ACADEMIC REGULATIONS, COURSE STRUCTURE
AND DETAILED SYLLABUS

M.Tech (ELECTRICAL POWER SYSTEMS)

FOR
MASTER OF TECHNOLOGY TWO YEAR POST GRADUATE COURSE
(Applicable for the batches admitted from 2014-2015)

R14

ANURAG
Engineering Engineers

ANURAG GROUP OF INSTITUTIONS
(AUTONOMOUS)
SCHOOL OF ENGINEERING
Venkatapur, Ghatkesar, Hyderabad – 500088
# M.TECH (ELECTRICAL POWER SYSTEMS)
## COURSE STRUCTURE AND SYLLABUS

### I Year - I Semester

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Subject</th>
<th>L</th>
<th>P</th>
<th>Credits</th>
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<tbody>
<tr>
<td>A31021</td>
<td>Advanced Power System Analysis</td>
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<td>A31022</td>
<td>Advanced Power System protection</td>
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<tr>
<td>A31023</td>
<td>Renewable Energy Systems</td>
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<td>A31024</td>
<td>Modern Control Theory</td>
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<td>A31025</td>
<td>Elective-I</td>
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<td>A31026</td>
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<td>Microcontrollers and Applications</td>
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<td>Power Quality</td>
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<td>Seminar-I</td>
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### I Year - II Semester

<table>
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<tr>
<th>Subject Code</th>
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<tr>
<td>A32021</td>
<td>Power System Dynamics</td>
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<td>Power System Operation and Deregulation</td>
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<td>A32024</td>
<td>AI Techniques in Electrical Power Engineering</td>
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<td>Elective-III</td>
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<td>Energy Auditing, Conservation and Management</td>
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<td>A32205</td>
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<td>Seminar-II</td>
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### II Year – I Semester

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<td>A33208</td>
<td>Project Seminar</td>
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<td>A33209</td>
<td>Project Work Part-I</td>
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<td><strong>Total</strong></td>
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### II Year – II Semester

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<th>Credits</th>
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<tr>
<td>A34203</td>
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<td>22</td>
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</table>
Academic Regulations for M. Tech (Regular) Degree Course
(Effective for the students admitted into 1 year from the Academic Year 2014-2015 onwards)

The M.Tech Degree of Jawaharlal Nehru Technological University Hyderabad shall be conferred on candidates who are admitted to the program and fulfill all the requirements for the award of the degree.

1.0 ELIGIBILITY FOR ADMISSIONS:
Admission to the above program shall be made subject to the eligibility, qualifications and specialization prescribed by the university from time to time.

Admissions shall be made on the basis of merit rank obtained by the qualifying candidate at an Entrance Test conducted by the University or on the basis of any other order of merit approved by the University, subject to reservations prescribed by the university from time to time.

2.0 AWARD OF M.TECH DEGREE:
2.1 A student shall be declared eligible for the award of the M.Tech degree, if he pursues a course of study and completes it successfully for not less than two academic years and not more than four academic years.
2.2 A Student, who fails to fulfill all the academic requirements for the award of the degree within four academic years from the year of his admission, shall forfeit his seat in M.Tech course.
2.3 The minimum instruction period for each semester is 90 clear instruction days.

3.0 COURSE OF STUDY
The following specializations are offered at present for the M.Tech Course of study.

1. CAD / CAM
2. Computer Science
3. Computer Science and Engineering
4. Electrical Power systems
5. Electronics and Communication Engineering
6. Embedded Systems
7. Machine Design
8. Power Electronics and Electrical Drives
9. Software Engineering
10. Structural Engineering
11. VLSI System Design
12. Wireless and Mobile Communications
13. Computer Networks and Information Security
14. Construction Management
4.0 ATTENDANCE:

The programs are offered on unit basis with each subject being considered as an unit.

4.1 A candidate shall be deemed to have eligibility to write end semester examinations in a subject if he has put in at least 75% of attendance in the subject.

4.2 Shortage of attendance up to 10% in any subject (i.e. 65% and above and below 75%) may be condoned by the college Academic council on genuine and valid reasons on representation by the candidate with supporting evidence.

4.3 A candidate shall get minimum required attendance at least in three (3) theory subjects in the present semester to get promoted to the next semester. In order to qualify for the award of the M.Tech Degree, The candidate shall complete all the academic requirements of the subjects, as per the course structure.

4.4 Shortage of attendance below 65% shall in no case be condoned.

4.5 A stipulated fee shall be payable towards condonation of shortage of attendance.

5.0 EVALUATION:

The performance of the candidate in each semester shall be evaluated subject-wise, with a maximum of 100 marks for theory and 100 marks for practical’s, on the basis of internal evaluation and End semester Examination.

For the theory subjects 60 marks shall be awarded based on the performance in the End semester Examination, 30 marks shall be awarded based on the internal evaluation and 10 marks for assignment.

5.1 For theory subjects, during the semester there shall be 2 midterm examinations. Each midterm examination consists of one subjective paper and one assignment. The subjective paper is for 30 marks with duration of 2 hours. Subjective paper of each semester shall contain 2 parts Section-A & Section-B. Section-A comprises of five (5) short answer type of questions. The student has to answer all the questions from section-A. Each question carries two marks. A total of ten marks are allocated to section-A. Section-B consists of five (5) essay type of questions from which the student has to answer three questions. Each question carry not more than seven (7) marks. A total of 20 marks are allocated for section-B. The questions in the first midterm examination includes the topics of first 2.5 units while the questions in the second midterm examination includes the topics of remaining 2.5 units. The assignments should be submitted before the conduct of respective midterm examinations.

The total marks secured by the student are out of 40 marks (30marks from midterm examination and 10 marks from assignment) in an internal examination for a subject. The average of marks secured in two midterm examinations shall be taken as final marks. If he/she is absent for any test / assignment, he/she are awarded zero marks for that test / assignment.

5.2 For practical subjects, 60 marks shall be awarded based on the performance in the End Semester Examinations, 40 marks shall be awarded based on the day-to-day performance as internal marks.

5.3 There shall be two seminar presentations during I year I semester and II Semester. For seminar, a student under the supervision of a faculty member, shall collect the literature on
a topic and critically review the literature and submit it to the department in a report from and shall make an oral presentation before the departmental committee. The departmental committee consists of Head of the department, supervisor and two other senior faculty members of the department. For each seminar there will be only internal evaluation of 50 marks. A candidate has to secure a minimum of 50% to be declared successful.

