# DEPARTMENT OF ELECTRICAL ENGINEERING

***Chairman***

**Dr. Ali Ahmad Al-Shaikhi**

***Faculty***

| | | |
|---|---|---|
| Al-Abeedi | Abido | Al-Absi |
| Abu Al-Saud | Abuelmaatti | Al-Ahmadi |
| Al-Ahmari | Al-Akhdar | El-Amin |
| Ashraf | Al-Awami | Al-Baiyat |
| Bakhshwain | Balghonaim | Al-Battal |
| Chokri | Deriche | Al-Dohan |
| Al-Duwaish | Al-Ghadban | Al-Ghahtani |
| Al-Ghamdi | Habiballah | Hammi |
| Al-Hamouz | Hassan | Hussein |
| Ibrir | Al-Jamid | Jauwad |
| Johar | Kassas | Kousa |
| Landolsi | Maghrabi | Mahnashi |
| Masoud | Masoudi | Mesbah |
| Mohandes | Mousa | Al-Muhaini |
| Muqaibel | Al-Nafouri | Noman |
| Nuruzaman | Al-Ohali | Al-Qahtani |
| Qureshi | Ragheb | Al-Saihati |
| Shafi | Al-Shahrani | Al-Shaikhi |
| Sharawi | Sheikh S | Shohail |
| Sorour | Al-Sunaidi | Al-Suwailem |
| Al-Zaher | Zerguine | Zidouri |
| Zummo | | |

The Department of Electrical Engineering (EE) offers degrees of Master of Science (MS), Master of Engneering (MENG), and Doctor of Philosophy (PhD) in six specializations: Energy, Electromagnetics, Electronics, Control, Communications, and Signal Processing. It also offers a Master of Science degree in Telecommunication Engineering and a Master of Engineering in Sustainabe Energy. Students have the chance to select a program of study suited to their interests, individual needs and talents. The programs are broad in perspective and maintain a balance between scholarly excellence and practical relevance. The programs are oriented towards strengthening the student's background in the area of their specialization but are so designed as to deepen their understanding in one or more selected areas in electrical engineering.

The Department has a variety of excellent laboratory facilities to support teaching and research in the areas of power systems, electromagnetics, digital systems, electronics, control systems, signal processing, and communications. The Department has special facilities for research which include a Telecommunications Research Laboratory (TRL), an indoor computer-controlled antenna test range, a process control laboratory, a programmable logic controller laboratory, PCB plotters that generate printed circuit prototypes, state of the art simulator software based on the HPC (high performance computing) platform, and several computer laboratories. Graduate students have opportunities to participate in existing research efforts in areas that include, but are not limited to, antennas and propagation; microwave; digital communication systems; digital and optical signal processing; information theory; applied digital signal processing; seismic signal processing; image processing; pattern recognition; sign language recognition; artificial intelligence; automatic control systems (adaptive, robust, non-linear, digital); process control; instrumentation; computer architecture; power systems; smart interconnected grids; renewable energy; distributed generation; electricity markets and deregulation; power quality & system reliability; high voltage engineering; HVDC transmission; power electronics; power system protection; applied ultrasonic; fiber optic communications; numerical electromagnetics; VLSI systems; electromagnetic fields and wave; analog and digital electronics; computer communication networks; wireless communication; digital filtering; robot simulation and control.

**Admission Requirements**

All applicants for admission to the department must satisfy the general Graduate School admission requirements. In particular, applicants must hold a B.S. degree in electrical engineering or equivalent when applying for the master's degree or the master's degree in telecommunication engineering. Applicants for the Ph.D. must hold a master's degree.

## MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

### Degree Requirements

| (a) Core Courses (15 credit hours) | | Credit Hours |
|---|---|---|
| Three EE Courses in Area of Depth | EE xxx | 9 |
| Seminar | EE 599 | 0 |
| Thesis | EE 610 | 6 |

| (b) Elective Courses (15 credit hours) | | Credit Hours |
|---|---|---|
| Two EE Courses in Areas of Breadth | EE xxx | 6 |
| Three Technical Elective Courses | XXX xxx | 9 |

### Degree Plan

| COURSE | TITLE | LT | LB | CR | COURSE | TITLE | LT | LB | CR |
|---|---|---|---|---|---|---|---|---|---|
| **First Year** | | | | | | | | | |
| EE xxx | EE Course in Area of Depth I | 3 | 0 | 3 | EE xxx | EE Course in Area of Depth III | 3 | 0 | 3 |
| EE xxx | EE Course in Area of Depth II | 3 | 0 | 3 | EE xxx | EE Course in Areas of Breadth II | 3 | 0 | 3 |
| EE xxx | EE Course in Areas of Breadth I | 3 | 0 | 3 | XXX xxx | Technical Elective I | 3 | 0 | 3 |
| | | | | | EE 599 | Seminar | 1 | 0 | 0 |
| | | **9** | **0** | **9** | | | **10** | **0** | **9** |
| **Second Year** | | | | | | | | | |
| XXX xxx | Technical Elective II | 3 | 0 | 3 | EE 610 | Thesis | 0 | 0 | 6 |
| XXX xxx | Technical Elective III | 3 | 0 | 3 | | | | | |
| EE 610 | Thesis | 0 | 0 | IP | | | | | |
| | | **6** | **0** | **6** | | | **0** | **0** | **6** |
| **Total credit hours required in Degree Program : 30** | | | | | | | | | |

## MASTER OF ENGINEERING IN ELECTRICAL ENGINEERING

### Degree Requirements

| (a) Core Courses (12 credit hours) | | Credit Hours |
|---|---|---|
| Three EE Courses in Area of Depth | EE xxx | 9 |
| Electrical Engineering Project | EE 600 | 3 |

| (b) Elective Courses (21 credit hours) | | Credit Hours |
|---|---|---|
| Two EE Courses in Areas of Breadth | EE xxx | 6 |
| Two EE Elective Courses | EE xxx | 6 |
| Two Technical Elective Courses | XXX xxx | 6 |
| One Free Non-Technical Elective Course | XXX xxx | 3 |

