M.Tech. Programme

in

POWER ELECTRONICS

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(Applicable for 2011 batch onwards)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, TIRUCHIRAPPALLI
The total minimum credits required for completing the M.Tech. Programme in Power Electronics is 62.

**SEMESTER - I**

<table>
<thead>
<tr>
<th>CODE</th>
<th>COURSE OF STUDY</th>
<th>L</th>
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<tbody>
<tr>
<td>MA603</td>
<td>Optimization Techniques</td>
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**SEMESTER - II**

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SEMESTER -III

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SEMESTER – IV

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For the elective courses, a student may take a maximum of two courses from other departments.

ELECTIVES

<table>
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<tr>
<th>CODE</th>
<th>COURSE OF STUDY</th>
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<td>Group I elective subjects recommended for 1st semester</td>
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Any One course from other department

| Group II elective subjects recommended for 2nd semester |
| EE660 | Flexible AC Transmission Systems       | 3 | 0 | 0 | 3 |
| EE662 | Computer Networking                     | 3 | 0 | 0 | 3 |
| EE664 | Fuzzy Systems                           | 3 | 0 | 0 | 3 |
| EE666 | Principles of VLSI Design               | 3 | 0 | 0 | 3 |

Or any one course from other departments.
LIST OF RESERVE ELECTIVES

From year to year the departmental electives subjects listed under group I and group II above may be replaced by suitable courses from the following list depending upon the interest of the majority of the students.

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tr>
<td>EE671</td>
<td>Modeling and Analysis of Electrical Machines</td>
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<td>EE672</td>
<td>Renewable Power Generation Sources</td>
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<td>EE673</td>
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<td>EE674</td>
<td>Electrical Distribution Systems</td>
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<td>EE675</td>
<td>Power System Planning and Reliability</td>
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<td>EE677</td>
<td>Digital Simulation of Power Electronic Systems</td>
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<td>EE678</td>
<td>Stochastic Models and Applications</td>
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<td>EE679</td>
<td>PWM Converters and Applications</td>
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<td>EE680</td>
<td>Transient over voltages in power systems</td>
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<td>EE681</td>
<td>High Voltage DC Transmission</td>
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<td>EE682</td>
<td>Embedded System Design</td>
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<td>EE683</td>
<td>Computer Relaying and wide area measurement systems</td>
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<tr>
<td>EE684</td>
<td>Architecture and programming for TMS320C6X DSK</td>
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<tr>
<td>EE685</td>
<td>Power System Restructuring</td>
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M.Tech. Programme in POWER ELECTRONICS

MA603 - OPTIMIZATION TECHNIQUES

Linear programming –formulation-Graphical and simplex methods-Big-M method-Two phase method-Dual simplex method-
Primal Dual problems.

Unconstrained one dimensional optimization techniques -Necessary and sufficient conditions –Unrestricted search methods-
Fibonacci and golden section method-Quadratic Interpolation methods, cubic interpolation and direct root methods.

Unconstrained n dimensional optimization techniques – direct search methods –Random search –pattern search and Rosen
brooch’s hill claiming method- Descent methods-Steepest descent, conjugate gradient, quasi -Newton method

Constrained optimization Techniques- Necessary and sufficient conditions –Equality and inequality constraints-Kuhn-Tucker
conditions-Gradient projection method-cutting plane method- penalty function method

Dynamic programming- principle of optimality- recursive equation approach-application to shortest route, cargo-loading,
allocation and production schedule problems.


EE651 – POWER CONVERTERS

Analysis of switched circuits- thyristor controlled half wave rectifier – R, L, RL, RC load circuits, classification and analysis of commutation

Single-Phase and Three-Phase AC to DC converters- half controlled configurations- operating domains of three phase full converters and semi-converters – Reactive power considerations.

Analysis and design of DC to DC converters- Control of DC-DC converters, Buck converters, Boost converters, Buck-Boost converters, Cuk converters

Single phase and Three phase inverters, Voltage source and Current source inverters, Voltage control and harmonic minimization in inverters.

AC to AC power conversion using voltage regulators, choppers and cyclo-converters, consideration of harmonics.


Review of switching regulators and switch mode power supplies-Uninterrupted power supplies- OFF-LINE AND ON-LINE TOPOLOGIES-Analysis of UPS topologies-solid state circuit breakers-solid-state tap-changing of transformer

Analog Controllers - Proportional controllers, Proportional – Integral controllers, PID controllers, derivative overrun, integral windup-cascaded control-Feedforward control-Digital control schemes- control algorithms-programmable logic controllers

Signal conditioners-Instrumentation amplifiers – voltage to current, current to voltage, voltage to frequency, frequency to voltage converters ; Isolation circuits – cabling; magnetic and electro static shielding and grounding.

