| Scheme of studies M.Sc. (Hons.) Energy Systems Engineering | | | | | |
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| **Existing w.e.f. 2017** | | | **Revised w.e.f. winter 2023** | | |
| **Course Code** | **Course Title** | **Cred. Hrs.** | **Course Code** | **Course Title** | **Cred. Hrs.** |
| ESE-701 | Energy Audit and Management | 3(2-1) | ESE-701 | Energy Audit and Management | 3(2-1) |
| ESE-702 | Solar Thermal Engineering and Storage Techniques | 3(2-1) | ESE-702 | Solar Thermal Engineering and Storage Techniques | 3(2-1) |
| ESE-703 | Bio Energy Engineering | 3(2-1) | ESE-703 | Bio Energy Engineering | 3(2-1) |
| ESE-704 | Hybrid Power Sources | 3(2-1) | ESE-704 | Hybrid Power Sources | 3(2-1) |
| ESE-705 | Hydro Power Engineering | 3(2-1) | ESE-705 | Hydro Power Engineering | 3(2-1) |
| ESE-706 | Wind Energy Engineering | 3(2-1) | ESE-706 | Wind Energy Engineering | 3(2-1) |
| ESE-707 | Materials for Energy Storage | 3(2-1) | ESE-707 | Materials for Energy Storage | 3(2-1) |
| ESE-708 | Refrigeration And air Conditioning | 3(2-1) | ESE-708 | Refrigeration And air Conditioning | 3(2-1) |
| ESE-709 | Power Electronics for Energy Conversion | 3(2-1) | ESE-709 | Power Electronics for Energy Conversion | 3(2-1) |
| ESE-710 | Electrical Power Transmission and Distribution (Replaced) | 3(2-1) | ESE-710 | Digitalization of Energy Systems (New Course) | 3(2-1) |
| ESE-711 | Energy Systems Modelling and Simulation | 3(2-1) | ESE-711 | Energy Systems Modelling and Simulation | 3(2-1) |
| ESE-712 | Coal Processing Technologies | 3(2-1) | ESE-712 | Coal Processing Technologies | 3(2-1) |
| ESE-713 | Fluid Flow and Heat Transfer in Industrial Applications | 3(2-1) | ESE-713 | Fluid Flow and Heat Transfer in Industrial Applications | 3(2-1) |
| ESE-714 | Hydrogen Technologies and Fuel Cells | 3(2-1) | ESE-714 | Hydrogen Technologies and Fuel Cells | 3(2-1) |
| ESE-715 | Research Methods and Project Management | 3(3-0) | ESE-715 | Research Methods and Project Management | 3(3-0) |
| ESE-716 | Photovoltaic Systems (Removed) | 3(2-1) | | | |

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| ESE-717 | Biofuels Engineering | 3(2-1) | ESE-716 | Biofuels Engineering (Course No Updated) | 3(2-1) |
| ESE-719 | Special Problem | 1(1-0) | ESE-719 | Special Problem | 1(1-0) |
| ESE-720 | Seminar | 1(1-0) | ESE-720 | Seminar | 1(1-0) |

| Existing | Proposed |
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| **ESE-701 ENERGY AUDIT AND MANAGEMENT 3(2-1)**<br><br>**Learning Objectives**<br>To train the students about energy management, monitoring and auditing.<br>**Theory**<br>Energy Overview – Energy Management Techniques, Role of Energy Managers in Industries- Energy monitoring, auditing & targeting – Economics of various Energy Conservation schemes.<br>Total Energy Systems Energy Audit -various Energy Conservation Measures in Steam-Losses in Boiler. Energy Conservation in Steam Systems -Case studies. Energy conservation in Centrifugal pumps, Fans & Blowers, Air compressors– energy consumption and energy saving potentials – Design consideration.<br>Refrigeration & Air conditioning - Heat load estimation -Energy conservation in cooling towers & spray ponds – Case studies Electrical Energy -Energy Efficiency in Lighting – Case studies. Organizational background desired for energy management motivation, detailed process of M&T-Thermostats, Boiler controls-proportional, differential and integral control, optimizers; compensators.<br>**Practical**<br>Study of energy use pattern in various energy units viz; chillers, central heating and cooling units, milk plants, food industries etc. Energy audit study and management strategies in industrial plants. Identification of energy efficient processing machines. Assessment | **No Change** |

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| of overall energy consumption, production and its cost in a processing plants, visit to related industry.<br><br>**Suggested Readings**<br><br>1. Abbi Y.P. & Shashank Jain. 2006. Handbook on Energy Audit and Environment Management (Eds.), Publisher: The Energy and Resources Institute (TERI) New Delhi ISBN: 9788179930922<br>2. Chen, C.J. 2011. Physics of Solar Energy. Published by John Wiley & Sons, Inc., Hoboken, New Jersey, Published simultaneously in Canada.<br>3. Kothari, D.P. and I.J. Nagrath. 2008. Power System Engineering, (2nd ed.). Tata McGraw- Hill, India. | |
| **ESE-702 SOLAR THERMAL ENGINEERING AND STORAGE TECHNIQUES 3(2-1)**<br><br>**Learning Objectives**<br>By the end of the course, students will be able to:<br>1. Understand the sound knowledge of solar thermal technologies<br>2. Understand how to measure and test solar thermal energy systems<br>3. General understanding of the design, modeling and optimization of thermal energy systems used in various energy production applications<br>4. Know how to integrate the solar thermal system with storage technologies for efficient utilization of solar energy for the communities.<br>**Theory** | No Change |