### Degree Plan

| COURSE | TITLE | LT | LB | CR | COURSE | TITLE | LT | LB | CR |
|---|---|---|---|---|---|---|---|---|---|
| **First Year** | | | | | | | | | |
| EE xxx | EE Course in Area of Depth I | 3 | 0 | 3 | EE xxx | EE Course in Area of Depth III | 3 | 0 | 3 |
| EE xxx | EE Course in Area of Depth II | 3 | 0 | 3 | EE xxx | EE Course in Areas of Breadth I | 3 | 0 | 3 |
| | | **6** | **0** | **6** | | | **6** | **0** | **6** |
| **Second Year** | | | | | | | | | |
| EE xxx | EE Course in Areas of Breadth II | 3 | 0 | 3 | EE xxx | EE Elective II | 3 | 0 | 3 |
| EE xxx | EE Elective I | 3 | 0 | 3 | XXX xxx | Technical Elective I | 3 | 0 | 3 |
| | | **6** | **0** | **6** | | | **6** | **0** | **6** |
| **Third Year** | | | | | | | | | |
| XXX xxx | Technical Elective II | 3 | 0 | 3 | | | | | |
| XXX xxx | Free Non-Technical Elective | 3 | 0 | 3 | | | | | |
| EE 600 | Electrical Engineering Project | 0 | 0 | 3 | | | | | |
| | | **6** | **0** | **9** | | | | | |
| **Total credit hours required in Degree Program : 33** | | | | | | | | | |

## MASTER OF ENGINEERING IN SUSTAINABLE ENERGY

### Degree Requirements

| (a) Core Courses (21 credit hours) | | Credit Hours |
|---|---|---|
| Power System Analysis | SEN 501 | 3 |
| Power System Control and Operation | SEN 502 | 3 |
| Advanced Energy Conversion | SEN 503 | 3 |
| Renewable Energy Sources | SEN 504 | 3 |
| Distribution System Planning | SEN 505 | 3 |
| Deterministic Operations Research | SEN 525 | 3 |
| Sustainable Energy Project | SEN 600 | 3 |

| (b) Elective Courses (12 credit hours) | | Credit Hours |
|---|---|---|
| SEN Elective I | SEN 506 or SEN 519 | 3 |
| Three SEN Elective Courses | SEN xxx | 9 |

### Degree Plan

| COURSE | TITLE | LT | LB | CR | COURSE | TITLE | LT | LB | CR |
|---|---|---|---|---|---|---|---|---|---|
| **First Year** | | | | | | | | | |
| SEN 501 | Power System Analysis | 3 | 0 | 3 | SEN 502 | Power System Control and Operation | 3 | 0 | 3 |
| SEN 503 | Advanced Energy Conversion | 3 | 0 | 3 | SEN 505 | Distribution System Planning | 3 | 0 | 3 |
| SEN 504 | Renewable Energy Sources | 3 | 0 | 3 | SEN 525 | Deterministic Operations Research | 3 | 0 | 3 |
| | | **9** | **0** | **9** | | | **9** | **0** | **9** |
| **Second Year** | | | | | | | | | |
| SEN 5xx | SEN Elective I | 3 | 0 | 3 | SEN xxx | SEN Elective IV | 3 | 0 | 3 |
| SEN xxx | SEN Elective II | 3 | 0 | 3 | SEN 600 | Sustainable Enegry Project | 0 | 0 | 3 |
| SEN xxx | SEN Elective III | 3 | 0 | 3 | | | | | |
| | | **9** | **0** | **9** | | | **3** | **0** | **6** |
| **Total credit hours required in Degree Program : 33** | | | | | | | | | |

## MASTER OF SCIENCE IN TELECOMMUNICATION ENGINEERING

### Degree Requirements

| (a) Core Courses (15 credit hours) | | Credit Hours |
|---|---|---|
| Stochastic Processes | EE 570 | 3 |
| Digital Communications I | EE 571 | 3 |
| Computer Networks | COE 540 | 3 |
| Seminar | EE 599 | 0 |
| Thesis | EE 610 | 6 |

| (b) Elective Courses (15 credit hours) | | Credit Hours |
|---|---|---|
| EE Elective | EE 573 or EE 577 | 3 |
| MIS Elective | MIS 502 or MIS 510 | 3 |
| Three Technical Elective Courses | XXX xxx | 9 |

### Degree Plan

| COURSE | TITLE | LT | LB | CR | COURSE | TITLE | LT | LB | CR |
|---|---|---|---|---|---|---|---|---|---|
| **First Year** | | | | | | | | | |
| EE 570 | Stochastic Processes | 3 | 0 | 3 | EE 5xx | EE Elective | 3 | 0 | 3 |
| EE 571 | Digital Communications I | 3 | 0 | 3 | XXX xxx | Technical Elective I | 3 | 0 | 3 |
| COE 540 | Computer Networks | 3 | 0 | 3 | XXX xxx | Technical Elective II | 3 | 0 | 3 |
| | | | | | EE 599 | Seminar | 1 | 0 | 0 |
| | | **9** | **0** | **9** | | | **10** | **0** | **9** |
| **Second Year** | | | | | | | | | |
| XXX xxx | Technical Elective III | 3 | 0 | 3 | EE 610 | Thesis | 0 | 0 | 6 |
| MIS 5xx | MIS Elective | 3 | 0 | 3 | | | | | |
| EE 610 | Thesis | 0 | 0 | IP | | | | | |
| | | **6** | **0** | **6** | | | **0** | **0** | **6** |
| **Total credit hours required in Degree Program : 30** | | | | | | | | | |

## PHD IN ELECTRICAL ENGINEERING

### Degree Requirements

| (a) Core Courses (12 credit hours) | | Credit Hours |
|---|---|---|
| Seminar | EE 699 | 0 |
| PhD Pre-Dissertation | EE 711 | 3 |
| PhD Dissertation | EE 712 | 9 |

| (b) Elective Courses (30 credit hours) | | Credit Hours |
|---|---|---|
| Three EE Courses in Major Area | EE xxx | 9 |
| Two EE Courses in Minor Area | EE xxx | 6 |
| Two Technical Non-EE Elective Courses | XXX xxx | 6 |
| Two Technical Elective Courses | XXX xxx | 6 |
| One Free Elective Course | XXX xxx | 3 |