Opto-Electronic devices and control , electronic circuits for photo-electric switches-output signals for photo-electric controls; Applications of opto-isolation, interrupter modules and photo sensors – Fibre optics – Bar code equipment, application of barcode in industry.

Stepper motors – types, operation, control and applications; servo motors- types, operation, control and applications – servo motor controllers – servo amplifiers – linear motor applications-selection of servo motor.


Introduction to state space modeling, modeling of physical systems. Solution to vector differential equations and state transition matrix.

Controllability and Observability definitions and Kalman rank conditions. Detectability and Stabilizability, Kalman decomposition.

Introduction to nonlinear systems. Phase plane analysis of nonlinear system using linear approximation. Limit cycle and periodic solutions. Singular points (equilibrium points) and qualitative behavior near singular points.

Stability of nonlinear systems. Lyapunov direct and indirect methods. Input to state stability. Various methods to check the stability of nonlinear systems.

State feedback controller design using pole placement. Observer design using Kalman filter algorithm. LQR and LQG controller design.


EE657 – POWER CONVERTERS LABORATORY

Experiments and computer simulations on:

Single phase, three phase Semi converters and Full converters,

DC-DC Choppers using SCRs and Self communicating Devices.

Single phase and three phase inverters using IGBTs,

AC-AC voltage regulators.

DC and AC drives
EE652 – SWITCHED MODE POWER CONVERSION


Basic concepts of Switched Mode power converters, DC-DC converters Characteristics, constituent elements, operating principles.

Steady state analysis, stress and sizing of elements, control methods, duty ratio, current programmed, frequency programmed and sliding mode control, Dynamic analysis and frequency domain models.

Classification of resonant converters, Basic resonant circuit concepts, Load resonant converters, Resonant switch converters, Zero voltage switching.

Design of feedback compensators, unity power factor rectifiers, resistor emulation principle and applications to rectifiers.


EE654 - POWER ELECTRONIC DRIVES


Conventional methods of D.C. motor speed control, single phase and three phase converter fed D.C. motor drive. Power factor improvement techniques, four quadrant operation.

Chopper fed drives, input filter design. Step-up chopper for photovoltaic systems. Braking and speed reversal of DC motor drives using choppers, multiphase choppers.


Speed control of synchronous motors, field oriented control, load commutated inverter drives, switched reluctance motors and permanent magnet motor drives.


EE656 – MICROCONTROLLER APPLICATIONS IN POWER CONVERTERS


PIC16F876 microcontroller memory organization – special function registers - I/O ports – timers - capture/compare/PWM modules (CCP)


Introduction to MPLAB IDE and PICSTART plus – device programming using MPLAB and PICSTART plus – generation of firing/gating pulses for typical power converters.

8051 microcontroller - architecture – addressing modes - I/O ports - instruction sets - simple assembly language programming.

1. **PIC16F87X datasheet 28/40-pin 8 bit CMOS flash microcontrollers, microchip technology Inc., 2001 and MPLAB IDE Quick start guide, Microchip Technology Inc., 2007.**
ELECTIVES

EE61 – ADVANCED POWER SYSTEM ANALYSIS

Single phase and three phase modeling of Synchronous generators, transformers, transmission lines and shunt components – per unit representation - network modeling – $Y_{bus}$ formulation & Conditioning – $Z_{bus}$ formulation - DC system modeling


Fault Studies -Analysis of symmetrical and unsymmetrical faults – open circuit faults.


Pattern classification – Learning and generalisation-structure of neural networks – ADA line and Mada line-perceptrons

Linear separability – Back propagation – XOR function-Back propagation algorithm-Hopfied and Hamming networks-Kohensen’s network-Boltzmann machine-in and out star network – Art 1 and Art 2 nets

Neuro adaptive control applications-ART architecture – Comparison layer – Recognition layer – ART classification process – ART implementation – Examples

Character recognition networks, Neural network control application, connectionist expert systems for medical diagnosis Self organizing maps

Applications of neural algorithms and systems -Character recognition networks, Neural network control application, connectionist expert systems for medical diagnosis

1. Martin T. Hogan, Howard B.Demuth, M, 'Neural network design'


Review of sequential circuits, Mealy & Moore Models, Analysis & Synthesis of Synchronous sequential circuits.