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| Solar radiation measurements: Solar charts; pyrheliometer; pyranometer; pyregeometer; net pyradiometer-sunshine recorder; Heat transfer in solar systems: Energy balance of Flat plate collector; Flat-plate collector performance: incidence angle modifier; thermal test data conversion; design of solar heating systems; passive solar energy systems; Case studies related to active and passive use of solar energy; Design of thermal systems: classification; and performance analysis of various concentrated collectors; Automatic tracking systems; Solar-assisted technologies (solar distillation still, solar cold storage plant; solar cooker; solar bakery system solar roaster etc.) solar process economics; cost of solar process systems; life cycle savings methods; Thermal energy storage: Solar thermal energy storage technologies; Sensible heat storage system; Latent heat storage system; Sorption and thermochemical heat storage system; Metal hydride based solar thermal energy storage reactor; Energy and Exergy Analyses; Numerical Modeling and Simulation; Thermal Management with Phase Change Materials; System operation and application.<br><br>**Practical**<br>To study the solar application in different process industries, performance evaluation of various solar heat collection systems, how solar thermal systems are designed, constructed and operated by showing some examples of each, and to give general tools necessary to analyse their thermal and fluid flow conditions. Solar radiation measurement, data sources. Calculation of global, beam and diffuse radiation on surfaces.<br><br>**Suggested Readings**<br>1. Cabeza, L.F. 2020. Advances in Thermal Energy Storage Systems - Methods and Applications, 2nd Ed. Woodhead Publishing Series in Energy Series, Cambridge, UK. | |

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| 2. Dincer, I. and M.A. Rosen. 2021. Thermal Energy Storage: Systems and Applications, 3rd Ed. John Wiley & Sons, New York, USA.<br>3. Duffie, J.A., W.A. Beckman and B. Nathan. 2020. Solar Engineering of Thermal Processes, Photovoltaics and Wind: Photovoltaics and Wind, 5th Ed. John Wiley and Sons, New York, USA.<br>4. Goswami, D.Y., F. Kreith and J.F. Kreider. 2015. Principles of Solar Engineering, 3rd Ed. Taylor & Francis, India.<br>Kalogirou, S.A. 2013. Solar Energy Engineering Processes and Systems, (2nd ed.) Academic Press, Washington, USA. | |
| **ESE-703 BIO ENERGY ENGINEERING 3(2-1)**<br><br>**Learning Objectives:**<br>By the end of the course, students will be able to:<br>1. Acquaint the knowledge of biomass resources, bioenergy technologies their design and power generation potential.<br>2. Acquire skills to be competent in technical approaches dealing with bio energy and with material use in the bio-based industry.<br>3. Develop and implement new ideas and approaches in technical systems for the use of biomass as a raw material.<br>4. Identify, adapt, and implement new technologies in terms of added value throughout the whole value chain.<br><br>**Theory**<br>Sources and Classification: Advantages and disadvantages in use of biomass as energy source; Sources of biomass available for energy use; Chemical composition; properties of biomass; Biomass conversion: Physical conversion; dewatering; drying; size reduction, steam explosion; densification; pelleting; chipping; oil extraction; Overview of biomass conversion Processes: Chemical conversion processes; thermal conversion processes; applications of biomass conversion products; Biomass properties for biological conversion; | No Change |

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| Biodiesel production; Vegetable oil and animal fat characteristics; Fatty acid composition; transesterification; Different technologies for biodiesel production; Various conversion paths or technology routes from lignocellulosic biomass to ethanol; Bioethanol;<br>Production technologies: Different fermentation modes; Household and village-level ethanol production systems; Biogas production; Feedstock for biogas; Microbial and biochemical aspects operating parameters for biogas production; Anaerobic digestion for methane production basic processes; Anaerobic fermentation; fermentation kinetics; digester design parameters; various types of biogas plants; Design installation operation and management: Design of biogas plant; Torrefaction of biomass; Comparison between torrefied biomass versus pelleted biomass; Pyrolysis: Various pyrolysis processes based on heating rates; Design of pyrolyzers; Gasification: Chemistry of biomass gasification; Various types of gasifiers; Applications of biomass gasifiers; Biochar production from biomass; Biochar production technologies.<br><br>**Practical**<br>Physical Properties of biomass, Particle density, bulk density, angle of repose, moisture contents, volatile matter contents, ash contents, heating value analysis, Biomass properties related to biological conversion, chemical conversion and thermal conversion.<br><br>**Suggested Readings:**<br>1. Azad, A., and M. Khan. 2021. Bioenergy Resources and Technologies. Academic Press, California, USA.<br>2. Konur, O. 2019. Bioenergy and Biofuels Science and technology. Bioenergy and Biofuels. CRC Press, USA.<br>3. Li, Y., and S. K. Khanal. 2020. Bioenergy: Principles and Applications. John Wiley & Sons, New Jersey, USA. | |

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| 4. Rezaiyan. J and N. P. Cheremisinoff. 2005. Gasification Technologies, A Primer for Engineers, and Scientists. Taylor & Francis Publishers, UK.<br>5. Riazi, M. R. and D. Chiaramonti. 2017. Biofuel's Production and Processing Technology. CRC Press, USA. | |
| **ESE-704 HYBRID POWER SOURCES 3(2-1)**<br>**Learning Objectives**<br>By the end of the course, students will be able to:<br>1. Understand the modeling and design considerations relevant to hybridization of sources.<br>2. Learn to analyze design and working principle of power converters, EMS, and various other components for EV functioning.<br>3. Understand design considerations for microgrids, their energy resources, control and management systems.<br>4. Design and implementation of various linear and non-linear control systems for energy management and efficient working of microgrids<br>**Theory**<br>Introduction of hybrid power system: PV and Wind diesel hybridization mechanism; Parameter consideration for hybridization of two or more sources; Diesel generator integration as backup source; History and motivation of Electric Vehicles: Electric Vehicle Debate; Types of Hybridization in EV's; Fuel cell-based hybrid EV design; powertrain structure and control mechanism; Future of Electric Vehicles; History and Introduction of Microgrids: Microgrids and energy storage systems; Modelling and design of microgrids; Primary energy sources and alternative fuels for transportation: Secondary batteries and fuel cells; Different type of batteries; Overview of fuel cell systems; Emerging trends in batteries; Linear and non-linear control systems: Energy management in hybrid power sources and electric vehicles; PID | **No Change** |