5.4 There shall be a Comprehensive Viva-Voce in II year I Semester. The comprehensive Viva-Voce will be conducted by a committee consisting of Head of the Department and two Senior Faculty members of the Department. The comprehensive Viva-Voce is aimed to assess the students' understanding in various subjects he/she studies during the M.Tech course of study. The Comprehensive viva-voce valued for 100 marks by the Committee. There are no internal marks for the Comprehensive viva-Voce.

5.5 A candidate shall be deemed to have secured the minimum academic requirement in a subject if he secures a minimum of 40% of marks in the End Examination and a minimum aggregate of 50% of the total marks in the End Semester Examination and Internal Evaluation taken together.

5.6 In case the candidate does not secure the minimum academic requirement in any subject (as specified in 4.3) he has to reappear for the End Examination in that subject. A candidate shall be given one chance to re-register for each subject provided the internal marks secured by a candidate are less than 50% and he has failed in the end examination. In such case candidate must re-register subject(s) and secure required minimum attendance. Attendance in the re-registered subject(s) has to be calculated separately to become eligible to write the end examination in the re-registered subject(s). The attendance of re-registered subject(s) shall be calculated separately to decide upon the eligibility for writing the end examination in those subject(s). In the event of taking another chance, the internal marks and end examination marks obtained in the previous attempt are nullified.

5.7 In case the candidate secures less than the required attendance in any subject(s), he shall not be permitted to appear for the End Examination in that subject(s). He shall re-register the subject when next offered.

5.8 Laboratory examination for M.Tech courses must be conducted with two Examiners, one of them being Laboratory Class Teacher and second examiner shall be other Laboratory Teacher.

6.0 EVALUATION OF PROJECT /DISSERTATION WORK:

Every candidate shall be required to submit thesis or dissertation after taking up a topic approved by the project review committee.

6.1 A Project Review Committee (PRC) shall be constituted with Principal as chair person, heads of all the departments which are offering the M.Tech programs and two other senior faculty members.

6.2 Registration of Project work: A candidate is permitted to register for the project work after satisfying the attendance requirement of all the subjects (theory and practical subjects).

6.3 After satisfying 6.2, a candidate has to submit, in consultation with his project supervisor, the title, objective and plan of action of his project work to the Departmental
Committee for its approval. Only after obtaining the approval of Departmental Committee the student can initiate the Project work.

6.4 If a candidate wishes to change his supervisor or topic of the project he can do so with the approval of Departmental Committee. However, the Departmental Committee shall examine whether the change of topic/supervisor leads to a major change of his initial plans of project proposal. If so, his date of registration for the project work starts from the date of change of Supervisor or topic as the case may be.

6.5 A candidate shall submit status report (in a bound-form) in two stages at least with a gap of 3 months between them.

6.6 The work on the project shall be initiated in the beginning of the second year and the duration of the project is for two semesters. A candidate is permitted to submit project thesis only after successful completion of theory and practical course with the approval of PRC not earlier than 40 weeks from the date of registration of the project work. For the approval of PRC the candidate shall submit the draft copy of thesis to the Principal (through Head of the Department) and shall make an oral presentation before the PRC.

6.7 Three copies of the Project Thesis certified by the supervisor shall be submitted to the College/School/Institute.

6.8 The thesis shall be adjudicated by one examiner selected by the Institution. For this, Chairman, BOS of the respective departments shall submit a panel of 5 examiners, who are eminent in that field with the help of the concerned guide and senior faculty of the department.

6.9 If the report of the examiner is not favourable, the candidate shall revise and resubmit the thesis, in the time frame as prescribed by PRC. If the report of the examiner is unfavourable again the thesis shall be summarily rejected.

6.10 If the report of the examiner is favourable, viva-voce examination shall be conducted by a board consisting of the supervisor, Head of the Department and the examiner who adjudicated the Thesis.

The Board shall jointly report candidates work as:

A. EXCELLENT
B. GOOD
C. SATISFACTORY
D. UNSATISFACTORY

Head of the Department shall coordinate and make arrangements for the conduct of viva-voce examination. If the report of the viva-voce is unsatisfactory, the candidate will retake the viva-voce examination after three months. If he fails to get a satisfactory report at the second viva-voce examination, he will not be eligible for the award of the degree.
7.0 AWARD OF DEGREE AND CLASS

After a student has satisfied the requirement prescribed for the completion of the program and is eligible for the award of M.Tech Degree, he shall be placed in one of the following four classes.

<table>
<thead>
<tr>
<th>Classes Awarded</th>
<th>% of marks to be secured</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Class with Distinction</td>
<td>70% and above</td>
</tr>
<tr>
<td>First Class</td>
<td>Below 70% but not less than 60%</td>
</tr>
<tr>
<td>Second Class</td>
<td>Below 60% but not less than 50%</td>
</tr>
</tbody>
</table>

(The marks in internal evaluation and end examination shall be shown separately in the marks memorandum)

8.0 WITH-HOLDING OF RESULTS:

If the candidate has not paid any dues to the institution or if any case of in-discipline is pending against him, the result of the candidate will be withheld and he will not be allowed into next higher semester. The issue of the degree is liable to be withheld in such cases.