Digital system design Hierarchy, ASM charts, Hardware description language, Control logic Design Reduction of state tables, State Assignments.

Analysis and synthesis of Asynchronous sequential circuits, critical and non-critical races, Essential Hazard.

Combinational and sequential circuit design with PLD's, Introduction to CPLD's & FPGA's.

Fault classes and models - Stuck at faults, Bridging faults, Transition and Intermittent faults. Fault Diagnosis of combination circuits by conventional methods- Path sensitization technique, Boolean different method and Kohavi algorithm.

EE660 – FLEXIBLE AC TRANSMISSION SYSTEMS

Fundamentals of ac power transmission, transmission problems and needs, emergence of FACTS-FACTS control considerations, FACTS controllers

Principles of shunt compensation – Variable Impedance type & switching converter type- Static Synchronous Compensator (STATCOM) configuration, characteristics and control.

Principles of static series compensation using GCSC, TCSC and TSSC, applications, Static Synchronous Series Compensator (SSSC)

Principles of operation-Steady state model and characteristics of a static voltage regulators and phase shifters- power circuit configurations

UPFC -Principles of operation and characteristics, independent active and reactive power flow control, comparison of UPFC with the controlled series compensators and phase shifters.


Data link layer - design issues, Data link protocols. Medium access sub layer - channel allocations, Multiple Access protocols, IEEE protocols.

Network layer - Design issues, routing algorithms, congestion control algorithms, QoS , Transport layer- Design issues, Connection management .

Application layer – DNs, Electronic mail, World Wide Web, multimedia, Cryptography,

Internet transport protocols - TCP :TCP congestion control, connection management-UDP-header format,RPC.

Different faces of imprecision – inexactness, Ambiguity, Undecidability, Fuzziness and certainty, Probability and fuzzy logic, Intelligent systems.

Fuzzy sets and crisp sets - Intersections of Fuzzy sets, Union of Fuzzy sets, the complement of Fuzzy sets.


Methodology of fuzzy design - Direct & Indirect methods with single and multiple experts, Adaptive fuzzy control, Rule base design using dynamic response.

Fuzzy logic applications to engineering, Fuzzy decision making, Neuro-Fuzzy systems, Fuzzy Genetic Algorithms.


MOS and Fabrication: VLSI technology- NMOS, CMOS and BICMOS circuit fabrication. Comparison of IC technologies. Operation characteristics, design equations, models and second order effects of MOS transistors, Fabrication of resistors and capacitors. Latch up, Driver circuits.

Hardware Description languages: VHDL- Modeling styles –Design of simple/ complex circuits using VHDL. Overview of Verilog HDL -Design of simple circuits using Verilog HDL.


Programmable Devices: Simple and Complex Programmable logic devices (SPLD and CPLDs), Field Programmable Gate Arrays (FPGAs), Internal components of FPGA, Case study: A CPLD and a 10 million gates type of FPGA.

ASIC: Types of ASICs-Design flow-Programmable ASICs-Programmable ASIC logic cells and interconnect for Xilinx and Altera families.

RESERVE ELECTIVES

EE671 - MODELING AND ANALYSIS OF ELECTRICAL MACHINES

Principles of Electromagnetic Energy Conversion, General expression of stored magnetic energy, co-energy and force/torque, example using single and doubly excited system.

Basic Concepts of Rotating Machines - Calculation of air gap mmf and per phase machine inductance using physical machine data; Voltage and torque equation of dc machine.

Three phase symmetrical induction machine and salient pole synchronous machines in phase variable form; Application of reference frame theory to three phase symmetrical induction and synchronous machines, dynamic direct and quadrature axis model in arbitrarily rotating reference frames.


Special Machines - Permanent magnet synchronous machine: Surface permanent magnet (square and sinusoidal back emf type) and interior permanent magnet machines. Construction and operating principle, dynamic modeling and self controlled operation; Analysis of Switch Reluctance Motors.


EE672 - RENEWABLE POWER GENERATION SOURCES

Basic characteristics of sunlight – solar energy resource – photovoltaic cell-characteristics – equivalent circuit – photo voltaic for battery charging.


Load forecasting - Unit commitment – Economic dispatch problem of thermal units – Gradient method- Newton’s method – Base point and participation factor method.