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| controllers; Artificial Intelligence based Fuzzy logic controller; Artificial Neural Network.<br><br>**Practical**<br>To design various types of hybrid power systems for energy generation and energy/load management in Matlab/Simulink, wind and solar renewable energy resources assessment methods, development of physical and mathematical models of hybrid renewable energy systems components.<br><br>**Suggested Readings**<br>1. Altas, 2017. Fuzzy Logic Control In Energy Systems With Design Applications, IET, UK<br>2. Blaabjerg, 2017. Renewable Energy Devices and System with Simulation in MATLAB and ANSYS, Taylor & Francis, USA.<br>3. Bengt, S. 2019. Hydrogen, Batteries and Fuel Cells, Elsevier, Netherland.<br>4. Jorge, G. 2020. Analysis and Design of Hybrid Systems, MDPI, Switzerland.<br>5. Nick, Y. 2006. The Essential Hybrid Car Handbook: A Buyer's Guide, (1st ed.). The Lyons Press, NY. USA.<br>6. Quaschning 2016. Understanding Renewable Energy Systems, Taylor & Francis, UK. | |
| **ESE-705 HYDRO POWER ENGINEERING 3(2-1)**<br><br>**Learning Objectives**<br><br>By the end of the course, students will be able to:<br>1. Understand the designing of hydro-power plants.<br>2. Know the operation and maintenance of turbine and efficiency measurements<br>3. Learn about the design of the turbine, dynamic sizing and control stability for power plants. | **No Change** |

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| 4. Understand hydro-mechanical installation<br><br>**Theory**<br><br>General Introduction: Hydropower potential; Hydropower Resource; Historical background of power development in Pakistan; Power potential in Pakistan and world; Gross technical and economic potentials; Hydropower development policy of Pakistan; Types of hydropower based on head storage capacity and layout; Stages of hydropower development: Reconnaissance; Pre-feasibility; Feasibility studies and detailed engineering design; Layout of run-of-river and storage hydropower projects; Components of run-of river; Peaking run-of river and storage type projects; Concept of modern hydro power plant; Location/site selection; Plant layout; Power plant safety reservoir; Dams & tunnels etc.; Constructional details and basic principles of Hydro-mechanical equipment; Hydrology & hydroelectric power plants; Site selection for hydroelectric power plants; Design construction & operation of Hydroelectric power plants: Components advantages & disadvantage of under-ground power station; Dam types: Embankment dam; Concrete gravity dam; Concrete arch dam; Methods of fixing installed capacity of a hydropower plant; Estimation of power and energy potential; Mean and peak load; load curve; load factor; utilization and diversity factors; Hydro-mechanical equipment; Hydro-mechanical installation in powerhouse; Type of turbines; Pelton, Francis; Kaplan and bulb turbines and their performance characteristics; Selection of turbines and their specific speed; Turbine setting; Preliminary design of francis and pelton turbines; Electro-mechanical installation; Generators and their types; Rating of generators; Purpose and working principle of Governors; Pumps; Introduction to Centrifugal and reciprocating pumps; Their performance characteristics; Powerhouse types; general arrangement; dimension of powerhouse; Cost of electricity generation from hydropower plants. | |

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| **Practical**<br>Performance characteristics of a Pelton Turbine; Performance characteristics of a Francis Turbine; Working principle of centrifugal pump and its characteristics; Working principle of reciprocating pump and its characteristics.<br><br>**Suggested Readings**<br>1. Breeze, P. 2019. Hydropower. eBook ISBN: 9780128129074 Academic Press NW, Suite 507 Washington, DC, USA.<br>2. Dandekar, M.M., and K.N. Sharma. Water Power Engineering. Vikas Publishing House, Uttar Pradesh, India.<br>3. Elliott, C. 2014. Planning and Installing Micro-Hydro Systems: A Guide for Designers, Installers and Engineers. Elsevier Publications, USA.<br>4. Nag P. K. 2002. Power Plant Engineering, Tata McGraw-Hill Education. New Delhi, India<br>5. Samadi-Boroujeni, H. 2012. Hydropower: Practice and application. Intechopen London, England. | |
| **ESE-706 WIND ENERGY ENGINEERING 3(2-1)**<br>**Learning Objectives**<br>By the end of the course, students will be able to<br>1. Learn about Wind turbine types, configurations, components, design of wind machines and wind farms.<br>2. Describe wind turbine aerodynamics. dynamics, air foil selection and control of wind turbines | No Change |

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| 3. Apply a strategy for controlling the rotor speed of a variable speed wind turbine.<br>4. Perform assessment of wind farm projects and cost analysis of wind.<br>**Theory**<br>Introduction: General characteristics of wind resources, wind data analysis and resource estimation, wind turbine energy production estimation methods; Wind measurement and instrumentation: Working principle of wind turbine components and their functions; Horizontal axis versus vertical axis wind turbines; Wind aerodynamics: Two- and three-dimensional aerodynamics of wind turbine blades; One-dimensional Momentum Theory and Betz limit; Blade element momentum method; Prandtl's tip loss and Glauert correction; Wake rotation in HAWT; Relation between far-wake and near-wake parameters; Aerodynamic of wind turbine blade; Selection and design of Air foil: Analysis of air foil flow pattern; Characteristics of lifting bodies; Kutta joukowski theorem; Multi element airfoil for wind turbines; Single stream tube Analysis; Multiple stream tube momentum theory; Beam theory for wind turbine blades; Sources for loads on a wind turbine; Blade natural frequencies; Rotor design: Basic rotor Parameters; Blade shape; Rotor performance; Aerodynamic control options; Power curve prediction; Economic assessment of wind energy systems; Environmental aspects of wind turbines.<br>**Practical**<br>Study of hardware design of wind turbines, rotor blades, and electrical systems of a wind mill. To analyze the aerodynamic properties of new air foil designs, Analyze and optimize the designs and layouts of supportive infrastructure and transmission lines, estimate budget and scheduling requirements for manufacturing processes. | |