9.0 TRANSITORY REGULATIONS:

Candidate who have discontinued or have been detained for want of attendance or who have failed after having undergone the course are eligible for admission to the same or equivalent subjects as and when subjects are offered, subject to 5.5 and 2.0

10.0 GENERAL:

10.1 The academic regulations should be read as a whole for purpose of any interpretation.
10.2 In case of any doubt or ambiguity in the interpretation of the above rules, the decision of the Academic Council is final.
10.3 The institution may change or amend the academic regulations and syllabus at any time and the changes and amendments made shall be applicable to all the students with effect from the date notified by the institution.
10.4 Wherever the word he, him or his occur, it will also include she, her and hers. There shall be no transfers within the constituent colleges of Jawaharlal Nehru Technological University.
### MALPRACTICES RULES

**DISCIPLINARY ACTION FOR IMPROPER CONDUCT IN EXAMINATIONS**

<table>
<thead>
<tr>
<th>Nature of Malpractices/Improper conduct</th>
<th>Punishment</th>
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</thead>
<tbody>
<tr>
<td><strong>If the candidate:</strong></td>
<td></td>
</tr>
<tr>
<td>1. (a) Possesses of keeps accessible in examination hall, any paper, note book, programmable calculators, cell phones, pager, palm, computers or any other form of material concerned with or related to the subject of the examination (theory or practical) in which he is appearing but has not made use of (material shall include any marks on the body of the candidate which can be used as an aid in the subject of the examination)</td>
<td>Expulsion from the examination hall and cancellation of the performance in that subject only</td>
</tr>
<tr>
<td>(b) Gives assistance or guidance or receives it from any other candidate orally or by any other body language methods or communicates through cell phones with any candidate or persons in or outside the exam hall in respect of any matter.</td>
<td>Expulsion from the examination hall and cancellation of the performance in that subject only of all the candidates involved. In case of an outsider, he will be handed over to the police and a case is registered against him.</td>
</tr>
<tr>
<td>2. Has copied in the examination hall from any paper, book, programmable calculators, palm computers or any other form of material relevant to the subject of the examination (theory or practical) in which the candidate is appearing.</td>
<td>Expulsion from the examination hall and cancellation of the performance in that subject and all other subjects the candidates has already appeared including practical examinations and project work and shall not be permitted to appear for the remaining examinations of the subjects of that semester/year. The hall ticket of the candidate is to be cancelled and sent to the controller of examinations, AGI.</td>
</tr>
<tr>
<td>3. Impersonates any other candidate in connection with the examination.</td>
<td>The candidate who has impersonated shall be expelled from examination hall. The candidate is also debarred and forfeits the seat. The performance of the original candidate who has been impersonated, shall be cancelled in all the subjects of the examination (including practical’s and project work) already appeared and shall not be allowed to appear for examinations of the remaining subjects of that semester/year. The candidate is also debarred for two consecutive semesters from class work and all semester examinations. The continuation of the course by the candidate is subject to the academic regulations in connection with forfeiture of seat. If the imposter is an outsider, he will be handed over to the police and a case is registered against him.</td>
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<tr>
<td>4. Smuggles in the Answer book or</td>
<td>Expulsion from the examination hall and</td>
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<td>additional sheet or takes out or arranges to send out the question paper during the examination or answer book or additional sheet, during or after the examination.</td>
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<tr>
<td>5.</td>
<td>Uses objectionable, abusive or offensive language in the answer paper or in letters to the examiners or writes to the examiner requesting him to award pass marks.</td>
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<tr>
<td>6.</td>
<td>Refuses to obey the orders of the Chief Superintendent/Assistant-Superintendent/any officer on duty or misbehaves or creates disturbance of any kind in and around the examination hall or organizes a walk out or instigates others to walk out, or threatens the officer-in-charge or any person on duty in or outside the examination hall of any injury to his person or to any office relations whether by words, either spoken or written or by signs or by visible representation, assaults the officer-in-charge, or any person on duty in or outside the examination hall or any of his relations, or indulges in any other act of misconduct or mischief which result in damage to or destruction of property in the examination hall or any part of the college campus or engages in any other act which in the opinion of the officer on duty amounts to use of unfair means or misconduct or has the tendency to disrupt the orderly conduct of the examination.</td>
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<tr>
<td>7.</td>
<td>Leaves the exam hall taking away answer script or intentionally tears of the script or any part thereof inside or outside the examination hall.</td>
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<tr>
<td>8.</td>
<td>Posses any lethal weapon or firearm in the examination hall.</td>
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<tr>
<td>9.</td>
<td>If student of the college, who is not a candidate for the particular examination or any person not connected with college indulges in any malpractice or improper conduct mentioned in clause 6 to 8</td>
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<tr>
<td>10.</td>
<td>Comes in a drunken condition to the examination hall.</td>
</tr>
<tr>
<td>11.</td>
<td>Copying detected on the basis of internal evidence, such as, during valuation or during special scrutiny.</td>
</tr>
<tr>
<td>12.</td>
<td>If any malpractice is detected which is not covered in the above clauses 1 to 11 shall be reported to the Malpractices committee, AGI for further action to award suitable punishment.</td>
</tr>
</tbody>
</table>
ADVANCED POWER SYSTEM ANALYSIS

UNIT-I:
Admittance Model and Network Calculations, Branch and Node Admittances, Mutually Coupled Branches in $Y_{BUS}$, An Equivalent Admittance Network, Modification of $Y_{BUS}$, Network Incidence Matrix and $Y_{BUS}$, Method of Successive Elimination, Node Elimination, Triangular Factorization, Sparsity and Near Optimal Ordering.

UNIT-II:
Impedance Model and Network Calculations, the BUS Admittance and Impedance Matrices, Thevenin's Theorem and $Z_{BUS}$, Algorithms for building $Z_{BUS}$, Modification of existing $Z_{BUS}$, Calculation of $Z_{BUS}$ elements from $Y_{BUS}$, Power Invariant Transformations, Mutually Coupled Branches in $Z_{BUS}$.

UNIT-III:
Gauss Seidel method, N-R Method, Decoupled method, fast decoupled method, comparison between power flow solutions. DC load flow.

UNIT-IV:

UNIT-V:
Fault Analysis: Symmetrical faults-Fault calculations using $Z_{BUS}$, Fault calculations using $Z_{BUS}$ equivalent circuits—Selection of circuit breakers- Unsymmetrical faults-Problems on various types of faults.

TEXT BOOK:

REFERENCE:
3. Power System Operation and Control, Dr. K. Uma Rao, Wiley India Pvt. Ltd.

REFERENCE BOOKS:
ADVANCED POWER SYSTEM PROTECTION

UNIT-I: STATIC RELAYS

Advantages of static relays-Basic construction of static relays-Level detectors-Replica impedance-Mixing circuits-General equation for two input phase and amplitude comparators-Duality between amplitude and phase comparators.

AMPLITUDE COMPARATORS: Circulating current type and opposed voltage type-rectifier bridge comparators, Direct and Instantaneous comparators.

UNIT-II: PHASE COMPARATORS

Coincidence circuit type- block spike phase comparator, techniques to measure the period of coincidence-Integrating type-Rectifier and Vector product type- Phase comparators.

