SAVITRIBAI PHULE PUNE UNIVERSITY
(Formerly University of Pune)

Revised Syllabus for Ph.D. (Energy Technology)
from Academic Year 2022-23 onwards

FACULTY: FACULTY OF SCIENCE AND TECHNOLOGY
BOARD: ENERGY TECHNOLOGY

Centre for Energy Studies
Savitribai Phule Pune University
Pune 411 007

July 2022

Savitribai Phule Pune University,
Centre for Energy Studies
Pune 411 007

Syllabus for Ph.D. (Energy Technology)

Coursework is compulsory for the candidates admitted to Ph.D. (Energy Technology) Program and total number of credits are 18 as per following schedule.

1) **Course 01 [4 credits]**
2) **Course 02 [4 credits]**
3) **Course 03 [8 credits]**
4) **Course 04 [2 credits]**

Total number of credits: 18

Detail description and Syllabus of each course:

1) Course 01: [4 credits]

Research Methodology [4 credits]

Designed by BOS or Syllabus module and course work available on SPPU website, same can be adopted by BOS. Mode of Conduct and Responsibility: Research Centre. The credits can be earned by student from the University run course and the credits can be adopted directly.

Learning Outcomes:

After completing this course, student should be able to:

1) Demonstrate the ability to choose methods appropriate to research aims and objectives

2) Understand the limitations of particular research methods

3) Develop skills in qualitative and quantitative data analysis and presentation

4) Develop advanced critical thinking skills

5) Demonstrate enhanced writing skills

2) Course 02: [4 credits]

i) Writing Research Proposal for Obtaining Financial Assistance from National Funding Agencies **[1 credit]**.

15 class hours. Designed or prescribed by BOS or respective guide. Research guide should teach and evaluate.

Learning Outcomes:

After completing this course, student should be able to:

1) Learn steps in writing good proposal for earning funds for research idea.

2) Learn terminology for funding of research proposals like technology readiness level, prototype, proof of concept etc.

ii) Writing of Reviews **[1 credit]**
Respective Research Guide should assign and check. The Research guide should teach and evaluate.

Learning Outcomes:

After completing this course, student should be able to:

Use writing to learn and synthesize new concepts

iii) Seminars **[2 credits]**
At least three seminars should be conducted by research guide.

Learning Outcomes:

After completing this course, student should be able to:

1) get enhanced Presentation Skills: students will be able to show competence in identifying relevant information, defining and explaining topics under discussion.

2) get enhanced Discussion Skills: students will be able to judge when to speak and how much to say, speak clearly and audibly in a manner appropriate to the subject, ask appropriate questions, use evidence to support claims, respond to a range of questions, take part in meaningful discussion to reach a shared understanding, speak with or without notes.

3) get enhanced Listening Skills: students will demonstrate that they have paid close attention to what others say and can respond constructively.

4) get Argumentative Skills and Critical Thinking: students will develop persuasive speech, present information in a compelling, well-structured, and logical sequence, respond respectfully to opposing ideas, show depth of knowledge of complex subjects, and develop their ability to synthesize, evaluate and reflect on information.

5) will develop habit of Questioning: through asking appropriate questions, students will demonstrate their understanding of discussions and spark further discussion.

3) Course 03: [8 credits]

Subject Specific Advanced Level Course
Students can Choose any combination of following List of courses to opt total 08 credits.

1] Software Packages for Design of Energy Systems [4.0 credits]

Module 01: Matlab, MathWorks, and Simulink for Energy Systems Design: [1.0 Credit]
The electrical devices used in renewable sources are with complicated inner structures, and thus methods of computer simulation make the development of these systems easier and faster. Matlab, MathWorks, and Simulink and its toolbox Simscape Electrical are the most popular means for simulation of electrical systems. The topic of wind-generator (WG), Electrical Vehicle Design, Energy Storage System design, Battery Management System (BMS) design etc. In-depth exploration of the simulation of WG systems, systems with batteries, photovoltaic systems, fuel elements, microturbines, and hydroelectric systems.

Module 02: Solar PV System Design Softwares: [1.0 Credit]

Pvsyst Software: A complete walkthrough of the PVSyst software, The science, mathematics & art behind solar PV system design, The complete understating of a client's requirements to prepare a PVSyst design, Performing a virtual and in-person site assessment, Learn to calculate all input values such as azimuth, tilt, losses, etc. and analyze the output, Detailed knowledge of losses, 3D modeling and near shading analysis, Analysing a PVSyst report and creating a professional sales proposal, Being able to independently perform grid-connected PVSyst simulations of up to 1-2 MW, Case studies.

PVSOL Software: Different Phases of PVSOL software use for PV System design, Different Loss Parameters, Simulation Result, Design of 100 kW Solar PV power Plant, Design of 500 kW solar Power Plnant, technical parameters, Overview of Shading Analysis, PR and CUF Discussion.