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| **Suggested Readings**<br>1. Hansen, M.O.L. 2015. Aerodynamics of wind turbines, 3rd Ed. Routledge, London.<br>2. Letcher, T. 2017. Wind Energy Engineering: A Handbook for Onshore and Offshore Wind Turbines, 1st Ed. Elsevier Science, Amsterdam.<br>3. Manwell, J.F., J.G. McGowan and A.L. Rogers. 2010. Wind energy explained : theory, design and application, 2nd Ed. Wiley, Chichester, U.K.<br>4. Patel, M.R. and O. Beik. 2021. Wind and Solar Power Systems design, analysis, and operation, 1st Ed. CRC press, USA.<br>Spera, D.A. 2009. Wind Turbine Technology: Fundamental Concepts in Wind Turbine Engineering, 2nd Ed., ASME Press, USA. | |
| **ESE-707 MATERIALS FOR ENERGY STORAGE 3(2-1)**<br>**Learning objectives**:<br>By the end of the course, students will be able to<br>1. Have a birds-eye view of the current materials in energy storage materials.<br>2. Learn about various synthesis techniques for materials<br>3. Learn various applications of materials in energy storage<br>4. Apply this knowledge in their respective research domain.<br>**Theory**<br>Introduction: Need of materials for energy; Why energy storage is necessary in today's age; Potential of recent materials solar cell materials: Basics of solar cells; Types of solar cells; Recent trends in solar cells materials and their synthesis/fabrication; Thermoelectric materials: Introduction; Where are they used; Piezoelectric materials: Basic principles; How are they prepared and their applications; Nanomaterials: Synthesis of graphene; Carbon nanotubes; Quantum dots; Applications. electrochemical storage: | No Chanage |

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| Material properties to be used as electrodes; Batteries; and supercapacitors etc.; PCM MOFs Metal hydrides: Types and potential applications in energy storage.<br><br>**Practical**<br>Usage of modern simulation tools for optimization and economic analysis of materials to be deployed for energy storage. Software such as COMSOL will be taught for simulation of materials.<br><br>**Suggested Readings**<br>1. Braun, A. 2019. Electrochemical Energy Systems, Foundations, Energy Storage and Conversion, De Gruyter, Berlin, Germany.<br>2. Kebede, M.A., and I.E. Fabian. 2022. Electrode Materials for Energy Storage and Conversion. CRC Press, USA.<br>3. Robert, H. 2016. Energy Storage, Fundamentals, Materials and Applications, 2nd Ed. Springer, Switzerland.<br>4. Stadler, I. and S. Miller. 2019. Handbook of Energy Storage, Demand, Technologies and Integration, Springer, Switzerland.<br>**5.** Tong, C. 2019. Introduction to Materials for Advanced Energy Systems, Springer, Switzerland. | |
| **ESE-708 REFRIGERATION AND AIR CONDITIONING 3(2-1)**<br><br>**Learning Objectives**<br><br>By the end of the course, students will be able to:<br>1. Learn about emerging technologies of refrigeration and air conditioning using conventional and solar thermal technologies<br>2. Understand the basic air conditioning processes on psychometric charts, calculate cooling load for its applications in comfort and industrial air conditioning. | **No Change** |

3. Understand various equipment-operating principles, operating and safety controls
4. Demonstrate knowledge of heating, ventilation, and air conditioning and refrigeration controls, including wiring configurations and technical components for optimum performance.

**Theory**

Thermodynamic concepts; Refrigeration cycles; Air and vapor compression; Characteristics of refrigerants; Refrigeration systems; Principles of operation and types of compressors; Expansion devices; Evaporators, condensers; Heat load estimation; Psychometric analysis; Design principle of cold storage; Principles of air conditioning and methods of refrigeration; Determination of sensible and latent heat factor; Absorption and adsorption cycles; Solid and liquid desiccant evaporative cooling systems; Ejector cooling cycle; Evaporative air cooling; Air-cycle steam jet; Refrigeration systems and their performances; Absorbers; Cooling towers; Fan coils; Air-duct system etc.; Comfort factors-specifications: Limits for humidity; Temperature etc.; Air distribution; Ventilation; Instrumentation; Alternate solar cooling systems; Design of commercial HVAC system.

**Practical**

Understand the difference between refrigeration and air conditioning, understand the difference between absolute pressure and gauge pressure. Identification of compressors, evaporators, condensers, connecting refrigerant lines, and system accessories; use of refrigerants; evacuation; pressurizing; testing for leaks; and charging. Parts identification; troubleshooting, and repair of air conditioning units including split systems.

**Suggested Readings**

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| 1. Hundy, G.F. 2016. Refrigeration, Air Conditioning and Heat Pumps. Butterworth-Heinemann, Oxford, UK.<br>2. John, T., and E. Silberstein. 2016. Refrigeration and Air-Conditioning Technology. ASME Press, USA.<br>3. Khurmi, R. S., and J.K. Gupta. 2019. Refrigeration & Air Conditioning. S. Chand Group, New Dehli, India.<br>4. Reddy, T., J.F. Kreider, P.S. Curtiss, and A. Rabl. 2016. Heating and Cooling of Buildings. CRC Press, USA.<br>5. Trott, A. R., and T.C. Welch. 2020. Refrigeration and Air Conditioning. Butterworth-Heinemann, Oxford, UK. | |
| **ESE-709 POWER ELECTRONICS FOR ENERGY CONVERSION 3(2-1)**<br><br>**Learning Objectives**<br>By the end of the course, students will be able to:<br>1. Understand the fundamentals of power semiconductor devices for energy conversion process<br>2. Understand the basic principles of uncontrolled and controlled rectifiers and their analysis under different loading conditions<br>3. Analyze and design converters for operation in steady state continuous and discontinuous conduction mode<br>4. Design and implementation of various control systems for energy management and conversion process<br>**Theory**<br>Introduction: Need of energy conversion; Solid state devices; Latest development in the area of power electronics covering modern | **No Change** |