STATIC OVER CURRENT RELAYS: Instantaneous over-current relay-Time over-current relays-basic principles -definite time and Inverse definite time over-current relays.

UNIT-III: STATIC DIFFERENTIAL RELAYS

Analysis of Static Differential Relays -Static Relay schemes -Duo bias transformer differential protection -Harmonic restraint relay.

STATIC DISTANCE RELAYS: Static impedance-reactance-MHO and angle impedance relay-sampling comparator -realization of reactance and MHO relay using sampling comparator.

UNIT-IV: MULTI-INPUT COMPARATORS

Conic section characteristics-Three input amplitude comparator -Hybrid comparator-switched distance schemes -Poly phase distance schemes- phase fault scheme -three phase scheme -combined and ground fault scheme.

POWER SWINGS: Effect of power swings on the performance of distance relays -Power swing analysis-Principle of out of step tripping and blocking relays-effect of line and length and source impedance on distance relays.

UNIT-V: MICROPROCESSOR BASED PROTECTIVE RELAYS

(Block diagram and flowchart approach only)-Over current relays-impedance relays-directional relay-reactance relay. Generalized mathematical expressions for distance relays-measurement of resistance and reactance-MHO and offset MHO relays-Realization of MHO characteristics-Realization of offset MHO characteristics -Basic principle of Digital computer relaying.

TEXT BOOK:


REFERENCE:

RENEWABLE ENERGY SYSTEMS

UNIT-I:
Photo voltaic power generation, spectral distribution of energy in solar radiation, solar cell configurations, voltage developed by solar cell, photo current and load current, practical solar cell performance, commercial photo voltaic systems, test specifications for PV systems, applications of super conducting materials in electrical equipment systems.

UNIT-II:
Principles of MHD power generation, ideal MHD generator performance, practical MHD generator, MHD technology.
Wind Energy conversion: Power from wind, properties of air and wind, types of wind Turbines, operating characteristics.

UNIT-III:
Tides and tidal power stations, modes of operation, tidal project examples, turbines and generators for tidal power generation.
Wave energy conversion: properties of waves and power content, vertex motion of Waves, device applications. Types of ocean thermal energy conversion systems Application of OTEC systems examples,

UNIT-IV:
Miscellaneous energy conversion systems: coal gasification and liquefaction, biomass conversion, geothermal energy, thermo electric energy conversion, principles of EMF generation, description of fuel cells, Co-generation and energy storage, combined cycle co-generation, energy storage.
Global energy position and environmental effects: energy units, global energy position.

UNIT-V:
Types of fuel cells, H₂-O₂ Fuel cells, Application of fuel cells – Batteries, Description of batteries, Battery application for large power. Environmental effects of energy conversion systems, pollution from coal and preventive measures steam stations and pollution, pollution free energy systems.

TEXT BOOKS:

M. TECH. (EPE/EPS/PEES/PSC&A) - R13 Regulations

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH - 1 YEAR - I SEM. (EPE/EPS/PEES/PSC&A)

MODERN CONTROL THEORY

UNIT-I: MATHEMATICAL PRELIMINARIES

UNIT-II: STATE VARIABLE ANALYSIS

UNIT-III: NON LINEAR SYSTEMS

UNIT-IV: STABILITY ANALYSIS

UNIT-V: OPTIMAL CONTROL

TEXT BOOKS:
1. Modern Control System Theory by M.Gopal – New Age International -1984

REFERENCES:
1. Optimal control by Kircs
HIGH VOLTAGE ENGINEERING
(Elective-I)

UNIT-I: INTRODUCTION TO HIGH VOLTAGE ENGINEERING
Electric Field Stresses, Gas / Vacuum as Insulator, Liquid Dielectrics, Solids and Composites, Estimation and Control of Electric Stress, Numerical methods for electric field computation, Surge voltages, their distribution and control, Applications of insulating materials in transformers, rotating machines, circuit breakers, cable power capacitors and bushings.

UNIT-II: BREAK DOWN IN DIELECTRIC MATERIALS
Gases as insulating media, collision process, ionization process, Townsend's criteria of breakdown in gases, Paschen's law. Liquid as Insulator, pure and commercial liquids, breakdown in pure and commercial liquids. Intrinsic breakdown, electromechanical breakdown, thermal breakdown, breakdown of solid dielectrics in practice; Breakdown in composite dielectrics, solid dielectrics used in practice.

UNIT-III: GENERATION & MEASUREMENT OF HIGH VOLTAGES & CURRENTS

UNIT-IV: OVER VOLTAGES & INSULATION CO-ORDINATION
Natural causes for over voltages - Lightning phenomenon, Overvoltage due to switching surges, system faults and other abnormal conditions, Principles of Insulation Coordination on High voltage and Extra High Voltage power systems.

UNIT-V: TESTING OF MATERIALS & ELECTRICAL APPARATUS

TEXT BOOKS:

REFERENCE BOOKS:
3. High Voltage Engineering, Theory and Practice by Mazen Abdel Salam, Hussein Anis, Ahdan El-Morsheedy, Rosdy Radwan, Marcel Dekker
M. TECH. (EPE/EPS/PEES/PSC&A) –R13 Regulations

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH -- I YEAR -- I SEM. (EPE/EPS/PEES/PSC&A)

EHV AC TRANSMISSION
(Effective-I)

UNIT-I:
E.H.V.A.C. Transmission line trends and preliminary aspect standard transmission voltages –
Estimation at line and ground parameters-Bundle conductor systems-Inductance and
Capacitance of E.H.V. lines – positive, negative and zero sequence impedance – Line
Parameters for Modes of Propagation.

UNIT-II:
Electrostatic field and voltage gradients – calculations of electrostatic field of AC lines – effect of
high electrostatic field on biological organisms and human beings - surface voltage gradients and
maximum gradients of actual transmission lines – voltage gradients on sub conductor.

UNIT-III:
Electrostatic induction in unenergized lines – measurement of field and voltage gradients for three
phase single and double circuit lines – un energized lines. Power Frequency Voltage control and
over-voltages in EHV lines: No load voltage – charging currents at power frequency-voltage
control – shunt and series compensation – static VAR compensation.