### Degree Plan

| COURSE | | TITLE | LT | LB | CR | COURSE | | TITLE | LT | LB | CR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **First Year** | | | | | | | | | | | |
| EE | xxx | Major Area Elective I | 3 | 0 | 3 | EE | xxx | Major Area Elective III | 3 | 0 | 3 |
| EE | xxx | Major Area Elective II | 3 | 0 | 3 | EE | xxx | Minor Area Elective II | 3 | 0 | 3 |
| EE | xxx | Minor Area Elective I | 3 | 0 | 3 | XXX | xxx | Non-EE Technical Elective I | 3 | 0 | 3 |
| | | | **9** | **0** | **9** | | | | **9** | **0** | **9** |
| **Second Year** | | | | | | | | | | | |
| XXX | xxx | Non-EE Technical Elective II | 3 | 0 | 3 | XXX | xxx | Technical Elective II | 3 | 0 | 3 |
| XXX | xxx | Technical Elective I | 3 | 0 | 3 | EE | 711 | PhD Pre-Dissertation | 0 | 0 | 3 |
| XXX | xxx | Free Elective | 3 | 0 | 3 | | | | | | |
| EE | 699 | Seminar | 1 | 0 | 0 | | | | | | |
| | | | **10** | **0** | **9** | | | | **3** | **0** | **6** |
| **Third Year** | | | | | | | | | | | |
| EE | 712 | PhD Dissertation | 0 | 0 | IP | EE | 712 | PhD Dissertation | 0 | 0 | 9 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | **0** | **0** | **0** | | | | **0** | **0** | **9** |
| **Total credit hours required in Degree Program : 42** | | | | | | | | | | | |

## ELECTRICAL ENGINEERING

**EE 520 Power System Steady State Analysis (3-0-3)**
Steady state modeling and simulation techniques. Large-scale power systems. Sparsity programming. Short-circuit and load-flow studies. Introduction to transient stability. Introduction to state estimation.
**Prerequisite:** Graduate Standing

**EE 522 Power System Dynamic Analysis (3-0-3)**
Dynamic model of synchronous machines. Excitation and governor systems. Nonlinear and linear modeling of single machine infinite bus systems. Stability analysis and control design. Direct method of stability determination. Multimachine system modeling. Power system dynamic equivalents.
**Prerequisite:** EE 520

**EE 523 Analysis and control of Electrical Machines (3-0-3)**
Steady-state and dynamic analysis of electrical machines: direct and quadrature axis transformation. Linear and nonlinear state space representation. Regulation and control devices. Simulation of electromechanical subsystems.
**Prerequisite:** Graduate Standing

**EE 524 Bulk Power System Planning (3-0-3)**
Mathematical methods and modern approaches to power system planning. Demand forecasting. Generation system planning: deterministic and probabilistic methods. Transmission system planning: heuristic and stochastic methods. Optimization methods for transmission planning. Route selection: environmental and other considerations.
**Prerequisite:** Graduate Standing

**EE 525 Transmission of Electrical Energy (3-0-3)**
Introduction to power system transients. Transmission lines/cable parameters, Propagation on loss-free lines, effects of termination and junctions. Transform methods of solution of T.L. Laplace transform and Fourier transform. Transients on T.L., potential and current distribution: standing waves. Traveling wave method: Lattice and graphical methods. Lighting and switching applications. Voltage limitation on power-handling capacity and T.L. effects. Transmission system protection.
**Prerequisite:** Graduate Standing

**EE 526 Sustainable Energy (3-0-3)**
Fundamentals of the sustainable energy sources. Solar energy, wind energy, fuel cell, integration of the renewable energy sources, renewable energy sources control, and impact of the renewable energy sources on power system operation, power flow control, and power system stability. This course will also discuss the various sustainable energy technologies.
**Prerequisite:** Graduate Standing

**EE 527 Reliability Assessment of Power Systems (3-0-3)**
Distribution system reliability: the system average interruption duration index (SAIDI)

and the system average interruption frequency index (SAIFI). Concept and characteristics of the reliability and availability of the power distribution systems. Analytical and simulation techniques. Assessment of reliability of the basic and networked power distribution systems. Integration of both the conventional and renewable distributed generation into the reliability models.
**Prerequisite:** Graduate Standing

**EE 528 Advanced Power Electronics (3-0-3)**
Review of power semiconductor devices: thyristors, GTO, power transistor, and MOSFET. Converter analysis, design, modeling, and control of switching converters will be presented as relevant to different applications. Practical design issues such as snubbers, gate drives and thermal design. Web content, computer analysis, and simulation tools such as Matlab and Pspice will be emphasized.
**Prerequisite:** Graduate Standing

**EE 530 Radiation and Propagation of Electromagnetic Waves (3-0-3)**
Review of Maxwell's equations, Constitutive Relations, Boundary Conditions, Power and Energy, Time Harmonic Fields, Electrical Properties of Matters, Wave Equation and its Solutions, Wave Propagation and Polarization, Electromagnetic Waves in Lossless, Lossy and Good Conductors Media, Waves at Plane Boundaries: Reflection and Transmission, Normal and Oblique Incidences, Single and Multilayers, Guided Waves Principles, Dielectric Waveguide Propagation, Rectangular Cross-Section Waveguides, Applications.
**Prerequisite:** Graduate Standing

**EE 531 Applied Electromagnetic Theory (3-0-3)**
Analytical solution of the wave equation in Cartesian, cylindrical and spherical coordinate systems. Applications to common boundary value problems (guidance, resonance, scattering and radiation). Perturbational and variational techniques. Numerical formulation and solution of selected boundary value problems.
**Prerequisite:** EE 530

**EE 532 Antenna Theory and Applications (3-0-3)**
Properties and characteristics of antennas. Polynomial representation of linear arrays. Pattern synthesis. Chebyshev array distributions. Thin linear antennas. Microstrip radiators and arrays. Huygen's principle. Radiation from apertures. Reflector type antennas. Frequency independent antennas. Reciprocity theorem and receiving antennas. Radar antennas. Antenna measurements.
**Prerequisite:** Graduate Standing