devices; Converter topologies & control strategies; Power electronics switches: Design and working principle of diode and MOSFET; Design and working of transistors; Various types of transistors; Power converters: Pulse width modulated rectifiers; Controlled rectifiers; Single phase and three phase inverters; AC voltage controllers; DC-DC converters; Switch mode converters; Cyclo-converters; Matrix converters; Resonant and Soft-Switching Converters; High frequency switching converters; State-space averaged modeling of power electronic converters; Power factor analysis and instrumentation of power electronic converters; Brief description of some special applications of power electronic converters; Control methods: Power electronic converters sliding-mode control of power converters; Fuzzy logic and neural network control of power converters.

**Practical**

To study the classes of power converters and their operations: rectifiers; understand how to design AC-AC Converters; DC-DC Converters; Inverters. Study of hard and soft-switching and resonant circuits. Power electronic applications in power systems, Designing of Power Electronics and Control Systems in Matlab.

**Suggested Readings**


1. Bimal, K.B. 2010. Power Electronics and Motor Drives: Advances and Trends, Kindle Ed. Academic Press, USA.
2. Erickson, R.W. 2012. Fundamentals of Power Electronics, 2nd ed. McGraw-Hill Company, USA.
3. Gilsoo, J. 2021. Power Electronics Applications in Renewable Energy Systems. Energies, MDPI. Switzerland.
4. Ogata. 2008. Matlab for Engineers, Pearson, UK.

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| 5. Rashid, M.H. 2011. Power Electronics Handbook. McGraw-Hill Company Ltd, USA. | |
| **ESE-710 ELECTRICAL POWER TRANSMISSION AND DISTRIBUTION** 3(3-0)<br><br>**Learning Objectives:**<br><br>By the end of the course, students will be able to:<br>1. Learn developmental and operational dynamics of a power system.<br>2. Understand the significance of the structure of power transmission lines.<br>3. Learn about the expected future developments in transmission lines to achieve DC transmission over long distances.<br>4. Know about the characteristics of power transmission and distribution in Pakistan.<br><br>**Theory:**<br><br>Transmission system planning; Complex power in balanced three phase transmission lines; Power flow in transmission lines; Performance analysis of transmission system; Transmission line constants; Bundled conductors; Parallel lines; Short transmission line and steady-state power limit and voltage regulation in it; Medium transmission line; A B C & D constants; Nominal $\pi$ and nominal T circuits; Analysis of long transmission lines; Line and load compensation; Series and shunt compensation; Environmental effects of overhead lines;<br>Underground Cables: Types of underground cables; Cable installation techniques; Electric stress; dielectric constant; Charging current; Insulation resistance; Skin effect and proximity effect; Current carrying capacity of cables; Distribution system planning; Importance of distribution system planning; Load forecasting; | Removed/Shifted to PhD Scheme of Studies |

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| Factors affecting distribution system planning; Planning methods; Distribution system automation and control; Distribution system in Pakistan; Planning constraints in Pakistan Distribution substation; Substation bus schemes; Rating of a distribution substation; limitation of service area; Square and hexagonal service area; Distribution transformer and its efficiency; Parallel operation of transformers; Vector groups design considerations for primary and secondary distribution systems: Primary distribution feeders; Primary feeder voltage level and loading; Design considerations for radial feeders; Economic design of secondary lines; Voltage fluctuation and regulation; Distribution system voltage control; line drop compensator.<br><br>**Suggested Readings:**<br>1. Das, B. 2016. Power Distribution Automation (Energy Engineering), IET, UK.<br>2. Fleckenstein, J.E. 2020. Three-Phase Electrical Power. CRC Press, USA.<br>3. Goran, T. 2014. Electrical Power transmission System Engineering, 3rd Ed. CRC Press, USA.<br>4. Grigsby, L.L. 2012. Electric Power Generation, Transmission and Distribution, 3rd Ed. CRC Press, USA.<br>**5.** Subbanna, S. R. and B. L. Rao. 2019. Electric Power Transmission and Distribution, Notion Press, Chennai, India. | |
| | **ESE-710 Digitalization of Energy Systems 3(2-1)**<br><br>**Learning Objectives**<br><br>By the end of the course, students will be able to get:<br>1. comprehensive knowledge of data analytics<br>2. learn machine learning techniques applied to the integration of renewable energy, smart and |

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| | microgrids, forecasting energy production and consumption.<br>3. Knowledge about Net Zero emissions techniques.<br><br>**Theory:**<br>The courses cover the following topics: Smart grids, distributed generation, energy management systems, centralized control systems, wireless control; Renewable energy; (Distributed) Artificial intelligence; Linear and nonlinear control systems; Co-simulation; Design and assessment of experiments; Control theory (PLCs and PACs); Critical engineering; Energy markets; Requirements engineering; Modelling and control.<br><br>**Practical:**<br><br>The course will cover market analysis and lab experimentations.<br><br>**Suggested Readings:**<br><br>1. Gilsoo, J. 2021. Power Electronics Applications in Renewable Energy Systems. Energies, MDPI. Switzerland.<br>2. Chaturvedi, D.K. 2010. Modeling and Simulation of Systems using MATLAB and Simulink, CRC Press, USA.<br>3. Theodore, L. 2011. Heat Transfer Applications for the Practicing Engineer, John Wiley & Sons, Inc. Hoboken., New Jersey, USA<br>4. Das, B. 2016. Power Distribution Automation (Energy Engineering), IET, UK. |