UNIT-IV:
Corona in E.H.V. lines – Corona loss formulae- attention of traveling waves due to Corona --
Audio noise due to Corona, its generation, characteristic and limits. Measurements of audio noise
radio interference due to Corona - properties of radio noise – frequency spectrum of RI fields –
Measurements of RI and RII.

UNIT-V:
Design of EHV lines based on steady state and transient limits - EHV cables and their
characteristics.

TEXT BOOKS:
1. EHVAC Transmission Engineering by R. D. Begamudre, New Age International (p) Ltd.
2. HVAC and DC Transmission by S. Rao.

REFERENCE BOOKS:
1. Rokosh Das Begamudre, “Extra High Voltage AC Transmission Engineering”- Wiley
M. TECH. (EPE/EPS/PEES/PSC&A) – R13 Regulations

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH – I YEAR – I SEM. (EPE/EPS/PEES/PSC&A)

MICROCONTROLLERS AND APPLICATIONS
(Elective-I)

UNIT-I: OVERVIEW OF ARCHITECTURE & MICROCONTROLLER RESOURCES
Architecture of a microcontroller – Microcontroller resources – Resources in advanced and next
generation microcontrollers – 8051 microcontroller – Internal and External memories – Counters
and Timers – Synchronous serial-cum asynchronous serial communication – Interrupts.

UNIT-II: 8051- MICROCONTROLLERS INSTRUCTION SET
Basic assembly language programming – Data transfer instructions – Data and Bit-manipulation
instructions – Arithmetic instructions – Instructions for Logical operations on the test among the
Registers, Internal RAM, and SFRs – Program flow control instructions – Interrupt control flow.

UNIT-III: REAL TIME CONTROL
INTERRUPTS: Interrupt handling structure of an MCU – Interrupt Latency and Interrupt deadline
– Multiple sources of the interrupts – Non-maskable interrupt sources – Enabling or disabling of the
sources – Polling to determine the interrupt source and assignment of the priorities among
them – Interrupt structure in Intel 8051.
TIMERS: Programmable Timers in the MCU’s – Free running counter and real time control –
Interrupt interval and density constraints.

UNIT-IV: SYSTEMS DESIGN
DIGITAL AND ANALOG INTERFACING METHODS:
Switch, Keypad and Keyboard interfacing – LED and Array of LED’s – Keyboard-cum-Display
controller (5279) – Alphanumeric Devices – Display Systems and its interfaces – Printer
interfaces – Programmable instruments interface using IEEE 488 Bus – Interfacing with the Flash
Memory – Interfaces – Interfacing to High Power Devices – Analog input interfacing – Analog
output interfacing – Optical motor shaft encoders – Industrial control – Industrial process control
system – Prototype MCU based Measuring instruments – Robotics and Embedded control –
Digital Signal Processing and digital filters.

UNIT-V: REAL TIME OPERATING SYSTEM FOR MICROCONTROLLERS:
Real Time operating system – RTOS of Keil (RTX51) – Use of RTOS in Design – Software
development tools for Microcontrollers.
16-BIT MICROCONTROLLERS: Hardware – Memory map in Intel 80196 family MCU system –
IO ports – Programmable Timers and High-speed outputs and input captures – Interrupts –
instructions.
ARM 32 Bit MCUs: Introduction to 16/32 Bit processors – ARM architecture and organization –
ARM / Thumb programming model – ARM / Thumb instruction set – Development tools.

TEXT BOOKS:

REFERENCE BOOKS:
3. Microcontroller Programming, Julio Sanchez, Maria P. Cantor, CRC Press.
5. Microprocessors and Microcontrollers, Architecture, Programming and System Design, Krishna
Kant, PHI Learning PVT. Ltd.
6. Microprocessors, Nilesh B. Bahadure, PHI Learning PVT. Ltd.
UNIT-I: INTRODUCTION
Introduction of the Power Quality (PQ) problem, Terms used in PQ: Voltage, Sag, Swell, Surges, Harmonics, over voltages, spikes, Voltage fluctuations, Transients, Interruption, overview of power quality phenomenon, Remedies to improve power quality, power quality monitoring.

UNIT-II: LONG & SHORT INTERRUPTIONS
Interruptions -- Definition -- Difference between failures, outage, Interruptions -- causes of Long Interruptions -- Origin of interruptions -- Limits for the Interruption frequency -- Limits for the interruption duration -- costs of interruption -- Overview of Reliability evaluation to power quality, comparison of observations and reliability evaluation.
Short interruptions: definition, origin of short interruptions, basic principle, fuse saving, voltage magnitude events due to re-closing, voltage during the interruption, monitoring of short interruptions, difference between medium and low voltage systems. Multiple events, single phase tripping -- voltage and current during fault period, voltage and current at post fault period, stochastic prediction of short interruptions.

UNIT III: 1 & 3-PHASE VOLTAGE SAG CHARACTERIZATION
Voltage sag -- definition, causes of voltage sag, voltage sag magnitude, and monitoring, theoretical calculation of voltage sag magnitude, voltage sag calculation in non-radial systems, meshed systems, and voltage sag duration.
Three phase faults, phase angle jumps, magnitude and phase angle jumps for three phase unbalanced sags, load influence on voltage sags.

UNIT-IV: POWER QUALITY CONSIDERATIONS IN INDUSTRIAL POWER SYSTEMS
Voltage sag -- equipment behavior of Power electronic loads, induction motors, synchronous motors, computers, consumer electronics, adjustable speed AC drives and its operation. Mitigation of AC Drives, adjustable speed DC drives and its operation, mitigation methods of DC drives.

UNIT-V: MITIGATION OF INTERRUPTIONS & VOLTAGE SAGS
Overview of mitigation methods -- from fault to trip, reducing the number of faults, reducing the fault clearing time changing the power system, installing mitigation equipment, improving equipment immunity, different events and mitigation methods. System equipment interface -- voltage source converter, series voltage controller, shunt controller, combined shunt and series controller.
Power Quality and EMC Standards:
Introduction to standardization, IEC Electromagnetic compatibility standards, European voltage characteristics standards, PQ surveys.

REFERENCE BOOK:

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH – I YEAR – I SEM. (EPE/EPS/PEES/PSC&A)

HVDC TRANSMISSION
(Effective-II)

UNIT-I: INTRODUCTION
General consideration, Power Handling Capabilities of HVDC Lines Basic Conversion principles, static converter configuration.

