. | L1,L2 | 1,2,6,8, 12 |
| C407.4 | Explain the different basic distribution systems, criteria for generation reliability. | L1,L2 | 1,2,6,8, 12 |
| C407.5 | Explain energy efficiency, demand response, principles of electricity market. | L1,L2 | 1,2,6,8, 12 |
| **Total Hours of instruction** | | **40** | |

## 4.0 Course Content

**Module-1**

**Power System:** Power Systems, Planning Principles, Planning Process, Project Planning, Power Development, Power Growth, National and Regional Planning, Enterprise Resources Planning, Structure of a Power System, Power Resources, Planning Tools, Power Planning Organization, Regulation, Scenario Planning.

**Electricity Forecasting:** Load Requirement, System Load, Electricity Forecasting, Forecasting Techniques, Forecasting Modeling, Spatial – Load Forecasting, Peak Load - Forecast, Reactive – Load Forecast, Unloading of a System. **8 Hours Revised Bloom's Taxonomy Level** L1 – Remembering, L2 – Understanding.

**Module-2**

**Power-System Economics:** Financial Planning, Techno – Economic Viability, Private Participation, Financial Analysis, Economic Analysis, Economic Characteristics – Generation Units, Transmission, Rural Electrification Investment, Total System Analysis, Credit - Risk Assessment, Optimum Investment, Tariffs.

**Generation Expansion:** Generation Capacity and Energy, Generation Mix, Conventional Generation Resources, Nuclear Energy, Clean Coal Technologies. **8 Hours. Revised Bloom's Taxonomy Level** L1 – Remembering, L2 – Understanding. L3 – Applying, L4 – Analyzing.

**Module-3**

**Generation Expansion (continued):** Distributed Power Generation, Renovation and Modernization of Power Plants.

**Transmission Planning:** Transmission Planning Criteria, Right – of – Way, Network Studies, High – Voltage Transmission, Conductors, Sub – Stations, Power Grid, Reactive Power Planning, Energy Storage. **8 Hours. Revised Bloom's Taxonomy Level** L2 – Understanding.

**Module-4**

**Distribution:** Distribution Deregulation, Planning Principles, Electricity – Supply Rules, Criteria and Standards, Sub – Transmission, Basic Network, Low Voltage Direct Current Electricity, Up gradation of Existing Lines and Sub – Stations, Network Development, System Studies, Urban Distribution, Rural Electrification, Villages Self – Sufficiency in Energy, Community Power, Self – Generation.

**Reliability and Quality:** Reliability Models, System Reliability, Reliability and Quality Planning, Functional Zones, Generation Reliability Planning Criteria, Transmission Reliability Criteria, Distribution Reliability, Reliability Evaluation, Grid Reliability, Reliability Target, Security Requirement, Disaster Management, Quality of Supply, Reliability and Quality Roadmap. **8 Hours. Revised Bloom's Taxonomy Level** L1 – Remembering, L2 – Understanding.

**Module-5**

**Demand-Side Planning:** Demand Response, Demand – Response Programmes, Demand– Response Technologies, Energy Efficiency, Energy - Economical Products, Efficient – Energy Users, Supply – Side Efficiency, Energy Audit.

**Electricity Market:** Market Principles, Power Pool, Independent System Operator, Distribution System Operator, Power Balancing, Market Participants, Power Markets, Market Rules, Bidding, Trading, Settlement System, Locational Marginal Pricing, Transmission Charges, Merchant Power, Differential Electricity, Congestion Management, Ancillary Services, Hedging, Smart Power Market. **8 Hours. Revised Bloom's Taxonomy Level** L1 – Remembering, L2 – Understanding.

## 5.0 Relevance to future subjects

| Sl No | Semester | Subject | Topics |
|---|---|---|---|
| 01 | VII | Computer techniques in power system analysis | All |
| 02 | VII | Power system simulation lab | Swing curve, power angle curve, fault analysis |
| 03 | VIII | Power system operation & control | All |

## 6.0 Relevance to Real World

| SL.No | Real World Mapping |
|---|---|
| 01 | Power system modeling |
| 02 | Analyze power system stability |
| 03 | Fault analysis of power system by software tools. |

## 7.0 Gap Analysis and Mitigation

| Sl. No | Delivery Type | Details |
|---|---|---|
| 01 | Practical | Doing fault analysis using mi-power simulation & obtaining power angle curve using MATLAB. |

## 8.0 Books Used and Recommended to Students

| Text Books |
|---|
| **Textbook** |
| 1. Electrical Power Planning, A.S. Pabla, McGraw Hill 2nd Edition, 2016 |

## 9.0 Relevant Websites (Reputed Universities and Others) for Notes/Animation/Videos Recommended

| Website and Internet Contents References |
|---|
| 1) http://www.power-eng.com/index.html |
| 2) http://www.ieee-pes.org/ |
| 3) http://www.electricalsolutions.net.au/content/efficiency-renewables/article/emergency-lighting-an-essential-service-783180538 |
| 4) http://www.edisontechcenter.org/LauffenFrankfurt.html |

## 10.0 Magazines/Journals Used and Recommended to Students

| Sl.No | Magazines/Journals | website |
|---|---|---|
| 1 | IEEE Transactions on power system | http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=59 |
| 2 | IEEE power engineering review | http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=39 |
| 3 | Power and Energy technology systems journal | http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=6687318 |

## 11.0 Examination Note

**Scheme of Evaluation for CIE (40 Marks)**
Internal Assessment test will be done in the same pattern as that of the main examination.
**Internal Assessment: 30 Marks**
**Assignment: 10 Marks**
**SCHEME OF EXAMINATION: 100 Marks, scaled down to 60 in VTU result sheet.**
The question paper will have ten questions.
Each full question is for 20 marks.
There will be 2 full questions (with a maximum of three sub questions in one full question) from each module.
Each full question with sub questions will cover the contents under a module.
Students will have to answer 5 full questions, selecting one full question from each module.

## 12.0 Course Delivery Plan

| Module | Lecture No. | Content of Lecture | % of Portion |
|---|---|---|---|
| I | 1. | **Power System:** Power Systems, Planning Principles, | 20 |
| | 2. | Planning Process, Project Planning, Power Development, Power Growth, | |
| | 3. | National and Regional Planning, Enterprise Resources Planning, Structure of a Power System, | |
| | 4. | Power Resources, Planning Tools, Power Planning Organization, Regulation, Scenario Planning. | |
| | 5. | **Electricity Forecasting:** Load Requirement, System Load, | |
| | 6. | Electricity Forecasting, Forecasting Techniques, Forecasting Modeling, | |
| | 7. | Spatial – Load Forecasting, Peak Load - Forecast, | |
| | 8. | Reactive – Load Forecast, Unloading of a System. | |
| II | 9. | **Power-System Economics:** Financial Planning, Techno – Economic Viability, | 20 |
| | 10. | Private Participation, Financial Analysis, Economic Analysis, | |
| | 11. | Economic Characteristics – Generation Units, Transmission, | |