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| **ESE-711 ENERGY SYSTEMS MODELLING AND SIMULATION 3(2-1)**<br><br>**Learning Objectives**<br><br>By the end of the course, students will be able to:<br>1. Understand the role of modeling of an energy system,<br>2. Learn methods of modeling that best capture the dynamic features of a system,<br>3. Analysis of simulation in evaluation and optimization test of a model,<br>4. Learn artificial intelligence (AI) as a simulation tool.<br><br>**Theory:**<br>Introduction to Modeling: Introduction to simulation; Importance of modeling and simulation in energy systems; Modeling of dynamic systems; Artificial Intelligence (AI) as a simulation tool; Bong graph modeling and causality; Generation of system equations; Bond graph models of electrical and mechanical systems; Basic system modeling of energy systems (Electrical, mechanical, hydraulic, thermal, electromechanical and hydromechanical); Dynamic response and performance measures: $1^{st}$ and $2^{nd}$ order systems; System transfer function; Signal flow graphs; State variable formulation; Frequency response; Bode plot; Simulation using Simulink; Validation and verification of simulation models; Parameter estimation method; Systems identifications; Introduction to optimization: Optimization with modeling of engineering problems; Optimization: Objectives/constraints; Problem formulation; Linear programming: Simplex tableau; Pivoting; Sensitivity analysis; Pinch analysis.<br><br>**Practical:** | No Change |

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| Introduction to MATLAB and Simulink, Using MATLAB for machine learning applications, simulating system models using neural networks in MATLAB for evaluation and optimization.<br>Simulation of Individual Process and component. Implement numerical design tools and employ computational skills for improvement individually and in teams.<br><br>**Suggested Readings**<br>1. Altiok, T. and B. Melamed. 2007. Simulation Modeling and Analysis with ARENA", Academic Press, USA.<br>2. Blaabjerg, F., and D.M. Ionel. 2020. Renewable Energy Devices and Systems with Simulations in MATLAB® and ANSYS®. CRC Press, USA.<br>3. Chaturvedi, D.K. 2010. Modeling and Simulation of Systems using MATLAB and Simulink, CRC Press, USA.<br>4. Perelmuter, V. 2020. Renewable Energy Systems Simulation with Simulink® and SimPowerSystems™. CRC Press, USA.<br>**5.** Zhange, L., B. P. Zeigler and Y. Laili. 2019. Model Engineering for Simulation, Elsevier, Netherland. | |
| **ESE-712 COAL PROCESSING TECHNOLOGIES 3(2-1)**<br><br>**Learning Objectives**<br>By the end of the course, students will be able to:<br>1. Gain knowledge regarding coal types<br>2. Learn various coal processing technologies<br>3. Learn about various products that can be obtained from coal<br>**4.** Learn how various methods can be employed to protect the environment<br>**Theory**<br>Introduction to clean coal technologies: Coal reserves and its uses; Direct and indirect coal liquefaction process description; Parameters; | **No Change** |

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| Catalyst preparation; Characterization; Hydrocracking/ Hydrotreating reaction mechanism and kinetics: Single stage and two stage liquefaction; Catalytic reactors system; FT reactor overview: Reaction mechanism, kinetics; Syn gas production and composition: Syn gas purification and process parameters; Energy analysis/Heat exchanger network optimization in FT synthesis; Products refinery products analysis and health safety and environmental considerations; Hybrid approach to synthesize liquid fuels; Comparison of ICL and DCL; Hybrid approach description/Process flow diagrams; Clean coal gasification: Process description,; Coal preparation; Gasifier design; Reaction kinetics; Gas cleaning; Integrated Gasification Combine cycle (IGCC): Process description; Thermodynamic cycle, $CO_2$ pre combustion capture and storage; Energy requirements; Underground coal gasification (UCG): Overview; Important geological aspects for design consideration; Channel formation between injection and production wells; Process parameters/coal and rock properties; Economics consideration; Carbon capture techniques: Power generation technologies incorporating $CO_2$ Capture; $CO_2$ Capture Chemical Processes.<br><br>**Practical**<br><br>Visit to a coal power plant followed by submission of report; Generating thermodynamics and energy efficiency analysis of a coal plant.; Computational analysis of coal combustion process using ASPEN Hysis or ANSYS CFX.<br><br>**Suggested Readings**<br><br>1. Bell, D.A. and B.F. Towner. 2010. Coal Gasification and its Applications, 1st ed. William Andrew, USA.<br>2. Jypthi, R. K. and P.K. Parhi. 2021. Clean Coal Technologies, Pringer Nature, Switzerland.<br>3. Miller, B. G., 2017. Clean Coal Engineering Technology, Elsevier, UK. | |

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| 4. Nicholas, P. 2012. Clean Electricity through Advanced Coal Technologies. William Andrew; 1st ed. USA.<br>5. Subba Rao, D.V. and T. Gouricharan. 2016. Coal Processing and Utilization. CRC Press, USA. | |
| **ESE-713 FLUID FLOW AND HEAT TRANSFER IN INDUSTRIAL APPLICATIONS 3(2-1)**<br><br>**Learning Objectives**<br>By the end of the course, students will be able to<br>1. Comprehend different aspects of fluid flow and heat transfer as encountered in various industrial applications<br>2. Analyze the problems to use the basic physical explanation of the phenomenon related to operation of process equipment.<br>3. Understand the operation and dimensioning of industrial heat exchangers, their limitations and typical uses.<br>4. Use the different software like Ansys and Comsol Multiphysics<br><br>**Theory**<br>Fluid properties and their transport characteristics:<br>Fluid properties; Fluid classification; Kinematics and dynamics of fluids; Hydrostatic pressure; Buoyancy and stability (fluid at rest); Velocity and pressure variation (fluid in motion); Oil and gas flow in process piping and long distance pipelines; Calculation of pressure losses and required flow power; Consideration of pipe networks; Drag and lift forces on 3D bodies in turbulent flow: Centrifugal pumps and hydro-turbines; Centrifugal and axial compressors; Gas and steam turbines; Hydraulics and pneumatics applications; Flow control and measurement techniques: Advanced measurements; Ultrasound and visualization techniques; Heat | No Change |