UNIT-II: STATIC POWER CONVERTERS
3-pulse, 6-pulse, and 12-pulse converters, converter station and Terminal equipment, commutation process, Rectifier and Inverter operation, equivalent circuit for converter – special features of converter transformers. Harmonics in HVDC Systems, Harmonic elimination, AC and DC filters.

UNIT-III: CONTROL OF HVDC CONVERTERS AND SYSTEMS
Constant current, constant extinction angle and constant ignition angle control Individual phase control and equidistant firing angle control DC power flow control. Interaction between HV AC and DC systems – Voltage interaction Harmonic instability problems and DC power modulation.

UNIT-IV: MTDC SYSTEMS & OVER VOLTAGES
Series parallel and series parallel systems their operation and control, Over voltages due to disturbances on DC side, over voltages due to DC and AC side line faults.

UNIT-V: CONVERTER FAULTS & PROTECTION
Converter faults, over current protection – valve group, and DC line protection over voltage protection of converters, surge arresters.

REFERENCE BOOKS:
UNIT-I: DISTRIBUTION AUTOMATION AND THE UTILITY SYSTEM
Introduction to Distribution Automation (DA), control system interfaces, control and data requirements, centralized (Vs) decentralized control, DA System (DAS), DA Hardware, DAS software.

UNIT-II: DISTRIBUTION AUTOMATION FUNCTIONS
DA capabilities, Automation system computer facilities, management processes, Information management, system reliability management, system efficiency management, voltage management, Load management.

UNIT-III: COMMUNICATION SYSTEMS FOR DA
DA communication requirements, Communication reliability, Cost effectiveness, Data rate Requirements, Two way capability, Ability to communicate during outages and faults, Ease of operation and maintenance, Conforming to the architecture of data flow
Communication systems used in DA : Distribution line carrier (Power line carrier), Ripple control, Zero crossing technique, telephone, cable TV, Radio, AM broadcast, FM SCA, VHF Radio, UHF Radio, Microwave satellite. Fiber optics, Hybrid Communication systems, Communication systems used in field tests.

UNIT-IV: TECHNICAL BENEFITS
DA benefit categories, Capital deferred savings, Operation and Maintenance savings, Interruption related savings, Customer related savings, Operational savings, improved operation, Function benefits, Potential benefits for functions, and function shared benefits, Guidelines for formulation of estimating equations Parameters required, economic impact areas, Resources for determining benefits impact on distribution system, integration of benefits into economic evaluation.

UNIT-V: ECONOMIC EVALUATION METHODS
Development and evaluation of alternate plans, Select study area, Select study period, Project load growth, Develop Alternatives, Calculate operating and maintenance costs, Evaluate alternatives. Economic comparison of alternate plans, Classification of expenses and capital expenditures, Comparison of revenue requirements of alternative plans, Book Life and Continuing plant analysis, Year by year revenue requirement analysis, short term analysis, end of study adjustment, Break even analysis, Sensitivity analysis computational aids.

REFERENCES:

1. IEEE Tutorial Course "Distribution Automation"
2. IEEE Working Group on "Distribution Automation"
1. Develop MATLAB program for \( Y_{bus} \) formation.
2. Develop MATLAB program for G-S Load Flow Analysis.
3. Develop MATLAB program for N-R Load Flow Analysis.
4. Develop MATLAB program for FDLF Load Flow Analysis.
5. Develop MATLAB program for Short Circuit Analysis.
9. Simulation of RLC Circuit using PSPICE.
10. Simulation of Single Phase Full Converter with RLE Load using PSPICE
11. Develop MATLAB model for Closed Loop Speed Control of Separately Excited D.C Motor.
UNIT-I: BASIC CONCEPTS
Power system stability states of operation and system security - system dynamics - problems system model analysis of steady State stability and transient stability - simplified representation of Excitation control.

UNIT-II: MODELING OF SYNCHRONOUS MACHINE
Synchronous machine - park’s Transformation-analysis of steady state performance per - unit quantities-Equivalent circuits of synchronous machine-determination of parameters of equivalent circuits.

UNIT-III: EXCITATION SYSTEM
Excitation system modeling-excitation systems block Diagram - system representation by state equations- Dynamics of a synchronous generator connected to infinite bus - system model Synchronous machine model-stator equations rotor equations - Synchronous machine model with field circuit - one equivalent damper winding on q axis (model 1:1) - calculation of Initial conditions.

UNIT-IV: ANALYSIS OF SINGLE MACHINE SYSTEM
Small signal analysis with block diagram - Representation Characteristic equation and application of Routh Hurwitz criterion- synchronizing and damping torque analysis-small signal model - State equations.

UNIT-V: APPLICATION OF POWER SYSTEM STABILIZERS
Basic concepts in applying PSS - Control signals - Structure and tuning of PSS - Washout circuit - Dynamic compensator analysis of single machine infinite bus system with and without PSS.

TEXT BOOK:

REFERENCE BOOKS:
1. F.M. Anderson and A.A. Fouad,"Power system control and stability",IEEE Presss
JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH – I YEAR – II SEM. (EPE/EPS/PEES/PSC&A)

FLEXIBLE AC TRANSMISSION SYSTEMS
(FACTS)

UNIT-I: FACTS CONCEPTS

Transmission interconnections power flow in an AC system, loading capability limits, Dynamic stability considerations, importance of controllable parameters basic types of FACTS controllers, benefits from FACTS controllers.

UNIT-II: VOLTAGE SOURCE CONVERTERS

Single phase three phase full wave bridge converters transformer connections for 12 pulse 24 and 48 pulse operation. Three level voltage source converter, pulse width modulation converter, basic concept of current source Converters, and comparison of current source converters with voltage source converters.

UNIT-III: STATIC SHUNT COMPENSATION

Objectives of shunt compensation, mid-point voltage regulation voltage instability prevention, improvement of transient stability, Power oscillation damping. Methods of controllable VAR generation, variable impedance type static VAR generators switching converter type VAR generators hybrid VAR generators.

UNIT-IV: SVC AND STATCON

The regulation and slope transfer function and dynamic performance, transient stability enhancement and power oscillation damping operating point control and summary of compensator control.