| | | | |
|---|---|---|---|
| | 12. | Rural Electrification Investment, Total System Analysis, | |
| | 13. | Credit - Risk Assessment, Optimum Investment, Tariffs. | |
| | 14. | **Generation Expansion:** Generation Capacity and Energy, | |
| | 15. | Generation Mix, Conventional Generation Resources, | |
| | 16. | Nuclear Energy, Clean Coal Technologies. | |
| **III** | 17. | **Generation Expansion (continued):** Distributed Power Generation, | **20** |
| | 18. | Renovation and Modernization of Power Plants. | |
| | 19. | **Transmission Planning:** Transmission Planning Criteria, | |
| | 20. | Right – of – Way, Network Studies, | |
| | 21. | High – Voltage Transmission, | |
| | 22. | Conductors, Sub – Stations, | |
| | 23. | Power Grid, Reactive Power Planning, | |
| | 24. | Energy Storage. | |
| **IV** | 25. | **Distribution:** Distribution Deregulation, Planning Principles, Electricity – Supply Rules, | **20** |
| | 26. | Criteria and Standards, Sub – Transmission, Basic Network, Low Voltage Direct Current Electricity, | |
| | 27. | Up gradation of Existing Lines and Sub – Stations, Network Development, System Studies, | |
| | 28. | Urban Distribution, Rural Electrification, Villages Self – Sufficiency in Energy, Community Power, Self – Generation. | |
| | 29. | **Reliability and Quality:** Reliability Models, System Reliability, Reliability and Quality Planning, | |
| | 30. | Functional Zones, Generation Reliability Planning Criteria, Transmission Reliability Criteria, | |
| | 31. | Distribution Reliability, Reliability Evaluation, Grid Reliability, Reliability Target, | |
| | 32. | Security Requirement, Disaster Management, Quality of Supply, Reliability and Quality Roadmap. | |
| **V** | 33. | **Demand-Side Planning:** Demand Response, Demand – Response Programmes, | **20** |
| | 34. | Demand– Response Technologies, | |
| | 35. | Energy Efficiency, Energy - Economical Products, | |
| | 36. | Efficient – Energy Users, Supply – Side Efficiency, Energy Audit. | |
| | 37. | **Electricity Market:** Market Principles, Power Pool, Independent System Operator, Distribution System Operator, | |
| | 38. | Power Balancing, Market Participants, Power Markets, Market Rules, Bidding, Trading, Settlement System, | |
| | 39. | Locational Marginal Pricing, Transmission Charges, Merchant Power, Differential Electricity, | |
| | 40. | Congestion Management, Ancillary Services, Hedging, Smart Power Market. | |

## 13.0 Assignments

| Sl.No. | Title | Outcome expected | Allied study | Week No. | Individual / Group activity | Reference: book/website /Paper |
|---|---|---|---|---|---|---|
| 1 | Assignment 1: Model Questions on power system and electricity forecasting | Students will understand about power system planning and forecasting & get practice to solve university questions. | Module 1 of the syllabus | 2 | Individual Activity. Written explanation expected. | Text Book 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | Assignment 2: Model Questions on power system economics and generation expansion | Students will understand the power system economics and generation expansion methods & get practice to solve university questions. | Module 2 of the syllabus | 4 | Individual Activity. Written explanation expected. | Text Book 1, |
| 3 | Assignment 3: Model Questions on Generation expansion and transmission planning | Students understand explain transmission planning, get practice to solve university questions. | Module 3 of the syllabus | 6 | Individual Activity. Written explanation expected. | Text Book 1, |
| 4 | Assignment 4: Model Questions on distribution and reliability and quality | Students understand the concepts of distribution and reliability, quality & get practice to solve university questions. | Module 4 of the syllabus | 8 | Individual Activity. Written explanation expected. | Text Book 1, |
| 5 | Assignment 5: Model Questions on demand side planning and electricity market | Students will understand the concepts of demand side planning and electricity market & get practice to solve university questions. | Module 5 of the syllabus | 10 | Individual Activity. Written explanation expected. | Text Book 1, |

## 14.0 QUESTION BANK

**Module I (Power System, Electricity Forecasting)**

1. List out the planning principles.
2. What do you mean by planning process? Mention the step by step procedure to planning action with block diagram.
3. Explain about planning components.
4. Explain the levels of planning.
5. Write a note on DPR?
6. Explain about project implementation.
7. Explain the planning of power system development.
8. Explain the power growth in India.
9. Explain the national and regional planning of India.
10. Explain the concept of least cost utility planning.
11. Explain about enterprise resources planning (ERP).
12. Describe the structure of power system indicating the power system component and types.
13. Explain the power resources of India.
14. Discus the different planning tools in detail.
15. With structural model explain different organizations in power systems.
16. Explain the need for electricity regulations.
17. What are the salient features of Electricity Act 2003?
18. List out the important provisions in electricity rules 2005.
19. Explain about the scenario planning.
20. Briefly categorize various loads and explain.
21. Briefly explain about electricity forecasting.
22. Explain different demand forecasting techniques used in power planning.
23. Briefly explain the forecasting modeling.
24. Briefly explain the spatial load forecasting.
25. Explain peak load forecast.
26. Explain Reactive Load forecast.

27. With the aid of schematic diagram, explain various strategies of load management.
28. What is demand response? Explain demand-response planning with block diagram.

**Module II (Power System Economics, Generation Expansion)**

1. Explain financial planning and mention the pattern of investment in the power sector.
2. Explain about techno-economic viability.
3. With block diagram explain private participation with respect to ownership options and modes of participation in power system planning.
4. Explain financial analysis.
5. Explain objective of economic analysis of a power project.
6. What are the economic characteristics of generating units? Briefly elaborate.
7. What are the main areas of transmission investment?
8. Explain briefly about rural electrification investment.
9. Explain total system analysis in brief.
10. Briefly explain credit-risk assessment with relevant diagram.
11. What is optimum investment? Explain any two mathematical forms.
12. Mention national tariff policies and explain two types of basic tariffs.
13. Explain the different types of generation capacity with the help of typical daily load duration curve.
14. What is generation mix? Explain the importance of pumped storage system.
15. Briefly explain the conventional generation resources.
16. Explain nuclear energy and nuclear technology in brief.
17. With a schematic arrangement explain a Pressurized Water Reactor (PWR) nuclear power plant.
18. Explain clean coal technologies used in coal based plants.

**Module III (Generation expansion(continued), Transmission planning)**

1. What is distributed power generation and explain with figure biomass gasification.
2. What is distributed power generation and explain wave energy power generation with typical diagram.
3. Explain geothermal energy.
4. Explain power from oceans.
5. Explain captive power/cogeneration in brief.
6. Explain uprating and modernization of hydro plants.
7. Explain steam turbine rehabilitation and boiler renovation.
8. Explain the criteria for transmission planning in power system.
9. What is Right-of-way?
10. Explain how network studies is important in transmission network.
11. Explain about high voltage ac transmission.
12. What are the reasons and advantages favoring HVDC transmission lines?
13. Mention and explain different conductors used in transmission system.
14. What are the general factors to be considered for substation planning?
15. List out and explain different substation bus bar schemes.
16. Explain i)Grid formulation ii)Smart grid
17. Explain the planning criteria for reactive power compensation.
18. Explain how energy storage, a critical component for future strength of an electric grid.

**Module IV (Distribution, Reliability and Quality)**

1. Explain distribution deregulation.
2. What are the principles of distribution planning?
3. Summarize the rules of a particular supply authority for electricity distribution system as per section 50 of Electricity Act 2003
4. Explain criteria and standards for the distribution scheme done by planning process.
5. Explain briefly the sub-transmission, sub-stations, size of substation, feeders and distributors.
6. What are the different basic distribution systems used by utilities and explain radial and loop systems with figure.
7. Explain the selection of voltage levels and mention the table for voltage-application range.
8. Explain about Low Voltage Direct Current Electricity.
9. Explain briefly about upgradation of existing lines and substations.
10. Explain about network development in distribution system.