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| transfer mechanisms: Conduction convection and radiation; Forced and free convection heat transfer; Heat exchangers and their effectiveness; Solar radiation applications; Combined heat transfer processes; Combustion in industrial boilers; Melting and solidification; Steam generators; Reboilers and condensers, cooling towers.<br><br>**Practical**<br>Application of computational techniques (like COMSOL Multiphysics, ANSYS Fluent) to design and optimize industrial heat transfer mechanism.<br><br>**Suggested Readings:**<br>1. Cengel, Y.A. 2002. Heat and Mass Transfer. McGraw Hill Publishing Co. Pvt. Ltd, USA.<br>2. Laidoudi, H. and O.D. Makinde. 2020. Engineering Fluid Flows and Heat Transfer Analysis, Trans Tech Publications, Switzerland.<br>3. Mayboudi, L.S. 2018. Heat Transfer Modelling Using COMSOL. Mercury Learning and Information., Virginia, USA.<br>4. Shenoy, A., S. Mikhail and P. Ioan. 2017. Convective Flow and Heat Transfer from Wavy Surfaces Viscous Fluids, Porous Media, and Nanofluids. CRC Press, USA.<br>5. Theodore, L. 2011. Heat Transfer Applications for the Practicing Engineer, John Wiley & Sons, Inc. Hoboken., New Jersey, USA. | |
| **ESE-714 HYDROGEN TECHNOLOGIES AND FUEL CELLS 3(2-1)**<br>**Learning Objectives**<br>By the end of the course, students will be able to<br>1. Learn about hydrogen generation technologies | **No Change** |

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| 2. Learn about various applications of hydrogen<br>3. Learn various fuel cells and their basic principles<br>4. Learn about various applications of fuel cells in energy generation<br>**Theory**<br><br>Overview of the hydrogen economy; Hydrogen production technologies: Principles and operation of hydrogen production systems; Hydrogen production from fossil fuels and nuclear energy; Renewable energy: Estimation of hydrogen energy potential; Economics of hydrogen; Hydrogen end-uses; Transportation, distribution and storage of hydrogen; Social and environmental aspects; Design and sizing of hydrogen systems; Simulation of hydrogen system performance; Future of hydrogen energy: Principles and operation of various types of fuel cells; Configuration of individual cells stack and fuel cell system; Thermodynamics of fuel cells; Introduction to electrochemical kinetics; Transport-related phenomena and conservation equations for reacting multi-component systems;<br>Fuel cell system design; Pptimization and economics; Fuel cell performance simulation; Applications of fuel cells; Social and environmental aspects; Challenges of fuel cell commercialization; Future of fuel cells.<br>**Practical**<br>To understand basic hydrogen production (steam reforming, electrolysis etc.) and fuel cell technologies (PEM, SOFC, MCFC, AFC, PAFC etc.). Build the system model consisting of PV modules, electrolyser, compressor, hydrogen storage, PEM fuel cell and the resistive loads and simulate it using Simulink software.<br>**Suggested Readings** | |

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| 1) Badea, G.F., A.F. Raluca and A Ioan. 2021, Hydrogen Fuel Cell Technology for Stationary Applications. Engineering Science Reference: Open Library<br>2) Gou, B., N. Woonki, and D. Bill. 2017. Fuel Cells Dynamic Modeling and Control with Power Electronics Applications. CRC Press, USA.<br>3) Maric, R., and M. Gholamreza. Solid Oxide Fuel Cells From Fundamental Principles to Complete Systems. 2020. CRC Press, USA.<br>**4)** Sorenson, B. 2011. Hydrogen and Fuel Cells-Emerging Technologies and Applications, Kindle ed. Elsevier Publishers Ltd, USA.<br>5) Sperling, D. and S. C. James. 2004. The Hydrogen Energy Transition-Moving Towards the Post Petroleum Age in Transportation, 1st ed. Elsevier Academic Press, USA. | |
| **ESE-715 RESEARCH METHODS AND PROJECT MANAGEMENT 3(3-0)**<br><br>**Learning objectives**<br>By the end of the course, students will be able to<br>1. Develop skills to conduct industrial research<br>2. Develop skills to carry out academic research<br>3. Develop skills to manage and execute impactful projects<br>4. Develop skills for engineering projects<br><br>**Theory** | No Change |

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| Introduction: Reading and summarizing relevant articles; Critical analysis techniques and evaluation methods for research; Identification of themes and comparators; Techniques for advanced engineering practice: Critical review of literature and research gap analysis; Data and information literacy; Written oral and graphical communication; Document preparation and version control; Reproducibility; Verification and validation of engineering models; Experimental design and research: Experimental methods; Quantitative and qualitative; Design methods; Simulation techniques; Data collection and management for quantitative data; Management techniques: Precise definition of objectives; Planning executing and monitoring projects; Risk and failure analysis and project management methodologies and financial flow of project; Project students will work in groups to develop a project plan and literature review for a transdisciplinary research or industry project.<br><br>**Suggested Readings**<br>1. Badiru, A.B., S. A. Badiru, and I. A. Badiru. 2019. Mechanics of Project Management Nuts and Bolts of Project Execution. CRC Press, USA.<br>2. Lecoeuvre, L. 2016. The Performance of Projects and Project Management Sustainable Delivery in Project Intensive Companies. Routledge, UK.<br>3. Micheal, J. P. 2019. Designing and Managing a Research Project, 4th Ed., SAGE Publishing, Australia, ISBN: 9781544316468.<br>4. Palmer-Trew, S., T. Peter. 2019. Project Management: It's All Bollocks! The Complete Exposure of the World of, and the Value of, Project Management. Routledge, UK.<br>Pasian, M. 2015. Design Methods and Practices for Research of Project Management, Routledge, London. ISBN-13: 978-1409448808. | |
| **ESE-716 PHOTOVOLTAIC SYSTEMS** 3(2-1) | |