UNIT-V: STATIC SERIES COMPENSATORS

Concept of series capacitive compensation, improvement of transient stability, power oscillation damping, and functional requirements of GTO thyristor controlled series capacitor (GSO), thyristor switched series capacitor (TSSC), and thyristor controlled series capacitor (TCSC) Control schemes for GSC TSSC and TCSC.

TEXT BOOKS:

M. TECH. (EPE/EPS/PEES/PSC&A) - R13 Regulations

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH - I YEAR - II SEM. (EPE/EPS/PEES/PSC&A)

POWER SYSTEM OPERATION AND DEREGULATION

UNIT-I: OPTIMAL POWER FLOW
Introduction- Solution to the optimal power flow-gradient method-Newton’s method-Linear sensitivity analysis- Linear programming methods- Security constrained OPF-Interior point algorithm- Bus incremental costs

UNIT-II: POWER SYSTEM SECURITY
Introduction- Factors affecting power system security-Contingency analysis-Detection of network problems-Linear sensitivity analysis-AC power flow methods-contingency selection-concentric relaxation-Bounding area method

UNIT-III: STATE ESTIMATION IN POWER SYSTEMS

UNIT-IV: POWER SYSTEM DEREGULATION
Introduction- motivation for restructuring of power systems- Electricity market entities model-benefits of deregulation- terminology-deregulation in Indian power sector-Operations in power markets-power pools-transmission networks and electricity markets.

UNIT-V: AVAILABLE TRANSFER CAPABILITY
Introduction methods: of determination of ATC - ATC calculation considering the effect of contingency analysis- Transmission open access and pricing-cost components of transmission system- transmission pricing methods-Incremental cost based transmission pricing.

TEXT BOOKS:
M. TECH. (EPE/EPS/PEES/PSC&A) –R13 Regulations

JAWAHARAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH – I YEAR – II SEM. (EPE/EPS/PEES/PSC&A)

AI TECHNIQUES IN ELECTRICAL ENGINEERING

UNIT – I: ARTIFICIAL NEURAL NETWORKS


UNIT- II: ANN PARADIGMS


UNIT – III: FUZZY LOGIC


UNIT – IV: GENETIC ALGORITHMS


UNIT-V: APPLICATIONS OF AI TECHNIQUES


TEXT BOOK:


REFERENCE BOOKS:

M. TECH. (EPE/EPS/PEES/PSC&A) - R13 Regulations

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH – I YEAR – II SEM. (EPE/EPS/PEES/PSC&A)

GAS INSULATED SYSTEMS (GIS)
(Elective–III)

UNIT-I: INTRODUCTION TO GIS AND PROPERTIES OF SF₆
Characteristics of GIS: Introduction to SF₆ - Physical properties - Chemical properties - Electrical properties - Specification of SF₆ gas for GIS application - Handling of SF₆ gas before use - Safe handling of SF₆ gas in electrical equipment - Equipment for handling the SF₆ Gas - SF₆ and environment.

UNIT-II: LAYOUT OF GIS STATIONS
Advancement of GIS station - Comparison with Air Insulated Substation - Economics of GIS - User Requirements for GIS - Main Features for GIS - Planning and Installation components of a GIS station.

UNIT-III: DESIGN AND CONSTRUCTION OF GIS STATION

UNIT-IV: FAST TRANSIENT PHENOMENA IN GIS
Introduction - Disconnectors Switching in Relation to Very fast Transients-Origin of VFTO - Propagation and Mechanism of VFTO-VFTO Characteristics - Effects of VFTO-Testing of GIS for VFTO.

UNIT-V: SPECIAL PROBLEMS IN GIS AND GIS DIAGNOSTICS

TEXT BOOK:
JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH - I YEAR - II SEM. (EPE/_EPS/PEES/PSC&A)

ELECTRIC SMART GRID
(Elective – III)

UNIT–I: INTRODUCTION
SMART GRID TO EVOLVE A PERFECT POWER SYSTEM: Introduction- Overview of the perfect power system configurations- Device level power system- Building integrated power systems- Distributed power systems- Fully integrated power system- Nodes of innovation.

UNIT–II: DC DISTRIBUTION AND SMART GRID
AC vs DC sources-Benefits of and drives of DC power delivery systems-Powering equipment and appliances with DC- Data centers and information technology loads-Future neighborhood-Potential future work and research.
INTELLIGRID ARCHITECTURE FOR THE SMARTGRID: Introduction- Launching intelligrid-Intelligrid today- Smart grid vision based on the intelligrid architecture- Barriers and enabling technologies.

UNIT–III: DYNAMIC ENERGY SYSTEMS CONCEPT
Smart energy efficient end use devices-Smart distributed energy resources-Advanced whole building control systems- Integrated communications architecture-Energy management-Roles of technology in demand response- Current limitations to dynamic energy management-Distributed energy resources-Overview of a dynamic energy management-Key characteristics of smart devices- Key characteristics of advanced whole building control systems-Key characteristics of dynamic energy management system.

UNIT–IV: ENERGY PORT AS PART OF THE SMART GRID:
Concept of energy -Port, generic features of the energy port.
MARKET IMPLEMENTATION: Framework-factors influencing customer acceptance and response - program planning-monitoring and evaluation.

UNIT–V: EFFICIENT ELECTRIC END – USE TECHNOLOGY ALTERNATIVES

TEXT BOOKS:
ENERGY AUDITING, CONSERVATION AND MANAGEMENT
(Effective-III)

UNIT-I: BASIC PRINCIPLES OF ENERGY AUDIT
Energy audit- definitions, concept, types of audit, energy index, cost index, pie charts, Sankey diagrams, load profiles, Energy conservation schemes- Energy audit of industries- energy saving potential, energy audit of process industry, thermal power station, building energy audit.

UNIT-II: ENERGY MANAGEMENT
Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting- Energy manager, Qualities and functions, language, Questionnaire — check list for top management.

UNIT-III: ENERGY EFFICIENT MOTORS
Energy efficient motors, factors affecting efficiency, loss distribution, constructional details, characteristics - variable speed, variable duty cycle systems, RMS hp- voltage variation-voltage unbalance- over motoring- motor energy audit.