Review of LFC and Economic Dispatch control (EDC) using the three modes of control viz. Flat frequency – tie-line control and tie-line bias control – AGC implementation – AGC features static and dynamic response of controlled two area system.

MVAR control - Application of voltage regulator – synchronous condenser – transformer taps – static var compensators.


EE674- ELECTRICAL DISTRIBUTION SYSTEMS

Industrial and commercial distribution systems – Energy losses in distribution system – system ground for safety and protection – comparison of O/H lines and under ground cable system.


Distribution system expansion planning – load characteristics – load forecasting – design concepts – optimal location of sub station – design of radial lines – solution technique.

Voltage control – Application of shunt capacitance for loss reduction – Harmonics in the system – static VAR systems –loss reduction and voltage improvement.

System protection – requirement – fuses and section analyzers-over current. Under voltage and under frequency protection – coordination of protective device.


Transmission system reliability model analysis-average interruption rate-LOLP method –frequency and duration method.

Two plant single load system–two plant two load system – Load forecasting uncertainly interconnection benefits.


General philosophy of protection-Classification and Characteristic function of various protective relays-basic relay elements and relay terminology-Development of relaying scheme.


Bus bar protection, line protection, distance protection–long EHV line protection, Power line carrier protection.

Reacter protection–Protection of boosters-capacitors in an interconnected power system.


EE677- DIGITAL SIMULATION OF POWER ELECTRONIC SYSTEMS


State space modeling and simulation of linear systems. Introduction to electrical machine modeling: induction, DC, and synchronous machines, simulation of basic electric drives, stability aspects.

Simulation of single phase and three phase uncontrolled and controlled (SCR) rectifiers, converters with self commutated devices- simulation of power factor correction schemes, Simulation of converter fed dc motor drives. Simulation of thyristor choppers with voltage, current and load commutation schemes, Simulation of chopper fed dc motor.

Simulation of single and three phase inverters with thyristors and self-commutated devices, Space vector representation, pulse-width modulation methods for voltage control, waveform control. Simulation of inverter fed induction motor drives.

1. Simulink Reference Manua, Math works, USA.


EE678- STOCHASTIC MODELS AND APPLICATIONS

Probability Spaces- Discrete probability distributions, Continuous probability densities, Conditional probability, distribution and densities. Distribution functions, Multiple random variables and joint distributions.

Expectations, moments, Characteristic functions and moments generating functions, sequence of random variables and Convergence Concepts.

Law of large numbers – Discrete and continuous random variables; Central limit theorem – Bernoulli trials, Discrete and continuous independent trials.


Poisson processes – Exponential distribution and applications; Birth-death processes and applications.


EE679- PWM CONVERTERS AND APPLICATIONS

AC/DC and DC/AC power conversion, overview of applications of voltage source converters, pulse modulation techniques for bridge converters.

Bus clamping PWM, space vector based PWM, advanced PWM techniques, practical devices in converter; calculation of switching and conduction losses.

Compensation for dead time and DC voltage regulation; dynamic model of a PWM converter, multilevel converters; constant V/F induction motor drives.

Estimation of current ripple and torque ripple in inverter fed drives; line – side converters with power factor compensation.

Active power filtering, reactive power compensation; harmonic current compensation.


EE680 - TRANSIENT OVER VOLTAGES IN POWER SYSTEMS

Transients in electric power systems – Internal and external causes of over voltages— Lightning strokes – Mathematical model to represent lightning– Travelling waves in transmission lines – Circuits with distributed constants – Wave equations – Reflection and refraction of travelling waves – Travelling waves at different line terminations

Switching transients – double frequency transients – abnormal switching transients – Transients in switching a three phase reactor- three phase capacitor.

Voltage distribution in transformer winding – voltage surges-transformers –generators and motors.Transient parameter values for transformers,reactors,generators and transmission lines.

Basic ideas about protection –surge diverters-surge absorbers-protection of lines and stations Modern lighting arrestors.

Insulation coordination- generation of high AC and DC – impulse voltages, currents- measurement .

Generation of high AC and DC – impulse voltages, currents-measurement using sphere gaps-peak voltmeters-potential dividers and CRO.


General aspects -HVAC and HVDC links –comparison – economic, technical performance reliability-limitation-properties of thyristor converter circuits -choice of best circuit for HVDC converters

Thyristor converter circuits -Analysis with overlap in converters - basic means of control-power reversal-desired features of control-actual control characteristics

Inverters- power control – commutation failure -D.C Reactors –voltage and current oscillations- Circuit breakers, over voltage protection

Characteristic and uncharacteristic harmonics-troubles due to harmonics-harmonic filters-converter charts of direct current and voltage-active and reactive power.