11. Explain urban distribution and mention how the underground distribution system has higher reliability than overhead.
12. What are the national rural electrification policies and main components of rural electrification?
13. What are the main components of rural electrification briefly explain.
14. Explain how every village in the country should be made self-sufficient in energy using local resources.
15. Explain about the participation of communities in making decisions about energy, including those for solar and wind power.
16. Explain how consumer is becoming prosumer in self generation.
17. List out the reliability models.
18. Explain about system reliability and list out the most typical causes of outages.
19. Explain reliability and quality planning. How to increase consumer's willingness to pay for a greater level of reliability?
20. What are functional zones and mention the different hierarchical levels.
21. Explain criteria for generation reliability.
22. Explain criteria for transmission reliability.
23. Explain criteria for distribution reliability.
24. Explain reliability evaluation in brief.
25. What are the purposes of conducting power system reliability studies?
26. The scope of reliability engineering in power system depends upon which factors?
27. With block diagram explain total system reliability cost analysis.
28. Explain grid reliability and mention the different aspects of reliability of the National power grid.
29. Explain reliability target.
30. Explain about security requirement.
31. Explain the disaster management and its planning.
32. Explain briefly about quality of supply.
33. Explain the planning for clean/conditioned power for the consumer.
34. Explain the reliability and quality roadmap.

**Module V (Demand side planning, Electricity Market)**

1. What is demand side planning? Briefly explain it.
2. What is demand response? Explain demand-response planning with block diagram.
3. List and explain demand response programmes.
4. Explain how demand response technologies facilitate communications with consumers and/or control air-conditioning systems.
5. With block diagram explain energy efficiency programmes.
6. Briefly explain energy economical products.
7. Write a note on efficient-energy uses.
8. Write a short note on supply-side efficiency.
9. Explain how an energy audit identifies where the potential for improvement lies.
10. What are the principles for the electricity market?
11. Explain how the Indian power market is a power-pool model. Draw the figure which shows transfer and supply of electricity via a pool (pool electricity marketing).
12. What are the functions of Distribution System Operator (DSO) to implement the code for embedded generation and in meeting system requirements?
13. What is power balancing? Draw the block diagram of power-market balancing mechanism.
14. What is optimal dispatch?
15. Who are the market participants? Explain.
16. Name different types of power markets.
17. List and briefly explain the different power markets.
18. Explain the concept of market rules.
19. What is meant by Bidding? Explain.
20. What is meant by Trading? Explain.
21. Explain about settlement system.
22. What is locational marginal pricing? Explain.
23. What are the major components in the costs of transmission transactions?

24. What is the meaning of wheeling? Explain.
25. Explain about merchant power.
26. What is differentiated electricity?
27. Explain congestion management.
28. What are ancillary services? Explain.
29. Briefly explain Hedging. What are hedge contracts, future contracts, forward and option contracts?
30. Explain smart power market and mention the aim of electricity market reforms.

## 15. University Result

| Examination | % Passing |
|---|---|
| Jan 2020 | 100% |

| Prepared by | Checked by | | |
|---|---|---|---|
| Prof. P M Murari | Prof. H. R Zinage | HOD | Principal |

| **Subject Title** | **TESTING AND COMMISSIONING OF ELECTRICAL EQUIPMENT** | | |
|---|---|---|---|
| **Subject Code** | 17EE752 | **CIE Marks** | 40 |
| **Number of Lecture Hrs / Week** | 03 | **SEE Marks** | 60 |
| **Total Number of Lecture Hrs** | 40 | **Exam Hours** | 03 |
| **CREDITS – 03** | | | |

| **FACULTY DETAILS:** | | |
|---|---|---|
| **Name:** Prof. S.G.Huddar | **Designation:** Asst .Professor | **Experience:**07 years |
| **No. of times course taught:**01 | **Specialization:** Power System Engineering. | |

## 1.0 Prerequisite Subjects:

| Sl. No | Branch | Semester | Subject |
|---|---|---|---|
| 01 | Electrical & Electronics Engineering | I/II | Basic Electrical Engineering |
| 02 | Electrical & Electronics Engineering | III | Transformer & Generator |
| 03 | Electrical & Electronics Engineering | IV | Electric motor |
| 04 | Electrical & Electronics Engineering | V | Direct current and synchronous machine |
| 05 | Electrical & Electronics Engineering | VI | Electrical machine design |

## 2.0 Course Objectives

1. Describe the process to plan, control and implement commissioning of electrical equipment's.
2. Differentiate the performance specifications of transformer and induction motor.
3. Demonstrate the routine tests for synchronous machine, induction motor, transformer & switchgears.
4. Identification of tools and equipment's used for installation and maintenance of electrical equipment.
5. Explain the operation of an electrical equipment's such as isolators, circuit breakers, insulators and switchgears.

## 3.0 Course Outcomes

Having successfully completed this course, the student will be able to

| | Course Outcome | Cognitive Level | POs |
|---|---|---|---|
| CO409.1 | Describe the process to plan, control and implement commissioning of electrical equipment's. | L1,L2 | 1,3,6,7 |
| CO409.2 | Differentiate the performance specifications of transformer and induction motor. | L1,L2 & L3 | 1,2,3,4,6, 7,8 |
| CO409.3 | Demonstrate the routine tests for synchronous machine, induction motor, transformer & switchgears. | L1,L2,L3, L4& L5 | 1,2,3,6,7, 9, |
| CO409.4 | Describe corrective and preventive maintenance of electrical equipment's. | L1,L2,L3, L4& L5 | 1,2,3,6,9 |
| CO409.5 | Explain the operation of an electrical equipment's such as isolators, circuit breakers, induction motor and synchronous machines. | L1,L2,L3, L4& L5 | 1,2,3,4,6 |
| **Total Hours of instruction** | | **40** | |

## 4.0 Course Content

**PART - A**

**Module-1**

**Electrical Tools, accessories**: Tools, Accessories and Instruments required for Installation, Maintenance and Repair Work, India Electricity Rules, Safely Codes Causes and Prevention of Accidents, Artificial Respiration, Workmen's Safety Devices.

**Transformers**:

Installation, Location Site Selection, Foundation Details, Code of Practice for Terminal Plates, Polarity and Phase Sequence, Oil Tanks, Drying of Winding sand General Inspection. Commissioning Tests As Per National and International Standards - Volts Ratio Earth Resistance, Oil Strength, Insulation Tests, Impulse Tests Polarizing Index, Load Temperature Rise Tests. Specific Tests for Determination of Performance Curves like Efficiencies, Regulation Etc., Determination Mechanical Stress Under Normal and Abnormal Conditions. **08 Hours**

**Revised Blooms Taxonomy level:** $L_1$-Remembering, $L_2$-Understanding.

**Module-2**

**Synchronous Machines:** Specifications as per BIS Standards. Installation - Physical Inspection, Foundation Details, Alignments, Excitation Systems, Cooling and Control Gear, Drying Out.

Commissioning Tests - Insulation, Resistance Measurement of Armature and Field Windings, Wave Form and Telephone Interference Tests, Line Charging Capacitance. Performance Tests -Various Tests to Estimate the Performance of Generator Operations, Slip Test, Maximum Lagging Current, Maximum Reluctance Power Tests, Sudden Short Circuit Tests, Transient Sub Transient Parameters, Measurement of Sequence Impedances, Capacitive Reactance, and Separation Of Losses, Temperature Rise Test, and Retardation Tests. Factory Tests -Gap Length, Magnetic Eccentricity, Balancing Vibrations, Bearing Performance. **08 Hours**

**Revised Blooms Taxonomy level:** $L_1$-Remembering, $L_2$-Understanding, $L_3$-Applying.

**Module-3**

**Induction Motor:** Specifications. Installation- Location of Motors and its Control Apparatus, Shaft Alignment for Various Coupling, Fitting of Pulleys and Coupling, Drying of Windings. Commissioning Tests -Mechanical Tests For Alignment, Air Gap Symmetry, Tests for Bearings, Vibrations and Balancing. Specific Tests -Performance and Temperature Raise Tests, Stray Load Losses, Shaft Alignment, Re-Writing and Special Duty Capability, Site Test

**08 Hours**

**Revised Blooms Taxonomy level:** $L_1$-Remembering, $L_2$-Understanding, $L_3$-Applying, $L_4$-Analysing.

**Module- 4**

**Laying of Underground Cables:** Inspection, Storage, Transportation and Handling of Cables, Cable Handing Equipment, Cable Laying Depths and Clearances from other Services such as Water Sewerage, Gas, Heating and other Mains, Series of Power and Telecommunication Cables and Coordination with these Services, Excavation of Trenches, Cable Jointing and Terminations Testing and Commissioning. Location of Faults using Megger, Effect of Open or Loose Neutral Connections, Provision of Proper Fuses on Service Lines and Their Effect on System, Causes and Dim, and Flickering Lights **.** **08 Hours**

**Revised Blooms Taxonomy level:** $L_1$-Remembering, $L_2$-Understanding, $L_3$-Applying, $L_4$-Analysing, $L_5$-Evaluating.