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| **Learning objectives**<br>By the end of this course, students will be able to<br>1. Learn about solar photovoltaic system design and performance measurement.<br>2. Describe the principle phenomena governing the function and conversion efficiency of a Photovoltaic cell.<br>3. Develop a comprehensive technological understanding of solar PV system components.<br>4. Pertain knowledge about planning, project implementation and operation of solar PV power generation.<br>**Theory**<br>Semiconductor properties: Fermi-Dirac distribution function and location of fermi-level in doped semiconductor; Dynamics and densities of electrons and holes; Bond model of Group IV semiconductors; Group III and V Dopants; Carrier concentration in intrinsic semiconductor; Carrier transport mechanism: Interaction of light with semiconductor; Bandgap-to-bandgap processes; Generation and recombination of electron-hole pairs; Minority carrier lifetime; Poisson's Equation; Current density and continuity equations; P-N junction: Characteristics under darkness and illumination; Solar cell parameters and equivalent circuit; Standard and improved silicon solar cell manufacturing technology; High-efficiency concepts based on crystalline silicon technology; Hetero and multi-junction solar cell; Measurement and monitoring: Solar PV system components; Solar charge controllers; Types; Characteristics; Solar inverters type and characteristics; Solar cables; Solar mounting system; Solar PV system types; Solar PV off grid; Hybrid and on grid systems; Solar photovoltaic applications; Solar system performance measurement and | Removed/Shifter to PhD Scheme of studies |

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| monitoring; Solar system operation and maintenance; Dy sensitized solar cells; Perovskite solar cells.<br><br>**Suggested Readings**<br>1. Duffie, J.A. and W.A. Beckman. 2013. Solar Engineering of Thermal Processes, 4th Ed. Wiley, Hoboken, New Jersey, USA.<br>2. Goswami, D.Y. 2015. Principles of Solar Engineering, 3rd Ed. CRC Press, USA.<br>3. Rabindra, S. and Pamuru V. 2020. Solar PV power design, manufacturing and applications from sand to systems, 1st Ed. Academic Press Cambridge, Massachusetts, UK.<br>4. Santos, J.J.C.S., J.C.E. Palacio, A.M.M. Reyes, M. Carvalho, A.J.R. Freire and M.A. Barone. 2018. Advances in Renewable Energies and Power Technologies Volume 1: Solar and Wind Energies I. Yahyaoui (ed.). Elsevier, USA.<br>5. Smets, A., K. Jager, O. Isabella, R. van Swaij and M. Zeman. 2016. Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems, 1st Ed. UIT Cambridge, UK. | |
| **ESE-717 BIOFUELS ENGINEERING 3(2-1)**<br><br>**Learning Objectives**<br>By the end of the course, students will be able to<br>1. Understand the key concepts of biomass to biofuel conversion technologies<br>2. Impart sound knowledge of biofuel production and processing<br>3. Analyze the availability of biomass feedstock to produce different types of biofuels<br>4. Demonstrate the process engineering for optimal operation of biofuels production | **No Change** |

| **Theory**<br><br>Introduction: Feedstock for biofuels production; Upstream processing of the feedstock for biofuels production; Types of different reactors/machinery for biofuels production; Process machinery-pumps; Valves; Heat exchangers; Cooling towers; Centrifuges; Compressors; Thermal oxidizers; Distillation towers; Refrigeration principles and boiler systems: Startup; Shutdown; Operation and troubleshooting; Instrumentation and Control: P and ID terminologies with applied applications; sequence of operation; Including residence time; Pressures and temperature seen in various stages of production; Design calculations: Calculations for equilibrium staged separation processes (e.g. distillation, absorption, solvent extraction); Mass transfer fundamentals; Biodiesel processes analysis: Overall process of biodiesel production; Review of biodiesel chemistry; Process engineering; Post reaction processing; Fuel specification and properties; Biodiesel process technologies and regulatory issues-investigates the underlying research and reaction processes that are used to produce biodiesel; Feedstock options coupled with past and present technologies provides foundational knowledge about the industry; In-depth review of the ASTM Standards for biodiesel and the regularity issues; Reaction kinetics and reactor design: Kinetic data; determination of rate laws; Analysis of complex reaction networks and design of ideal isothermal reactors; Analyze data for heterogeneous catalytic reactions; Design reactor systems for given synthesis with special emphasis on trans-esterification and bio-fermentation feedstock preparation; Treatment and recovery of side streams; Fuel transportation storage and general plant operations; Bio-ethanol process and separation technology: Fundamentals process of ethanol production; Process flow diagram (PFD) of a typical ethanol plant; Operation including residence time pressure and temperature; Rationale for feedstock and additives used in ethanol processing as well as product and co-product production and use; Basic principles | |
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of ethanol distillation; Evaporation and dehydration; Operating components in a distillation system.

**Practical**

Determination of bulk density, particle density and particle distribution, proximate analysis, Heating value, Elemental analysis of biomass, Efficiency analysis of a downdraft gasifier. Study of various processes used in converting biomass into biofuels and chemicals. Case Studies. Field Trips

**Suggested Readings**


1. Bhaskar, T. and A. Pandey. 2021. Biomass, Biofuels, Biochemicals. 1st Ed. Elsevier, Netherland.
2. Drapcho, C.M., N.P. Nhuan and T.H. Walker. 2020. Biofuels Engineering Process Technology. 2nd Ed. MC Graw-Hill, New York, USA.
3. Hiller, E.A. and B.A. Stout. 1985. Biomass Energy: A Monograph, 1st ed. Texas A&M University Press, College Station, Texas, USA.
4. Mehla, S.K. 2008. Biofuels: Marketing Strategies and Impact on Rural Development. Aavishkar Publishers, and Distributers, Jaipur, India.
5. Pereira, L. 2017. Algal Biofuels. CRC Press, USA.