UNIT-IV: POWER FACTOR IMPROVEMENT, LIGHTING AND ENERGY INSTRUMENTS
Power factor — methods of improvement, location of capacitors, Pf with non linear loads, effect of harmonics on power factor, power factor motor controllers - Good lighting system design and practice, lighting control , lighting energy audit- Energy Instruments- wattmeter, data loggers, thermocouples, pyrometers, lux meters, tongue testers , application of PLC's.

UNIT-V: ECONOMIC ASPECTS AND ANALYSIS
Economics Analysis-Depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, life cycle costing analysis- Energy efficient motors- calculation of simple payback method, net present worth method- Power factor correction, lighting - Applications of life cycle costing analysis, return on investment.

REFERENCE BOOKS:
5. Energy management and good lighting practice : fuel efficiency- booklet12-EEE
UNIT-I: LOAD COMPENSATION
Objectives and specifications – reactive power characteristics – inductive and capacitive approximate biasing – Load compensator as a voltage regulator – phase balancing and power factor correction of unsymmetrical loads – examples.

UNIT-II: STEADY – STATE REACTIVE POWER COMPENSATION IN TRANSMISSION SYSTEM
Uncompensated line – types of compensation – Passive shunt and series and dynamic shunt compensation – examples
Transient state reactive power compensation in transmission systems:

UNIT-III: REACTIVE POWER COORDINATION
Objective – Mathematical modeling – Operation planning – transmission benefits – Basic concepts of quality of power supply – disturbances – steady state variations – effects of under voltages – frequency – Harmonics, radio frequency and electromagnetic interferences

UNIT-IV: DEMAND SIDE MANAGEMENT
Load patterns – basic methods load shaping – power tariffs – KVAR based tariffs penalties for voltage flickers and Harmonic voltage levels
Distribution side Reactive power Management:

UNIT-V: USER SIDE REACTIVE POWER MANAGEMENT
KVAR requirements for domestic appliances – Purpose of using capacitors – selection of capacitors – deciding factors – types of available capacitor, characteristics and Limitations
Reactive power management in electric traction systems and arc furnaces:
Typical layout of traction systems – reactive power control requirements – distribution transformers-Electric arc furnaces – basic operations - furnaces transformer –filter requirements – remedial measures – power factor of an arc furnace

REFERENCE BOOKS:
1. Reactive power control in Electric power systems by T.J.E.Miller, John Wiley and sons, 1982 (Units I to IV)
M. TECH. (EPE/EPS/PEES/PSC&A) – R13 Regulations

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M. TECH – I YEAR – II SEM. (EPE/EPS/PEES/PSC&A)

POWER SYSTEM RELIABILITY
(Elective-IV)

UNIT-I: GENERATING SYSTEM RELIABILITY ANALYSIS – I

UNIT-II: GENERATING SYSTEM RELIABILITY ANALYSIS – II
Frequency and Duration methods – Evaluation of equivalent transitional rates of identical and non-identical units – Evaluation of cumulative probability and cumulative frequency of non-identical generating units – 2-level daily load representation - merging generation and load models – Examples.

UNIT-III: OPERATING RESERVE EVALUATION
Basic concepts - risk indices – PJM methods - security function approach – rapid start and hot reserve units – Modelling using STPM approach.

Bulk Power System Reliability Evaluation:
Basic configuration – conditional probability approach – system and load point reliability indices – weather effects on transmission lines – Weighted average rate and Markov model – Common mode failures.

UNIT-IV: INTER CONNECTED SYSTEM RELIABILITY ANALYSIS
Probability array method – Two inter connected systems with independent loads – effects of limited and unlimited tie capacity - Imperfect tie – Two connected Systems with correlated loads – Expression for cumulative probability and cumulative frequency.

Distribution System Reliability Analysis – I (Radial configuration):

UNIT-V: DISTRIBUTION SYSTEM RELIABILITY ANALYSIS - II
(PARALLEL CONFIGURATION)

Substations and Switching Stations:

REFERENCE BOOKS:

UNIT-I: INTRODUCTION TO VOLTAGE STABILITY
Definitions: Voltage Stability, Voltage Collapse, Voltage Security; Physical relation indicating dependency of voltage on reactive power flow; Factors affecting Voltage collapse and instability; Previous cases of voltage collapse incidences.

UNIT-II: GRAPHICAL ANALYSIS OF VOLTAGE STABILITY
Comparison of Voltage and angular stability of the system; Graphical Methods describing voltage collapse phenomenon: P-V and Q-V curves; detailed description of voltage collapse phenomenon with the help of Q-V curves.

UNIT-III: ANALYSIS OF VOLTAGE STABILITY
Analysis of voltage stability on SMLB system: Analytical treatment and analysis.
Voltage Stability Indices:
Voltage collapse proximity indicator; Determinant of Jacobin as proximity indicators; Voltage stability margin.

UNIT-IV: POWER SYSTEM LOADS
Loads that influences voltage stability: Discharge lights, Induction Motor, Air-conditioning, heat pumps, electronic power supplies, OH lines and cables.
Reactive Power Compensation:
Generation and Absorption of reactive power; Series and Shunt compensation; Synchronous condensers, SVCs; OLTCs; Booster Transformers.

UNIT-V: VOLTAGE STABILITY MARGIN
Stability Margin: Compensated and un-compensated systems.
Voltage Security
Definition; Voltage security; Methods to improve voltage stability and its practical aspects.

TEXT BOOKS:


REFERENCE:

1. Determination of Equivalent circuit of a 3-Winding Transformer.
3. Fault Analysis:
   i. Single Line to Ground fault (L-G).
   ii. Line to Line fault (L-L).
   iii. Double Line to Ground fault (L-L-G).
   iv. Triple Line to Ground fault (L-L-L-G).
5. Determination of Sequence Impedances of Three Phase Transformer
6. Characteristics of Over Current Relays
   i. IDMT Electromagnetic Relay (7051 A).
   ii. Microprocessor based Relay (7051 B).
   i. Electromagnetic Relay (7054 A).
   ii. Static Relay (7054 B).
   i. Electromagnetic Relay (7053 A).
   ii. Microprocessor based Relay (7053 B).
9. Characteristics of Under Voltage (UV) and Negative sequence Relays
   i. UV Electromagnetic Relay (7052 A).
   ii. UV Microprocessor based Relay (7052 B).
   iii. Static Negative Sequence Relay (7055 B).