**Module-5**

**Switchgear and Protective Devices:** Standards, Types, Specification, Installation, Commissioning Tests, Maintenance Schedule, Type and Routine Tests.

**Domestic Installation:** Introduction, Testing of Electrical Installation of a Building, Testing of Insulation Resistance to Earth, Testing of Insulation and Resistance between Conductors Continuity or Open Circuit Test, Short Circuit Test, Testing of Earthing Continuity, Location of Faults, IE Rules for Domestic Installation. **08 Hours**

**Revised Blooms Taxonomy level:** $L_1$-Remembering, $L_2$-Understanding, $L_3$-Applying, $L_4$-Analysing, $L_5$-Evaluating.

## 5.0 Relevance to future subjects

| Sl No | Semester | Subject | Topics |
|---|---|---|---|
| 01 | VII & VIII | Project work | Testing of machines |
| 02 | VII & VIII | Seminar | |

## 6.0 Relevance to Real World

| SL.No | Real World Mapping |
|---|---|
| 01 | Knowledge of specifications as per BIS for Purchase of electrical machines. |
| 02 | Testing and commissioning of Electrical machines at site |
| 03 | Testing and commissioning of switchgear and protective devices |

## 7.0 Gap Analysis and Mitigation

| Sl. No | Delivery Type | Details |
|---|---|---|
| 01 | Industry also Field Visit | Testing and commissioning of Electrical machines . |
| 02 | Field Visit | Substation. |

## 8.0 Books Used and Recommended to Students

**Text & Reference Books**

1. Testing, Commissioning, Operation and Maintenance of Electrical Equipment . S. Rao, Khanna Publishers 6th Edition, 19th Reprint, 2015
2. Testing and Commissioning of Electrical Equipment . R.L.Chakrasali , Prism Books Pvt Ltd. 1st Edition,2014
3. Preventive Maintenance of Electrical Apparatus . S.K.Sharotri. Katson Publishing House , 1st Edition, 1980
4. Handbook of Switchgears, BHEL , McGraw Hill , 1st Edition, 2005
5. Transformers, BHEL, McGraw Hill, 1st Edition, 2003
6. The J&P Transformer Book , Martin J. Heathcote , Newnes , 12th Edition, 1998

## 9.0 Relevant Websites (Reputed Universities and Others) for Notes/Animation/Videos Recommended

**Website and Internet Contents References**

1) http://www.electrical4u.com
2) www.nptel.com
3) https://en.wikipedia.org/wiki/**Testing and commissioning of electrical equipment**
4) www.electrical4u.com/**testing and commissioning -of-transformer/**
5) www.ijset.net/journal/68.pdf
6) www.electrical4u.com/**testing and commissioning of induction machine**
7) www.electrical4u.com/**testing and commissioning of synchronous machine**
8) www.electricaleasy.com/.../**tesing and commissioning of circuit breakers**

## 10.0 Magazines/Journals Used and Recommended to Students

| Sl.No | Magazines/Journals | website |
|---|---|---|
| 1 | Omics journal | **www.omicsonline.org/Engineering/CitationReports** |
| 2 | Ge grid journal | **https://www.gegridsolutions.com/multilin/journals/issues/PCJ-** |

| | | |
|---|---|---|
| | | **October2008.pdf** |
| 3 | Neta world journal | **www.wtol.com/.../top-stories-on-electrical-testing-from-neta-world-journals-winter-2016** |
| 4 | IAEI magazine | **iaeimagazine.org/magazine/.../third-party-electrical-testing** |
| 5 | ES magazine | **www.esmagazine.com/ext/resources/ES/Home/Files/PDF/0906Schneider Electric.pdf** |

## 11.0 Examination Note

**Scheme of Evaluation for CIE (40 Marks)**

Internal Assessment test will be done in the same pattern as that of the main examination.

**Internal Assessment: 30 Marks**

**Assignment: 10 Marks**

**SCHEME OF EXAMINATION: 100 Marks, scaled down to 60 in VTU result sheet.**

The question paper will have ten questions.

- Each full question is for 20 marks.
- There will be 2 full questions (with a maximum of three sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module.

## 12.0 Course Delivery Plan

| Unit No. | Lecture No. | Content of Lecture | % of Portion |
|---|---|---|---|
| MODULE-I | 1 | **Electrical Tools, accessories**: Tools, Accessories and Instruments required for Installation, Maintenance and Repair Work, India Electricity Rules, Safely Codes Causes and Prevention of Accidents, Artificial Respiration, Workmen's Safety Devices | 20.00% |
| | 2 | **Installation:** Location, site, oil tanks, drying of windings and general inspection. | |
| | 3 | selection, foundation details (like bolts size, their number, etc) | |
| | 4 | Code of practice for terminal plates, | |
| | 5 | polarity & phase sequence, Oil tanks, Drying of windings | |
| | 6 | **Commissioning tests:** As per national & International Standards,. Volt ratio test, Earth resistance, oil strength, | |
| | 7 | Insulation test, impulse test, Polarizing index, load & temperature rise test | |
| | 8 | **Specific Tests:** Determination of performance curves like efficiency, regulation etc, &abnormal conditions. Determination of mechanical stress under normal & abnormal conditions | |
| MODULE-II | 9 | **Synchronous machines: Specifications-** As per BIS standards | 20% |
| | 10 | **Installation:** Physical inspection, foundation details, alignments, excitation systems, cooling and control gear, drying out | |
| | 11 | **Commissioning Tests:** Insulation, Resistance measurement of armature & field windings, waveform | |
| | 12 | Telephone interference tests, line charging capacitance | |
| | 13 | **Performance tests:** Various tests to estimate the performance of generator operations, slip test, maximum lagging current, maximum reluctance power tests | |
| | 14 | Sudden short circuit tests, transient & sub transient parameters, Measurements of sequence impedances | |
| | 15 | Capacitive reactance, and separation of losses. Temperature rise test, and retardation tests | |
| | 16 | **Factory tests:** Gap length, magnetic eccentricity, balancing vibrations, bearing performance | |
| MODULE -III | 17 | **INDUCTION MOTORS:** a. **Specifications** for different types of motors, **Installation** Location of Motors | 20% |
| | 18 | Its control apparatus, shaft & alignment for various coupling | |
| | 19 | Fitting of pulleys & coupling, drying of windings | |
| | 20 | **Commissioning Test:** Mechanical tests for alignment, air gap symmetry, | |

| | | | |
|---|---|---|---|
| | 21 | Tests for bearings, vibrations & balancing | |
| | 22 | **Specific Tests:** Performance & temperature raise tests, | |
| | 23 | Stray load losses, shaft alignment, | |
| | 24 | Re-rating & special duty capability, Site test | |
| **MODULE-IV** | 25 | **Laying of Underground Cables:** Inspection, Storage, Transportation and Handling of Cables, Cable Handing Equipment. | 20% |
| | 26 | Cable Laying Depths and Clearances from other Services such as Water Sewerage, Gas, | |
| | 27 | Heating and other Mains, Series of Power and Telecommunication Cables and Coordination with these Services | |
| | 28 | Excavation of Trenches, Cable Jointing and Terminations Testing and Commissioning. | |
| | 29 | Location of Faults using Megger, | |
| | 30 | Effect of Open or Loose Neutral Connections | |
| | 31 | Provision of Proper Fuses on Service Lines | |
| | 32 | Their Effect on System, Causes and Dim, and Flickering Lights | |
| **MODULE-V** | 33 | **Switch gear & protective devices:** Standards, types, specification. | 20% |
| | 34 | Installation, commissioning tests, maintenance schedule. | |
| | 35 | Type & routine tests. | |
| | 36 | **Domestic Instalation:** Introduction, Testing of Electrical Installation of a Building | |
| | 37 | Testing of Insulation Resistance to Earth, Testing of Insulation and Resistance between Conductors Continuity | |
| | 38 | Open Circuit Test, Short Circuit Test | |
| | 39 | Testing of Earthing Continuity, Location of Faults | |
| | 40 | IE Rules for Domestic Installation | |