**EE 533 Microwave Integrated Circuits (3-0-3)**
Overview of microwave circuits technologies (MIC, MHMIC, MMIC). Modulation, transmitters and receivers. Antenna, RF link, and RF systems. Transmission line structures. Analysis of microstrip lines. Microwave network analysis. Passive components (termination and attenuators, hybrids, combiners, splitters, couplers, filters, ...). Active components (small-signal amplifiers, power amplifiers, oscillators, mixers, diodes, ...). TR modules. Modern microwave measurements (S-parameters, spectrum

analysis, power meters, load-pull, vector signal analysis).
**Prerequisite:** Graduate Standing

**EE 541 Design of Digital Systems (3-0-3)**
Conventional and non-conventional number systems and their applications. Hardware organization of digital systems. Arithmetic and logic units: high-speed addition, multiplication and division algorithms and implementation. Use of a Hardware Description Language (Verilog-HDL) to design complete digital systems and FPGA implementation. Transistor Level design of basic digital systems. Introduction to High Speed Digital Design and Signal Integrity.
**Note:** Equivalent to COE 561
**Prerequisite:** Graduate Standing

**EE 542 Analog Integrated Circuit Design (3-0-3)**
Review of device-level models. Basic equations and higher-order effects. Basic building blocks of bipolar, MOS and CMOS analog circuits: current mirrors, differential pairs, level-shift stages, gain stages, references and Op-Amp circuits. The translinear principle and applications. Typical examples of IC amplifier design.
**Prerequisite:** Graduate Standing

**EE 543 Computer System Architecture (3-0-3)**
Architectural techniques for advanced and high performance microprocessors including CPU architecture, pipelining, in-order and out-of-order superscalar architecture, memory hierarchy, and VLIW machines. Power management. Advanced I/O systems. Parallel architectures. Fundamentals of multiprocessors: multithreading and multi-core. System performance trade-offs and optimization techniques.
**Note:** Equivalent to COE 501
**Prerequisite:** EE 541

**EE 544 Embedded System Design and Applications (3-0-3)**
Microprocessors, Microcontrollers and DSP hardware and software architectures. Advanced programming and interrupts. Interface to real-time systems. Applications and case studies including projects.
**Prerequisite:** EE 541

**EE 545 Advanced Analog Electronics (3-0-3)**
Small-signal equivalent circuits and noise models of active devices. Design and analysis of linear wide-band low-noise feedback amplifiers. High frequency design using operational amplifiers and operational transconductance amplifiers. Application of specialized electronic systems in analog signal processors. Introduction to emerging technologies and advanced topics from recent literature.
**Prerequisite:** Graduate Standing

**EE 546 Semiconductor Device Theory (3-0-3)**
Electronic states in semiconductors. Carrier transport models and current equations. Analysis of pn junctions, bipolar and FET transistors. Introduction to microwave devices and semiconductor optoelectronics.

**Prerequisite:** Graduate Standing

**EE 550 Linear Control Systems (3-0-3)**
State space representation of systems. Theory of multivariable systems. Jordan canonical forms. Transformation matrices. Realization theory. Controllability and observability. Stability. State estimators. Output and state feedback. Compensation. Decoupling and model matching. Introduction to optimal control.
**Note:** Equivalent to SCE 507
**Prerequisite:** Graduate Standing

**EE 551 System Identification (3-0-3)**
Introduction to dynamic systems, models, and identification process. Models of linear time-invariant systems. Models of time-varying and nonlinear systems. Parametric estimation methods. Convergence and consistency of solutions. Asymptotic distribution. Recursive and non-recursive computation methods. Model selection and validation.
**Note:** Equivalent to SCE 513
**Prerequisite:** Graduate Standing

**EE 552 Optimal Control Theory and Applications (3-0-3)**
Nonlinear optimal control of continuous-time systems. Minimum time and constrained input problems. Linear quadratic regulator. Optimal output-feedback. Optimal state estimation. Linear quadratic Gaussian design. Case studies.
**Note:** Equivalent to SCE 514
**Prerequisite:** EE 550 or equivalent

**EE 554 Advanced Digital Control Systems (3-0-3)**
Digital controller design. Pole-assignment design and state-estimation. Linear quadratic optimal control. Sampled-data transformation of Analog filters. Digital filter structures. Microcomputer implementation of digital filters.
**Prerequisite:** Graduate Standing

**EE 555 Neural Networks Theory and Applications (3-0-3)**
Introduction, background and biological inspiration. Survey of fundamentals methods of artificial neural networks: single and multi-layer networks; Perceptions and back propagation. Associative memory and statistical networks. Supervised and unsupervised learning. Merits and limitations of neural networks. Applications.
**Note:** Equivalent to ICS 586
**Prerequisite:** Graduate Standing

**EE 556 Intelligent Control (3-0-3)**
Intelligent control strategies: Expert systems, Fuzzy logic control, Neural networks. Optimization control techniques: genetic algorithms, simulated annealing, tabu search. Hybrid systems. Applications.
**Note:** Equivalent to SCE 562
**Prerequisite:** Graduate Standing

**EE 562 Digital Signal Processing I (3-0-3)**
Classification of discrete-time signals and systems. Basic and lattice structures, Finite-word length effects. Discrete Fourier Transform and its efficient implementations. Introduction to spectral analysis. FIR and IIR filter design techniques: Windowing techniques, Analog-to-Digital transformation techniques, Computer-aided design techniques.
**Note:** Equivalent to SCE 534
**Prerequisite:** Graduate Standing

**EE 563 Speech and Audio Processing (3-0-3)**
Speech analysis, Digital processing of wave forms, Wavelet transformation Waveform coding, Parametric coding of speech: linear predictive coding, Text-to-Speech synthesis, Recognition, Stochastic modeling of speech signals, Pattern recognition and its application to speech, Speech coding for Packet Networks, Echo removal.
**Prerequisite:** EE 562

**EE 570 Stochastic Processes (3-0-3)**
Basic set theory and measure theory, probability spaces, joint probability, conditional probability, and independence. Random variables, distribution functions, and moments. Multiple random variables, convergence concepts, and mean square estimation. Stochastic processes, stationarity and ergodicity, second-order processes, and systems with random inputs. Markov processes.
**Prerequisite:** Graduate Standing