Interaction between ac and dc systems- converter transformers-earth electrodes-design of back to back thyristor converter system.


Sensor and Actuator I/O – ADC, DAC, timers, Servos, Relays, stepper motors, H-Bridge, CODECs, FPGA, ASIC, diagnostic port.

Real time operating systems (RTOS) – real time kernel – OS tasks – task states – task scheduling – interrupt processing – clocking communication and synchronization – control blocks – memory requirements and control – kernel services.

Embedded Networks - Distributed Embedded Architecture – Hardware and Software Architectures, Networks for embedded systems– I2C, CAN Bus, Ethernet, Internet, Network-Based design– Communication Analysis, system performance Analysis, Hardware platform design, Allocation and scheduling, Design Example: Elevator Controller.


EE683 -COMPUTER RELAYING AND WIDE AREA MEASUREMENT SYSTEMS

Introduction to computer relaying- Historical background, Expected benefits, computer relay architecture, Analog to digital converters, Anti-aliasing filters, Substation computer hierarchy, Fourier series, Exponential fourier series, Sine and cosine fourier series, Phasor.


Phasor Measurement Unit– Introduction, Phasor representation of sinusoids, Fourier series and Fourier transform and DFT Phasor representation, Phasor Estimation of Nominal Frequency-Signals, Formulas for updating phasors -Nonrecursive updates- Recursive updates, Frequency Estimation

Phasor Measurement Units and Phasor Data Concentrators-A generic PMU, The global positioning system, Hierarchy for phasor measurement systems, Functional requirements of PMUs and PDCs, Transient Response of Phasor Measurement Units-of instrument transformers, filters, During electromagnetic transients, Transient response during power swings


EE684- ADVANCED DSP ARCHITECTURE AND PROGRAMMING FOR

TMS320C6X DSK

DSP Development system: Introduction to DSP, Example of DSP system A to D signal conversion, DSP Support tools, code composer studio, compiler, assembler and linker, input and output with the DSK

Architecture of C6x Processor: Introduction TMS321 C6x architecture, functional units, fetch and execute packets, pipeline, registers, Linear and circular addressing modes

Instruction of C6x Processor: Instruction set assembly directives, liner assembly, ASM statement within C, timers, interrupts, multi channel buffering serial ports, direct memory access, memory consideration, fixed and floating points format, code improvement and constraints. Fast Fourier Transform: Introduction, DIT FFT algorithm with Radix 2, DIF FFT algorithm with Radix 2, inverse fast Fourier transform, fast convolution, programming example using C language

Real Time FIR Filtering: Design of FIR filter, FIR lattice structure, FIR implementation using Fourier series, windows function, programming examples using C language. Real Time IIR Filtering: Design of IIR filter, IIR lattice structure, impulse invariance, bilinear transformation programming examples using C language.

DSP/BIOS and RTDX using MATLAB & Lab View: Introduction to DSP/BIOS, RTDX using MATLAB provide interface between PC and DSK, RTDX using Lab VIEW provide interface between PC and DSK.

1. Digital signal processing and applications C6713 and C6416 DSK by Rulph Chassaing, Wiely publication.
2. Real-Time digital signal processing based on the TMS320C6000 by Nasser Kehtarnavaz, ELSEVIER publication
3. DSP applications using C and the TMS320c6x DSK by Rulph Chassaing, Wiely publication.
EE685 POWER SYSTEM RESTRUCTURING


Operational and planning activities of a Genco - Electricity Pricing and Forecasting -Price Based Unit Commitment Design - Security Constrained Unit Commitment design. - Ancillary Services for Restructuring- Automatic Generation Control (AGC).

Introduction-Components of restructured system-Transmission pricing in Open-access system-Open transmission system operation; Congestion management in Open-access transmission systems- FACTS in congestion management - Open-access Coordination Strategies; Power Wheeling-Transmission Cost Allocation Methods

Open Access Distribution - Changes in Distribution Operations- The Development of Competition – Maintaining Distribution Planning

Power Market Development – Electricity Act, 2003 - Key issues and solution; Developing power exchanges suited to the Indian market - Challenges and synergies in the use of IT in power- Competition- Indian power market- Indian energy exchange- Indian power exchange- Infrastructure model for power exchanges- Congestion Management-Day Ahead Market- Online power trading.