## 13.0 Assignments, Pop Quiz, Mini Project, Seminars

| Sl. No. | Title | Outcome expected | Allied study | Week No. | Individual / Group activity | Reference: book/website /Paper |
|---|---|---|---|---|---|---|
| 1 | Assignment 1: University Questions on transformer | Students study the Topics and write the Answers. Get practice to solve university questions. | Module-I | 3 | Individual Activity. group activity like site visit. | Book 1, 2 of the reference list. Website of the Reference list |
| 2 | Assignment 2: University Questions on synchronous machine | Students study the Topics and write the Answers. Get practice to solve university questions. | Module-II | 5 | Individual Activity. group activity like site visit. | Book 1, 2 of the reference list. Website of the Reference list |
| 3 | Assignment 3: University Questions on induction motor | Students study the Topics and write the Answers. Get practice to solve university questions. | Module-III | 7 | Individual Activity. group activity like site visit. | Book 1, 2 of the reference list. Website of the Reference list |
| 4 | Assignment 4: University Questions on switchgear and protective device | Students study the Topics and write the Answers. Get practice to solve university questions. | Module-IV | 9 | Individual Activity./group activity like site visit. | Book 1, 2 of the reference list. Website of the Reference list |
| 5 | Assignment 5: University Questions on switchgear and protective device | Students study the Topics and write the Answers. Get practice to solve university questions. | Module-V | 10 | Individual Activity./ Industrial visit | Book 1, 2 of the reference list. Website of the Reference list |

## 14.0 QUESTION BANK

**Module -I**

1. Explain the principles, objectives and significance of protection and monitoring of transformers.
2. Explain the principle of circulating current differential protection, supplied to power transformer.
3. Explain the significance of temperature rise test and method to conduct temperature rise test on power transformer.
4. Explain the procedure of drying out of power transformer.
5. State the various commissioning tests on power transformer.
6. Explain the various procedure of procuring power transformer before it is commissioned.
7. What are properties of good insulating oil used in transformer.
8. Explain breakdown voltage test conducted on transformer.
9. What is drying of transformer? Explain different methods of drying out.
10. Explain various accessories of power transformer.
11. Explain different methods of cooling of power transformers.
12. What are different standards and what is the need for standardization of specifications.
13. Mention the specifications of power transformer.
14. What is the significance of testing. Explain various tests performed on power transformers.
15. Mention the safety precautions to be taken while commissioning and maintaining the transformer.

**Module -II**

1. State and explain essential steps in unit commissioning of synchronous machines.
2. State and explain the procedure of various tests on synchronous machine & their significance.
3. State the causes for vibrations in motors and generators. How are the vibrations measured? State how to overcome the vibration problems at site.
4. Explain the procedures of foundation of electric machines.
5. Mention the various specifications of alternator.
6. Explain suitability of hydrogen as coolant used in turbo alternator.
7. Explain the sudden three phase short circuit test conducted on alternators.
8. Define SCR of synchronous machine. What is its significance? Explain the procedure to determine it.
9. Explain the procedure of measuring DC resistance of armature winding of a synchronous machine.
10. Explain the protection scheme of rotating electrical machine.
11. Describe the negative phase sequence test on synchronous machine.
12. Explain different methods of starting synchronous machines.
13. Explain the typical specification of an alternator.
14. Explain types of methods of cooling and types of enclosures of an alternator.
15. What are steps involved in installation of an alternator?

**Module -III**

1. Write a short note on Temperature rise in IM
2. Explain the foundation details for installing IM.
3. Explain the various methods of measuring the slip of IM.
4. What are the different methods of measuring temperature rise IM.
5. Explain de-rating of IM.
6. Explain the drying out methods for induction motor.
7. Explain the methods of measuring slip of an IM.
8. Explain different duties of IM.
9. Explain specifications of three phase IM.
10. Write a short note on performance requirements and other special requirements of IM.

**Module -IV**

1. What are the points to be considered for inspection and storage of UG cables?
2. How the cables handled and lying of cables.
3. Excavation of Trenches, Cable Jointing and Terminations Testing and Commissioning
4. Explain the Location of Faults using Megger.
5. Effect of Open or Loose Neutral Connections & Provision of Proper Fuses on Service Lines

**Module -V**

1. What are different types of type tests conducted on CB? Explain.
2. What are the factors to be considered while selecting a CB? Explain.

3. State and explain the various tests performed on high voltage a.c circuit breakers.
4. Explain the various steps in maintenance of CB.
5. Write a short note on various steps in installation and commissioning of outdoor CB.
6. Describe the general guidelines to maintain high voltage CB.
7. Explain briefly testing of Insulation resistance to Earth.
8. Explain the open circuit test & short circuit test and continuity test.
9. What are the I E Rules for Domestic Installation?

## 15.0 University Result

| Examination | S+ | S | A | B | C | D | E | F | % Passing |
|---|---|---|---|---|---|---|---|---|---|
| Jan 2020 | 0 | 0 | 3 | 16 | 17 | 5 | 4 | 0 | 100% |
| Jan 2019 | 0 | 2 | 10 | 13 | 13 | 6 | 3 | 0 | 100% |

| Prepared by | Checked by | | |
|---|---|---|---|
| Prof. S.G.Huddar | Prof.H.R.Zinage | HOD | Principal |

| **Subject Title** | **RELAY AND HIGH VOLTAGE LAB** | | |
|---|---|---|---|
| **Subject Code** | 17EEL77 | **CIE Marks** | 40 |
| **No of Practical Hrs / Week** | 03 | **SEE Marks** | 60 |
| **Total No of Practical Hrs** | 42 | **Exam Hours** | 03 |
| | | **Credits-02** | |

| **FACULTY DETAILS:** | | |
|---|---|---|
| **Name:** Prof. S. D. Hirekodi | **Designation:** Asst. Professor | **Experience:** 20Years |
| **No. of times course taught:** 04 | **Specialization:** Power Electronics | |

## 1.0 Prerequisite Subjects:

| Sl. No | Branch | Semester | Subject |
|---|---|---|---|
| 01 | Electrical and Electronics Engineering | VII | High Voltage Engineering |
| 01 | Electrical and Electronics Engineering | VII | Power System Protection |

## 2.0 Course Objectives

1.To conduct experiments to verify the characteristics of over current, over voltage, under Voltage relays both electromagnetic and static type.
2. To verify the operation of negative sequence relay.
3. To conduct experiments to verify the characteristics of microprocessor based over current, Over Voltage, under voltage relays and distance relay.
4. To conduct experiments on generator, motor and feeder protection.
5.To conduct experiments to study the spark over characteristics for both uniform and non-Uniform Configurations using High AC and DC voltages.
6.To measure high AC and DC voltages
7. To experimentally measure the breakdown strength of transformer oil.
8. To experimentally measure the capacitance of different electrode configuration models using Electrolytic Tank. To generate standard lightning impulse voltage and determine efficiency, Energy of Impulse generator and 50% probability flashover voltage for air insulation.