**EE 571 Digital Communications I (3-0-3)**
Review of probability and random processes. Space representation of signals. Optimal detection of signals in Gaussian noise. Matched filter and correlator receivers. Band-pass modulation techniques. Error performance of binary and M-ary modulation techniques. Spectral density and autocorrelation of digital signals. Differential modulation and non-coherent receivers. Introduction to source coding, channel capacity and error control coding. Linear block codes and convolutional codes.
**Prerequisite:** Graduate Standing

**EE 573 Digital Communications II (3-0-3)**
Review of digital transmission over AWGN channels. Spectral analysis of digital signals. Digital, transmission over band-limited channels. Intersymbol lnterference. Signal design for band-limited channels. Channel equalization. Characterization of fading multipath channels. Performance of digital transmission over fading channels. Diversity techniques. Spread spectrum. Multi-user communication. Multi-channel and multicarrier systems, introduction to MIMO systems.
**Prerequisite:** EE 571

**EE 574 Detection and Estimation (3-0-3)**
Binary and M-hypotheses Detection techniques: Maximum likelihood, Newman Pearson, Minimum probability of error, Maximum a posteriori probability, Bayes decision and minimax detection. Parameter estimation: weighted least squares, BLUE,

Maximum likelihood, Mean square estimation. Signal estimation and filtering: Wiener filtering, Kalman filtering and estimation. Simultaneous detection and estimation. Application to system identification and communication systems.
**Prerequisite:** EE 570

**EE 575 Information Theory (3-0-3)**
Measures of information, entropy, source coding theorem, lossless data compression, Huffman codes and Lempel-Ziv codes, sources with memory, lossy data compression, rate distortion theory, mutual information, memoryless channels, channel capacity, channel coding theory, differential entropy, capacity of AWGN channels, multiple access channels if time permits.
**Prerequisite:** Graduate Standing

**EE 576 Error Control Coding (3-0-3)**
Finite field arithmetic, Linear codes, Block codes, Cyclic codes, BCH and Reed-Solomon codes, Encoding and decoding methods, Performance analysis of block and cyclic codes, Convolutional codes, Trellis representation, The Viterbi algorithm, Performance analysis of convolutional codes, Coded modulation, Turbo codes.
**Prerequisite:** Graduate Standing

**EE 577 Wireless and Personal Communications (3-0-3)**
The Cellular concept, Propagation modeling, Digital transmission techniques, multiple access techniques, Cellular frequency planning, Link control, Handoffs, Power control, Traffic capacity, Wireless networking, Privacy and security of wireless systems, Examples of current wireless systems standards.
**Prerequisite:** EE 571

**EE 578 Simulation of Communication Systems (3-0-3)**
Generation of pseudo-random signals and noise, Basic techniques for bit error rate estimation, Simulation of a binary system, Simulation of Intersymbol interference, Channel modeling, Signal-to-Noise Ratio estimation, Multi-rate simulation, Adaptive equalization and Coded systems simulation, Importance sampling.
**Prerequisite:** EE 573

**EE 599 Seminar (1-0-0)**
This course requires attending the seminars given by faculty, visiting scholars, and fellow graduate students. Among other things, this course is designed to give the student an overview of research in the department, and a familiarity with the research methodology, journals and professional societies in his discipline. Graded on a Pass or Fail basis.
**Prerequisite:** Graduate Standing

**EE 600 Electrical Engineering Project (0-0-3)**
This course gives the students an opportunity to complete a project related to the Electrical Engineering Program. Apply knowledge gained during the previous

semesters and practice a variety of skills such as: researching for technical information, organization, planning, looking up sources, designing and testing, and delivering oral and written presentations. Graded on a Pass or Fail basis.
**Prerequisite:** Graduate Standing

**EE 606 Independent Research (0-0-3)**
This course is intended to allow the student to conduct research in advanced problems in his M.S. research area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course. Graded on a Pass or Fail basis.
**Prerequisite:** Prior arrangement with an instructor

**EE 608 Special Topics in Electrical Engineering I (3-0-3)**
The contents of this course will be in one of the specialized areas of Electrical Engineering. The specific contents of the special topics of course will be given in detail at least one semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**EE 609 Special Topics in Electrical Engineering II (3-0-3)**
The contents of this course will be in one of the specialized areas of Electrical Engineering. The specific contents of the special topics of course will be given in detail at least one semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**EE 610 M.S. Thesis (0-0-6)**
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**Corequisite:** EE 599

**EE 620 High Voltage Engineering (3-0-3)**
Breakdown in gases, solids and liquids. Analysis of high voltage transmission: switching and lighting surges. Insulation coordination in electrical power system. Basic impulse levels. System grounding and insulation designs. High voltage generation and measurement.
**Prerequisite:** Graduate Standing

**EE 622 Power System Operation (3-0-3)**
Fundamentals of power system economics. Background concepts on optimization and power system operation are discussed. Then, the structure and operation of deregulated electricity markets taking into account the behavior of the physical system is discussed thoroughly.
**Prerequisite:** Graduate Standing

**EE 623 HVDC Transmission System (3-0-3)**

Development of HVDC technology Comparison between AC and DC transmission. Converter circuit configuration. Converter operation and analysis. Harmonics and filters. Ground return. Integration of HVDC links into power systems. AC-DC load flow, short circuit and stability calculations. FACTS devices and system operation. Trends for HVDC applications: wind farm and IGBT technology.
**Prerequisite:** Graduate Standing

**EE 624 Smart Grids (3-0-3)**
Fundamentals of the smart grid, microgrids, and distributed generation (DG). Distribution system basics, DG integration, unbalanced power flow including DG, electricity markets, smart meters, electric vehicles and storage integration, reliability and self-healing of microgrids. This course will also discuss the various demand side management (DSM) programs and technologies.
**Prerequisite:** Graduate Standing

**EE 625 Power System Protection (3-0-3)**
Fundamentals of power system protection concepts and applications. Analysis of symmetrical and unsymmetrical faults on power systems, Study of protective relaying for protection of power systems components against faults, Digital relays, and relay coordination and computer solutions are emphasized.
**Prerequisite:** Graduate Standing

**EE 629 Special Topics in Power Systems (3-0-3)**
The contents of this course will be in one of the areas of interest in power systems. The specific contents of the special topics course will be given in detail at least one semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**EE 631 Microwave Measurements (1-6-3)**
Microwave signal sources. Waveguide components. Network analyzer measurements. Scattering parameters of microwave planar transistors. Doppler effect. Time domain reflectometry. Microwave links. Antenna impedance and pattern measurements. Microstrip transmission lines. Resonant cavities.
**Prerequisite:** Graduate Standing

**EE 633 Optical Fiber Communication (3-0-3)**
Dielectric slab waveguides. Classification of mode types. Parabolic two-dimensional media. Circular waveguides. Step-index and graded-index optical fibers. Effect of loss. Dispersion effects. Fabrication methods in integrated optics and optical fibers. Light sources. Light Detectors. WDM concepts and components. Optical Amplifiers. Point-to-point link system considerations. Photonic devices. Applications in communication systems.
**Prerequisite:** Graduate Standing

**EE 635 Computational Electromagnetics (3-0-3)**
Review of basic electromagnetic theory and partial differential equations (PDEs). Finite-difference approximation of PDEs. The finite-difference time domain (FDTD) in 2D and 3D. The Yee's mesh. Scalar formulation of the FDTD method. Related topics including numerical stability and dispersion, boundary conditions, materials,etc. Introduction to other methods such as the finite-element method, the method of lines, beam propagation method, and the method of moments. Applications and case studies.
**Prerequisite:** Graduate Standing

**EE 636 Theory and Applications of Antenna Arrays (3-0-3)**
Antenna array fundamentals. Analysis and synthesis of discrete linear arrays. Two-dimensional arrays. Concept of adaptive arrays. Adaptive beam forming and nulling. Superdirective array functions. Suppression of side lobes in linear arrays.
**Prerequisite:** Graduate Standing

**EE 639 Special Topics in Electromagnetics (3-0-3)**
The contents of this course will be in one of the areas of interest in electromagnetics. The specific contents of the special topics of course will be given in detail at least one semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**EE 642 Analog VLSI Circuit Design (3-0-3)**
MOS and CMOS technology: building blocks, devices, capacitors and limitations. Operational amplifiers and other analog systems. Application to filter design and data converters. Layout considerations and CAD tools.
**Prerequisite:** EE 542

**EE 645 VLSI Architecture (3-0-3)**
Review of MOS transistors: fabrication, layout and characterization. Review of CMOS circuit and logic design: fully complementary CMOS logic, pseudo-NMOS logic, dynamic CMOS logic, pass-transistor logic, clocking strategies. Subsystem design: ALUs, multipliers, memories, PLAs. Architecture design: iterative cellular design and systolic arrays. Application to system level designs.
**Prerequisite:** EE 541

**EE 649 Special Topics in Digital Systems and Electronics (3-0-3)**
The contents of this course will be in one of the areas that has the nature of research topics in digital and electronics systems. For example: VLSI architectures, Advanced analog ICs, Physics of ultra small devices, etc.
**Prerequisite:** Consent of Instructor

**EE 651 Adaptive Control (3-0-3)**
Introduction to the various approaches of adaptive controller design. Real-time parameter estimation. Model reference adaptive control. Self-tuning controllers. Variable structure systems. Gain Scheduling. Robustness issues. Practical aspects and

implementation. Typical Industrial applications.
**Note:** Equivalent to SCE 527
**Prerequisite:** EE 550

**EE 652 Nonlinear Systems (3-0-3)**
Introduction to nonlinear systems and control. Overview of phase plane analysis, describing function and limit cycles. Linear systems and linearization. Lyapunov stability, Invariance principal, different notions of stability (uniform, uniform asymptotic, exponential, global uniform asymptotic), input-output stability, Input-to-State-Stability (ISS), region of attraction. Invariance Theorems. System linearization by state transformation and feedback, partial linearization, zero dynamics. Back-stepping method.
**Note:** Equivalent to SCE 517
**Prerequisite:** EE 550

**EE 653 Robust Control (3-0-3)**
Elements of robust control theory. Norms of signals and systems. Performance specifications. Modeling of uncertain linear systems and system parameterization. Model uncertainty and robustness. Polytopic uncertainties and norm-bounded uncertainties. Domain stability, H∞ norm, and H2 norm. Linear matrix inequalities and their numerical solutions. Stability of uncertain linear systems in continuous time and discrete time. H∞ Filtering, Loop transfer recovery. H∞ Control, Mixed H2− H∞ control. Case studies.
**Note:** Equivalent to SCE 614
**Prerequisite:** EE 550

**EE 654 Large Scale Systems (3-0-3)**
Introduction to large scale systems. Classical Model reduction techniques. Component cost analysis method. L2 model reduction. Hankel norm approximation. Introduction to H∞-model reduction. Relations between modeling and control. Closed loop model reduction. Decentralized control design schemes. System's interactions. Coordinated and hierarchical control. Case studies.
**Prerequisite:** EE 550

**EE 656 Robotics and Control (3-0-3)**
Basic concepts of robotics. Mathematical description of industrial manipulator. Homogeneous transformation and the Denavit-Hartenberg notation. Transformation between frames. Forward, and inverse kinematics and dynamics. Newton - Euler and Lagrange formulations. Joint space, and Cartesian space trajectories and dynamic control. Trajectory planning. Advance control schemes.
**Note:** Equivalent to SCE 571
**Prerequisite:** EE 550

**EE 659 Special Topics in Control (3-0-3)**
The contents of this course will be in one of the areas of interest in control. The specific contents of the special topics of course will be given in detail at least one

semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**EE 661 Digital Signal Processing II (3-0-3)**
Optimal one- dimensional filter design techniques. Multidimensional digital signals and systems. Multidimensional Fourier transform. Analysis of multidimensional systems and digital filter design. Implementation issues. Parametric and non-parametric spectral estimation. Applications.
**Prerequisite:** Graduate Standing

**EE 662 Adaptive Filtering and Applications (3-0-3)**
Introduction to adaptive Signal Processing. Fundamentals of Adaptive Filter Theory. The LMS Algorithm, LMS-based Algorithms. Conventional RLS Adaptive Filtering. Adaptive Lattice-based RLS Algorithms. Fast Algorithms. Implementation Issues. Adaptive IIR filters. HOS-based adaptive filtering. Introduction to nonlinear filtering. Applications to Echo cancellation, equalization, noise canceling and prediction.
**Prerequisite:** Graduate Standing