## 3.0 Course Outcomes

The student, after successful completion of the course, will be able to

| CO | Course Outcome | RBT level | POs |
|---|---|---|---|
| C413.1 | Experimentally verify the characteristics of over current, over voltage, under voltage and negative sequence relays of both electromagnetic and static type. | $L_3$-$L_5$ | 1,2,8,9,10 |
| C413.2 | Experimentally verify the characteristics of microprocessor based over current, over voltage, under voltage relays and distance relay. | $L_3$-$L_5$ | 1,2,8,9,10 |
| C413.3 | Justify knowledge of protection schemes of generator, motor and feeders. | $L_3$-$L_5$ | 1,2,8,9,10 |
| C413.4 | Analyze the spark over characteristics for both uniform and non-uniform field configurations using High voltage AC and DC. | $L_3$-$L_5$ | 1,2,8,9,10 |
| C413.5 | Measure high AC and DC voltages and breakdown strength of transformer oil. | $L_3$-$L_5$ | 1,2,8,9,10 |
| C413.6 | Draw electric field lines and measure the capacitance of different electrode configuration models. | $L_3$-$L_5$ | 1,2,8,9,10 |
| C413.7 | Justify knowledge of generating standard lightning impulse voltage to determine efficiency, energy of impulse generator and 50% probability flashover voltage for air insulation. | $L_3$-$L_5$ | 1,2,8,9,10 |
| **Total Hours of instruction** | | **42** | |

## 4.0 Course Content

**PART A**

1. over current relay
   (a) IDMT non-directional characteristics
   (b) Directional features
   (c) IDMT directional
2. IDMT characteristics of over voltage or under voltage relay (Solid state or electromechanical type)
3. Operation of negative sequence relay.

**PART B**

4. Operating characteristics of microprocessor based (numeric) over current relay.
5. Operating characteristics of microprocessor based (numeric) distance relay.
6. Operating characteristics of microprocessor based (numeric) over/under voltage relay.

**PART C**

7. Generator protection –Merz-Price- protection scheme.
8. Feeder protection against faults.
9. Motor protection against faults.

**PART D**

10. Spark Over Characteristics of Air subjected to High Voltage AC with Spark Voltage Corrected to Standard Temperature and Pressure for Uniform [as per IS1876: 2005] and Non-uniform [As per IS2071 (Part 1): 1993] Configurations: Sphere – Sphere, Point –Plane, Point – Point and Plane – Plane.
11. Spark over characteristics of air subjected to high voltage DC.
12. Measurement of HVAC and HVDC using standard spheres as per IS 1876:2005
13. Measurement of Breakdown Strength of Transformer Oil as per IS 1876:2005
14. Field Mapping using Electrolytic Tank for any one of the following Models: Cable/ Capacitor/ Transmission Line/ Sphere Gap.
15. (a) Generation of standard lightning impulse voltage and to determine efficiency and energy of impulse Generator. (b) To determine 50 % probability flashover voltage for air insulation subjected to Impulse voltage.

## 5.0 Relevance to future subjects

| SL. No | Semester | Subject | Topics / Relevance |
|---|---|---|---|
| 01 | VIII | Project work | Design and Testing of hardware models related to HVE |

## 6.0 Relevance to Real World

| SL. No | Real World Mapping |
|---|---|
| 01 | Electric breakdown phenomena in gases and liquid dielectrics |
| 02 | High voltage AC, DC generation in power research laboratory for insulation testing of electrical equipments and switchgear. |
| 03 | High voltage measurements in research laboratory during testing of electrical equipments and switchgear. |
| 04 | Working of electromechanical type over current, over voltage and microprocessor based over current and over /under voltage relay. |
| 05 | Equi-potential lines of different electrode models |
| 06 | Fault analysis of 3-phase Induction motor |

## 7.0 Books Used and Recommended to Students

| **Text Books** |
|---|
| 1. **High Voltage Engineering** by M.S.Naidu and Kamaraju- 4th Edition, THM, 2008.<br>2. **High Voltage Engineering Fundamentals** by E.Kuffel and W.S. Zaengl, 2nd Edition, Elsevier Press, 2005.<br>3. **High Voltage Engineering** by C.L.Wadhwa, New Age International Private limited, 1995. |
| **Reference Books** |
| 1.**High Voltage Engineering Theory and Practice** by Mazen Abdel-Salam, Hussein Anis, Ahdab El-Morshedy, Roshdy Radwan, 2nd Edn(Revised & Expanded) Marcel-Dekker Publishers (Special Indian Edn.).<br>2. **High voltage Engineering** by Subir Ray, Newage International |
| **Additional Study material & e-Books** |
| 1. High Volatge test and measuring techniques: Springer<br>2. High voltage and electrical insulation engineering by Ravindra Arora |

## 8.0 Relevant Websites (Reputed Universities and Others) for Notes/Animation/Videos Recommended

| **Website and Internet Contents References** |
|---|
| 1) http://www.cpri.in/about-us/departmentsunits/high-voltage-division-hvd.html<br>2) http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6432571 |

## 9.0 Magazines/Journals Used and Recommended to Students

| Sl.No | Magazines/Journals | website |
|---|---|---|
| 1 | IEEE Technology Navigator | http://technav.ieee.org/tag/8470/relays#concepts |

## 10.0 Examination Note

**Scheme of Evaluation for** CIE**: (40 Marks)**

(a) Internal Assessment test in the same pattern as that of the main examination: 16marks.

(b) Continuous assessment for laboratory experiments: 24 marks.

**SCHEME OF EXAMINATION:**

One question is to be set for 100 marks.

a) Write-up: 15% of Maximum marks
b) Conduction: 70% of Maximum marks
c) Viva-voce: 15% of Maximum marks

## 11.0 Course Delivery Plan

| Part | Expt. No. | Name of the experiment | % of Portion |
|---|---|---|---|
| D | 1 | Spark over characteristics of air subjected to high voltage DC. | 36% |
| | 2 | Measurement of HVAC and HVDC using standard spheres as per IS 1876:2005 | |
| | 3 | Spark Over Characteristics of Air subjected to High Voltage AC with Spark Voltage Corrected to Standard Temperature and Pressure for Uniform [As per IS1876: 2005] and Non-uniform [As per IS2071 (Part 1): 1993] Configurations: Sphere – Sphere, Point –Plane, Point – Point and Plane – Plane. | |
| | 4 | Measurement of Breakdown Strength of Transformer Oil as per IS 1876:2005 | |
| | 5 | Field Mapping using Electrolytic Tank for any one of the following Models: Cable/ Capacitor/Transmission Line/ Sphere Gap. | 9% |
| C | 6 | Motor protection against faults | 18% |
| | 7 | Generator protection –Merz-Price- protection scheme. | |

| | | | |
|---|---|---|---|
| **B** | 8 | Operating characteristics of microprocessor based (numeric) over current relay | 18% |
| | 9 | Operating characteristics of microprocessor based (numeric) over/under voltage relay. | |
| A | 10 | Over current relay<br>(a) IDMT non-directional characteristics<br>(b) Directional features<br>(c) IDMT directional | 18% |
| | 11 | IDMT characteristics of over voltage or under voltage relay (Electromechanical type) | |