**EE 663 Image Processing (3-0-3)**
Two-dimensional systems and mathematical preliminaries. Perception and human vision systems. Sampling and quantization. Image transforms. Image representation by stochastic models. Image data compression, enhancement, filtering, and restoration. Reconstruction from projection. Analysis and computer vision.
**Prerequisite:** Graduate Standing

**EE 664 Wavelet Signal Processing (3-0-3)**
Cosine transform and short-time Fourier transform, Analysis of filter banks and wavelets, Sub-band and wavelet coding, Multirate signal processing, Wavelet transform, Daubechies wavelets, Orthogonal and biorthogonal wavelets, Time-frequency and time-scale analysis, Design methods. Applications of wavelets to audio and image compression, Medical imaging, Geophysics, Scientific visualization.
**Prerequisite:** Graduate Standing

**EE 665 Signal and Image Compression (3-0-3)**
Principles and techniques of signal compression, Quantization theory, Linear prediction, Coding techniques: predictive, transform, entropy, and vector quantization, Fidelity, bit-rate, and complexity trade-offs. Compression standards, Applications to speech, audio, image, and video compression.
**Prerequisite:** Graduate Standing

**EE 669 Special Topics in Signal Processing (3-0-3)**
The contents of this course will be in one of the areas of interest in signal processing. The specific contents of the special topics of course will be given in detail at least one semester in advance of that in which it is offered.

**Prerequisite:** Consent of Instructor

**EE 677 Advanced Wireless Communications (3-0-3)**
Review of propagation models, modulation, and diversity for second-generation systems. Information theoretic capacity of fading channels: ergodic and outage capacity. Single-user MIMO systems: channel models, capacity, and trans-receive schemes. Introduction to multiuser information theoretic models: Multiple Access, Broadcast, and Interference channels. Multiuser-user MIMO systems: trans-receive schemes and capacity results. Multi-user scheduling and multi-user diversity. Introduction to Cognitive radio. Cooperative communications. Ad hoc networks. Future and open research topics.
**Prerequisite:** EE 577

**EE 679 Special Topics in Communication (3-0-3)**
The contents of this course will be in one of the areas of interest in communication. The specific contents of the special topics of course will be given in detail at least one semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**EE 699 Seminar (1-0-0)**
This course requires attending the seminars given by faculty, visiting scholars, and fellow graduate students. Among other things, this course is designed to give the student an overview of research in the department, and a familiarity with the research methodology, journals and professional societies in his discipline. Graded on a Pass or Fail basis.
**Prerequisite:** Graduate Standing

**EE 701 Directed Research I (0-0-3)**
This course is intended to allow the student to conduct research in advanced problems in his Ph.D. research area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course. Graded on a Pass or Fail basis.
**Prerequisite:** Prior arrangement with an instructor

**EE 702 Directed Research II (0-0-3)**
This course is intended to allow the student to conduct research in advanced problems in his Ph.D. research area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course. Graded on a Pass or Fail basis.
**Prerequisite:** EE 701, Prior arrangement with an instructor

**EE 711 Pre-Dissertation (0-0-3)**
This course enables the student to submit his Ph.D. Dissertation Proposal and defends

it in public. The student passes the course if the Ph.D. Dissertation committee accepts the submitted dissertation proposal report and upon successfully passing the Dissertation proposal public defense. The course grade can be NP, NF or IP.
**Prerequisite:** EE 699, Ph.D. Candidacy

**EE 712 Ph.D. Dissertation (0-0-9)**
This course enables the student work on his Ph.D. Dissertation as per the submitted dissertation proposal, submit its final report and defend it in public. The student passes this course if the Ph.D. Dissertation committee accepts the submitted final dissertation report and upon successfully passing the Dissertation public defense. The course grade can be NP, NF or IP.
**Prerequisite:** EE 711

## SUSTAINABLE ENERGY

**SEN 501 Power System Analysis (3-0-3)**
Steady State modeling and Simulation of power systems by digital computers: sparsity programming. Load-flow, Short circuit, and Stability studies for power system planning and operation. Application of industry software for study cases.
**Note:** Equivalent to EE 520
**Prerequisite:** Graduate Standing

**SEN 502 Power System Control and Operation (3-0-3)**
Power generation systems; economic dispatch; unit commitment; hydrothermal coordination problem; production cost models; automatic generation control; interchange of power and energy; power system security techniques; state estimation; optimal power flow. Modern Industry operating modes. Electricity market structures.
**Note:** Equivalent to EE 622
**Prerequisite:** Graduate Standing

**SEN 503 Conventional Generation (3-0-3)**
Introduction to conventional technologies used for generating electricity. Studying of technical problems associated with operation of different types of power plants. Understanding of the complex systems involved in generation of electricity. Introducing the economic, management aspects, and the environmental impact of power generation.
**Prerequisite:** Graduate Standing

**SEN 504 Renewable Energy Sources (3-0-3)**
Electric energy from renewable energy sources including solar, wind, hydro and geothermal; biofuels and fuel cells. Characteristics of energy conversion and storage systems. Issues related to integration of small scale energy sources into electricity grid.
**Note:** Equivalent to EE 526
**Prerequisite:** Graduate Standing

**SEN 505 Distribution Systems Planning (3-0-3)**
Fundamentals of distribution systems planning. Load characteristics. Distribution transformers. Application of capacitors to distribution systems. Voltage regulation. Design of sub-transmission substations. Design considerations of primary and secondary systems. Distribution system protection. Concept and characteristics of the reliability and availability of the power distribution systems. The integration of conventional and renewable distributed generation into the distribution system.
**Prerequisite:** Graduate Standing

**SEN 506 Power System Economics (3-0-3)**
Fundamentals of power system economics. Background concepts on optimization and power system operation. Structure and operation of deregulated electricity markets as

impacted by the behavior of the physical system.
**Prerequisite:** Graduate Standing