## 12.0 QUESTION BANK

1. What is protective relay? Explain its function in an electrical system.
2. What are the fundamental requirements of protective relaying?
3. Define the following terms as applied to protective relaying.
    a. Pick up current
    b. Current setting
    c. Plug setting multiplier (PSM)
    d. Time setting multiplier (TSM)
4. What is the difference between a fuse and a relay?
5. What is the difference between an over current relay and current differential relay?
6. Why are differential relays more sensitive than over current relays?
7. Sketch a typical time Vs PSM curve.
8. What do you understand by differential relay?
9. What are the different types of differential relay?
10. How do you classify relays based on their time of operation?
11. How do you classify relays based on their operating principle?
12. How do you classify relays based on their application?
13. List out some important types of electromagnetic attraction relays.
14. What are the various steps to be followed for calculating the actual relay operating time?
15. How do you classify relays based on their application?
16. What is a fuse? What are its advantages and disadvantages?
17. Why do we prefer silver as a fuse element?
18. Define the following terms as applied to fuse.
    Fusing current, Cut-off current, Operating Time, Breaking capacity, Fusing factor, Current rating of fuse element, Prospective current, Pre-arcing time, Arcing time
19. What is the difference between a fuse and a circuit breaker?
20. Why are circuit breakers preferred to fuses?
21. Why fuses cannot provide adequate discrimination on heavy short circuit?
22. Why fuses can interrupt heavy short circuit currents successfully?
23. On what factors fusing current of fuse element depends?
24. What are commonly used materials for manufacturing fuse elements?
25. What are desirable characteristics of fuse elements?
26. What is fuse law?
27. What do you understand by fuse constant? What are typical values of fuse constant for different fuse elements?
28. How do you classify fuses?
29. What are the protection schemes available for induction motor?
30. What are causes of over currents in an Induction motor?
31. How to protect Induction motor against over currents?
32. What do you understand by “single phasing’’ of an Induction motor?
33. How to protect Induction motor against “single phasing’’ problems?
34. What are the causes of over voltages in an Induction motor?
35. How to protect Induction motor against over voltages?
36. What are the advantageous of micro-processor based relays over electro-mechanical relays?

37. What is the definition of high voltage?
38. What are the different types of voltages occurring in high voltage practice?
39. What is the usual classification of voltages used in A.C. transmission?
40. What are the materials used for high voltage equipment and transmission lines?
41. For what purposes are materials used in H.V. work?
42. What are the usual materials for conductors used in high voltage equipment and transmission lines/
43. What are the salient characteristics of metals to consider for use in high voltage work?
44. How are insulating materials used in H.V. work classified?
45. What are the most important types of solid insulation?
46. What are the physical and electrical properties of important solid insulations suitable for high voltage work?
47. Define the following terms as applied to solid insulation
    1) Dielectric strength 2) Loss angle 3) Dielectric constant.
48. What are most usual insulating materials used in high voltage equipment?
49. What are the salient properties of liquid insulating materials?
50. What are the most usual gaseous insulating media used in high voltage equipment?
51. What are the physical and electrical properties of important gaseous insulating media?
52. What are the important properties of vacuum as insulation?
53. What is meant by Electrical Breakdown?
54. What are the units for measurement of the breakdown strength of insulating materials?
55. What is meant by the withstand strength of an insulations?
56. What are the breakdown voltage values of some important insulating materials?
57. What are the shapes of electrodes in common use in high voltage equipment?
58. What are the major factors causing electrical breakdown of solid insulation?
59. What is the mechanism of electrical breakdown of a solid insulating material such as paper?
60. What are the mechanisms for breakdown of liquid dielectrics?
61. What is the principal mechanism for breakdown of a gaseous insulation?
62. What is the formula for spark over voltage for an air gap in uniform field?
63. What is meant by Corona in non-uniform field gaps?
64. What are the different types of cables used for high voltage work?
65. What is meant by Corona? How and where does it occur in high voltage equipment?
66. What are the effects of corona in high voltage equipments?
67. What is the minimum clearance prescribed by the national electrical Code or Codes for high voltage transmission lines from safety considerations?
68. What is a cascade –connected transformer and where is this used?
69. What are the standard high voltages used for A.C. transmission lines and high voltage equipment?
70. What are the types of protection required in high voltage systems?
71. What are the types of sources required to perform tests on equipment in a high voltage laboratory?
72. What is the wave shapes of voltage and current used in high voltage testing?
73. What are the major types of measurement to be carried out in a high voltage laboratory for testing equipment?
74. How does a sphere gap measure a voltage? What is the technique to be followed in using this?
75. How is a resistive voltage divider used for measuring high voltage?

| Prepared by | Checked by | | |
|---|---|---|---|
| Prof. A. U. Neshti | Prof. M. P. Yanagimath | HOD | Principal |

| **Subject Title** | **POWER SYSTEM SIMULATION LABORATORY** | | |
|---|---|---|---|
| **Subject Code** | 17EEL76 | **CIE Marks** | 40 |
| **No of Practical Hrs / Week** | 03 | **SEE Marks** | 60 |
| **Total No of Practical Hrs** | 42 | **Exam Hours** | 03 |
| **Credits-02** | | | |

| **FACULTY DETAILS:** | | |
|---|---|---|
| **Name:** Prof. Hemalata R. Zinage | **Designation:** Asst. Professor | **Experience:** 20Years |
| **No. of times course taught:** 05 Times | | **Specialization:** Power System |

## 1.0 Prerequisite Subjects:

| Sl. No | Branch | Semester | Subject |
|---|---|---|---|
| 01 | Electrical and Electronics Engineering | IV | Transmission and Distribution |
| 01 | Electrical and Electronics Engineering | VI | Power System Analysis-I |
| 01 | Electrical and Electronics Engineering | VII | Power System Analysis-II |

## 2.0 Course Objectives

1.To explain the use of MATLAB package to assess the performance of medium and long transmission lines.
2. To explain the use of MATLAB package to obtain the power angle characteristics of salient and non- salient pole alternator.
3. To explain the use of MATLAB package to study transient stability of radial power systems under three phase fault conditions.
4. To explain the use of MATLAB package to develop admittance and impedance matrices of interconnected power systems.
5.To explain the use of Mi-Power package to solve power flow problem for simple power systems.
6. To explain the use of Mi-Power package to perform fault studies for simple radial power systems.
7. To explain the use of Mi-Power package to study optimal generation scheduling problems for thermal power plants.

## 3.0 Course Outcomes

The student, after successful completion of the course, will be able to

| CO | Course Outcome | Cognitive Level | POs |
|---|---|---|---|
| C406.1 | Develop a program in MATLAB to assess the performance of medium and long transmission lines. | $L_3$-$L_6$ | 1,2,9,10 |
| C406.2 | Develop a program in MATLAB to obtain the power angle characteristics of salient and non-salient pole alternator. | $L_3$-$L_6$ | 1,2,9,10 |
| C406.3 | Develop a program in MATLAB to assess the transient stability under three phase fault at different locations in a of radial power systems. | $L_3$-$L_6$ | 1,2,9,10 |
| C406.4 | Develop programs in MATLAB to formulate bus admittance and bus impedance matrices of interconnected power systems. | $L_3$-$L_6$ | 1,2,9,10 |
| C406.5 | Use Mi-Power package to solve power flow problem for simple power systems. | $L_3$-$L_6$ | 1,2,9,10 |
| C406.6 | Use Mi-Power package to study unsymmetrical faults at different locations in radial power systems. | $L_3$-$L_6$ | 1,2,9,10 |
| C406.7 | Use of Mi-Power package to study optimal generation scheduling problems for thermal power plants. | $L_3$-$L_6$ | 1,2,9,10 |
| **Total Hours of instruction** | | **42** | |

## 4.0 Course Content

| Sl. No | | Experiments |
|---|---|---|
| 1 | Use of MATLAB package | Formation for symmetric $\pi$ /T configuration for Verification of $AD-BC=1$, Determination of Efficiency and Regulation. |
| 2 | | Determination of Power Angle Diagrams, Reluctance Power, Excitation, Emf and Regulation for Salient and Non-Salient Pole Synchronous Machines. |
| 3 | | To obtain Swing Curve and to Determine Critical Clearing Time, Regulation, Inertia Constant/Line Parameters /Fault Location/Clearing Time/Pre-Fault Electrical Output for a Single Machine connected to Infinite Bus through a Pair of identical Transmission Lines Under 3-Phase Fault On One of the two Lines. |
| 4 | | Y Bus Formation for Power Systems with and without Mutual Coupling, by Singular Transformation and Inspection Method. |
| 5 | | Formation of Z Bus (without mutual coupling) using Z-Bus Building Algorithm. |
| 6 | | Determination of Bus Currents, Bus Power and Line Flow for a Specified System Voltage (Bus) Profile. |
| 7 | Use of Mi-Power package | Formation of Jacobian for a System not Exceeding 4 Buses (No PV Buses) in Polar Coordinates. |
| 8 | | Load Flow Analysis using Gauss Siedel Method, NR Method and Fast Decoupled Method for Both PQ and PV Buses. |
| 9 | | To Determine Fault Currents and Voltages in a Single Transmission Line System with Star-Delta Transformers at a Specified Location for LG and LLG faults by simulation. |
| 10 | | Optimal Generation Scheduling for Thermal power plants by simulation. |
| **Revised Bloom's Taxonomy Level** | | $L_1$ – Remembering, $L_2$ – Understanding, $L_3$ – Applying, $L_4$ – Analysing, $L_5$ – Evaluating, |

## 5.0 Relevance to future subjects

| SL. No | Semester | Subject | Topics / Relevance |
|---|---|---|---|
| 01 | VIII | Project work | Analysis of power system using MATLAB &Mi-power |

## 6.0 Relevance to Real World

| SL. No | Real World Mapping |
|---|---|
| 01 | Calculating A, B, C, D parameters of transmission line. |
| 02 | Stability study of power system. |
| 03 | Load flow analysis of power system. |
| 04 | Fault analysis of power system. |
| 05 | Economic dispatch of power system. |

## 7.0 Books Used and Recommended to Students

**Text Books**

**Text Books:**1 Modern Power System Analysis D. P. Kothari McGraw Hill 4th Edition, 2011

**Reference Books**

1. Stag, G. W., and EI-Abiad, A. H., "Computer Methods in Power System Analysis", McGraw Hill International Student Edition. 1968

2. .Pai, M. A., "Computer techniques in Power System Analysis", TMH, 2nd edition, 2006.

4.Hadi Saadat,"power system analysis"
McGraw Hill 2nd Edition, 2002

**Additional Study material & e-Books**

1. http://pdfstuff4u.com/ebook.php?id=1071881
2. http://sjbit.edu.in

## 8.0 Relevant Websites (Reputed Universities and Others) for Notes/Animation/Videos Recommended

| Website and Internet Contents References |
|---|
| 1)ieeexplore.ieee.org/document/152452/ |
| 2) https://engineering.purdue.edu/jump/8cb309 |
| *3)nptel.iitg.ernet.in* |

## 9.0 Magazines/Journals Used and Recommended to Students

| Sl.No | Magazines/Journals | website |
|---|---|---|
| 1 | Society of energy engineers and managers | www.energyprofesionals.in |
| 2 | IEEE Explore | ieeexplore.ieee.org/xpl/RecentIssue |
| 3 | Journal of Modern Power Systems and Clean Energy | www.springer.com |

## 10.0 Examination Note

**Internal Assessment:**
**Scheme of Evaluation for Internal Assessment (40 Marks)**
(a) Internal Assessment test in the same pattern as that of the main examination: 16marks.
Writeup-03 marks, Conduction-10 marks, Viva-Voce-03 marks
(b) Continuous assessment for laboratory experiments: 24marks.

**SCHEME OF EXAMINATION (60 Marks)**
One question is to be set for 100 marks, scaled down to 60 in VTU result sheet.
a) Write-up: 15% of Maximum marks b)Conduction: 70% of Maximum marks
c) Viva-voce: 15% of Maximum marks

## 11.0 Course Delivery Plan

| Sl. No | | Experiments | % of Portion |
|---|---|---|---|
| 1 | Use of MATLAB package | Formation for symmetric $\pi$ /T configuration for Verification of $AD-BC=1$, Determination of Efficiency and Regulation. | 10 |
| 2 | | Determination of Power Angle Diagrams, Reluctance Power, Excitation, Emf and Regulation for Salient and Non-Salient Pole Synchronous Machines. | 10 |
| 3 | | To obtain Swing Curve and to Determine Critical Clearing Time, Regulation, Inertia Constant/Line Parameters /Fault Location/Clearing Time/Pre-Fault Electrical Output for a Single Machine connected to Infinite Bus through a Pair of identical Transmission Lines Under 3-Phase Fault On One of the two Lines. | 10 |
| 4 | | Y Bus Formation for Power Systems with and without Mutual Coupling, by Singular Transformation and Inspection Method. | 10 |
| 5 | | Formation of Z Bus (without mutual coupling) using Z-Bus Building Algorithm. | 10 |
| 6 | | Determination of Bus Currents, Bus Power and Line Flow for a Specified System Voltage (Bus) Profile. | 10 |
| 7 | Use of Mi-Power package | Formation of Jacobian for a System not Exceeding 4 Buses (No PV Buses) in Polar Coordinates. | 10 |
| 8 | | Load Flow Analysis using Gauss Siedel Method, NR Method and Fast Decoupled Method for Both PQ and PV Buses. | 10 |
| 9 | | To Determine Fault Currents and Voltages in a Single Transmission Line System with Star-Delta Transformers at a Specified Location for LG and LLG faults by simulation. | 10 |
| 10 | | Optimal Generation Scheduling for Thermal power plants by simulation. | 10 |
| **Revised Bloom's Taxonomy Level** | | $L_1$ – Remembering, $L_2$ – Understanding, $L_3$ – Applying, $L_4$ – Analysing, $L_5$ – Evaluating, | |

## 12.0 QUESTION BANK

1. What is importance of Ybus?
2. What is reactance diagram?
3. Define Per Unit.
4. What are symmetrical components?
5. How symmetrical components are useful in solution of Power System?
6. What are unsymmetrical faults?
7. Define Stability.
8. What is singular transformation?
9. What is load flow study?
10. What are the different methods of LFS?
11. Compare different methods of LFS?
12. What is the importance of Jaccobian matrix?
13. What is bus building algorithm?
14. Give formulas for different modifications in building algorithm?
15. What are A, B, C, D parameters?
16. How transmission lines are classified &represented?
17. What is voltage regulation?
18. What is maximum& minimum voltage regulation?
19. What is power angle diagram?
20. What are salient & non salient pole machines?
21. What is reluctance power?
22. What is the effect of saliency &saturation?
23. What is swing equation?
24. What is the importance of swing curve?
25. What is critical clearing angle &time?
26. How to determine critical clearing time graphically?
27. Classify faults in the power system?
28. What are sequence impedances &sequence networks?
29. Explain different types of buses in the power system
30. What is single line diagram?
31. What are the conditions to draw single line diagram?
32. How sequence networks are connected in case of different faults?
33. What is economic operation of power system?
34. What are the conditions for economic dispatch with &without loss?
35. What are the guidelines to select initial value of lambda?
36. What is spinning reserve?
37. Give guidelines to select spinning reserve?
38. What are the constraints in unit commitment &economic dispatch?
39. What is the difference between steady state & transient stability?
40. Stability limits have single or multiple values?
41. What are the methods to improve steady state & transient stability?
42. Explain equal area criterion?
43. How stability is improved using equal area criterion?
44. What is the advantage of MATLAB& simulation?

| Prepared by | Checked by | | |
|---|---|---|---|
| HRZinage | HRZinage | 25/8 | |
| Prof. Hemalata R Zinage | Prof. Hemalata R Zinage | HOD | Principal |