**SEN 507 Bulk Power System Planning (3-0-3)**
Mathematical methods and modern approaches to power system planning. Demand forecasting. Generation system planning: deterministic and probabilistic methods. Transmission and distribution system planning: heuristic and stochastic methods. Optimization methods for transmission planning. Route selection: environmental and other considerations. Advanced aspects of power system planning: microgrid planning, planning for distributed energy resources, demand response. Practical case studies for planning.
**Note:** Equivalent to EE 524
**Prerequisite:** Graduate Standing

**SEN 508 Power System Protection (3-0-3)**
Analysis of symmetrical and unsymmetrical faults on power systems. Study of protective relaying for protection of power systems components against faults. Digital relays, relay coordination and computer solutions are emphasized.
**Prerequisite:** Graduate Standing

**SEN 509 Power System Dynamics and Control (3-0-3)**
Dynamic models of synchronous machines, Turbine, governor, and excitation systems, Nonlinear and small signal modeling of single machine infinite bus systems, Stability analysis and control design, power system dynamic equivalents. Industrial examples and case studies on power system stabilizer design and implementation will be explained.
**Note:** Equivalent to EE 522
**Prerequisite:** SEN 501

**SEN 510 Power Transmission (3-0-3)**
Fundamentals of overhead transmission lines and underground cables. Transmission line parameters and constants. Transmission Line Steady State operation, Natural loading and reactive compensation. Flexible AC Transmission Systems (FACTS) devices. Basic principles of operation and control of High-Voltage DC (HVDC). Substations, switching stations. Underground transmission. Monitoring and control of smart grid. Special transmission: Grids for railway, superconducting cables, Single wire with earth return, wireless power transmission.
**Note:** Equivalent to EE 525
**Prerequisite:** Graduate Standing

**SEN 511 Power Electronics (3-0-3)**
Analysis, design, and control of modern, solid-state, high power, static, ac-to-dc, dc-to-dc, dc-to-ac, and ac-to-ac power converters. Motor drive applications.
**Note:** Equivalent to EE 528
**Prerequisite:** Graduate Standing

**SEN 512 Power Quality (3-0-3)**
General Classes of Power Quality Problems, Transients, Long-Duration Voltage Variations, Short-Duration Voltage Variations, Voltage Imbalance, Harmonics, Waveform Distortion, Voltage Fluctuation, Power Frequency Variations, Power Quality Terms, CBEMA & ITI Curves.
**Prerequisite:** Graduate Standing

**SEN 513 Renewable Energy Sources - Wind Engineering (3-0-3)**
Fundamentals of wind generation, Wind turbines, Wind generators and their models. Control and protection of wind turbine generators. Grid integration aspects.
**Prerequisite:** Graduate Standing

**SEN 514 Smart Grids (3-0-3)**
Description of smart electric grids. Smart grid challenges and modeling. The integration of distributed generation, renewables, and storage media. Smart grids and demand response, Microgrids, and virtual power plants. Market aspects of the smart grid.
**Note:** Equivalent to EE 624
**Prerequisite:** Graduate Standing

**SEN 515 High Voltage Engineering (3-0-3)**
Introduction to High Voltage engineering, Generation of testing voltages. High Voltage measurements. High Voltage insulation. Electric fields and electric breakdown. High Voltage Insulators. Circuit breakers. Switchgears. Case studies on industrial applications: fly ash collection by electrostatic precipitators, metallic powder coating, car electrostatic painting and waste electrostatic.
**Note:** Equivalent to EE 620
**Prerequisite:** Graduate Standing

**SEN 516 Computational Intelligence in Power Systems (3-0-3)**
Intelligent control strategies; fuzzy logic control, neural networks; Heuristic optimization techniques: genetic algorithms, simulated annealing, Tabu search, particle swarm, differential evolution, hybrid systems, hands-on learning experience, applications and case studies on intelligent control implementation.
**Note:** Equivalent to EE 556
**Prerequisite:** Graduate Standing

**SEN 517 Nuclear Engineering (3-0-3)**
Introduction to nuclear engineering. Basic concepts and overview of the nuclear power technology. Fundamentals of reactor analysis including diffusion theory.
**Prerequisite:** Graduate Standing

**SEN 518 Introduction to Fuel-Cell Systems (3-0-3)**

Fundamental of Fuel cell systems. Fuel cell types and their applications. Integration of fuel cells in electric power systems.
**Prerequisite:** Graduate Standing

**SEN 519 Engineering Economics and Risk Management for Energy (3-0-3)**
Core concepts and advanced techniques for economic decision. Analysis of capital investment. Managing and valuing risk in energy engineering systems; Basic terminology, concepts of financial engineering and management.
**Prerequisite:** Graduate Standing

**SEN 520 Energy Efficiency and Demand Side Management (3-0-3)**
Introduction to energy efficiency and demand side management (DSM). Benefits of energy efficiency and DSM. Historical development of tariffs. Efficiency of generation, transmission and distribution systems. Technologies to improve the system efficiency. Demand energy and load management. International practices in demand side management.
**Prerequisite:** Graduate Standing

**SEN 521 Special Topics in Sustainable Energy I (3-0-3)**
The contents of this course will be in one of the areas of sustainable energy systems. The specific contents of the special topics course will be given in detail at least one semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**SEN 522 Special Topics in Sustainable Energy II (3-0-3)**
The contents of this course will be in one of the areas of sustainable energy systems. The specific contents of the special topics course will be given in detail at least one semester in advance of that in which it is offered.
**Prerequisite:** Consent of Instructor

**SEN 525 Deterministic Operations Research (3-0-3)**
Model construction and modelling issues. Linear programming (LP) formulation, Simplex method: two-phase algorithm, dual simplex method, network simplex method. Duality, sensitivity analysis, economic interpretation and applications. Integer programming (IP), modelling techniques using zero-one variables. Branch and bound algorithm for integer programming. Various applications of integer programming. Computer packages and case studies.
**Note:** Equivalent to ISE 501
**Prerequisite:** Graduate Standing

**SEN 600 Sustainable Energy Project (0-0-3)**
This course gives the students an opportunity to complete a project related to the Sustainable Engineering Program. Apply knowledge gained during the previous semesters and practice a variety of skills such as: researching for technical information, organization, planning, looking up sources, designing and testing, and delivering oral

and written presentations. Graded on a Pass or Fail basis.
**Prerequisite:** Graduate Standing