Module 03: Building Energy Analysis Softwares: [1.0 Credit]

Any two building energy analysis softwares prescribed by IGBC e.g. i) GRIHA (Green Rating for Integrated Habitat Assessment), the National Rating System for green buildings in India. ii) LEED (Leadership in Energy and Environmental Design), the most widely used green building rating system in the world.

Module 04: Any two Computer Simulation Softwares from the following: [C = 1.0]

1) ANSYS: Basics of Ansys, Selection Logic, solid modelling, meshing, sample thermal analysis.
2) COMSOL Multiphysics
3) SILIDWORKS
4) EnergyPro
5) AutoCAD
6) Fusion 360

Learning Outcomes:

After completing this course, student should be able to:

1) use software tool to optimize design of prototype before actual model / steps in the experiment.

2) optimize the use of experimental resources by computational inputs.

Recommended Reading:

1) Guide to Energy Management, Eighth Edition, by Barney L. Capehart, Wayne C. Turner, and William J. Kennedy, ISBN-10: 1498759335, ISBN-13: 978-1498759335
2) Design of Smart Power Grid Renewable Energy Systems, 3rd Edition, by Ali Keyhani, ISBN: 978-1-119-57334-0 (2019)
3) Renewable Energy Systems Simulation with Simulink® and SimPowerSystems™, By Viktor Perelmuter (2017), ISBN 9780367736668, CRC Press.
4) Internet Resources

2] Energy and Environment for sustainable development [4.0 Credits]

Module 01: [1.0 credit]

Ecosystems: Concept of an ecosystem, Structure and function of an ecosystem, Producers, consumers and decomposers. Energy flow in the ecosystem. Ecological succession.

Food chains: Food webs and ecological pyramids.

Module 02: [1.0 credit]
Environment pollution, global warming and climate change, Ecology, Structure and functioning of natural ecosystems, Natural resources.

Module 03: [1.0 credit]
Agricultural, industrial systems and environment, Energy technologies and environment.

Module 04: [1.0 credits]
Energy, Demand and Energy resources.
Energy, environment and society.
Energy, ecology and the environment.
Politics of energy policy and our energy future.
Group assignments

Learning Outcomes:

After completing this course, student should be able to:

1) get in depth understanding of the sustainable development goals

2) get understanding of correlation between energy usage and sustainable development.

3) able to understand the optimal use of resources for sustainable development.

4) correlate the energy use optimization for sustainable agriculture yield.

Recommended Reading:

1) Pretty, Jules, Andrew Ball, et al. "Introduction to Environment and Society." The Sage Handbook of Environment and Society. Sage Publications, 2007. ISBN: 9781412918435
2) World Economic Forum. "Beyond the Anthropocene | Johan Rockstrom." Feb. 14, 2017. YouTube.Bharucha, E., Textbook of Environmental Studies, Universities Press (2005).
3) Chapman, J.L. and Reiss, M.J., Ecology-Principles and Application, Cambridge University Press (LPE) (1999).
4) Joseph, B., Environmental Studies, Tata McGraw-Hill (2006).
5) Eastop, T.P. and Croft, D.R. Energy Efficiency for Engineers and Technologists, Longman and Harow (2006).
6) Miller, G.T., Environmental Science- Working with Earth, Thomson (2006).
7) Wright, R.T., Environmental Science-Towards a sustainable Future, Prentice Hall (2008) 9th ed.
8) O'Callagan, P.W., Energy Management, McGraw Hill Book Co. Ltd. (1993).

Following M. Tech. (Energy Technology) Courses run by Centre for Energy Studies, SPPU can also be opted by Ph.D. students if those were not covered in the M.Tech. / M.E. curriculum.

i. Environmental Impact of Energy Systems [4.0 Credits]

Module 01: Impact of Energy Systems on Environment (1.0 Credits]

Environmental degradation due to energy production and utilization, Primary and Secondary pollution due to Green House Gases Emission such as SOx, NOx, SPM in air, thermal and water pollution, depletion of ozone layer, global warming, Positive and Negative Impacts, biological damage due to environmental degradation, Sociological and Economical problems due to thermal and other energy projects,

Physiological, ecological, environmental and health problems due to energy plants, Industrial and urban waste, Pollution control: Causes, Process and exhaust gases and its control, mechanism and devices for pollution control. Methods of Environmental Impact Assessment (EIA), Principles, origin and development of EIA, Essential components of EIA, Project Screening, Baseline study, Impact Identification, Impact prediction, evaluation and mitigation, methodology matrix method, network, overlay, problems of EIA in developing countries, Future of EIA.

Module 02: Pollution due to Thermal, Hydel and Nuclear Power Plants (1.0 Credits)

Potential sources of pollution in thermal power plant, air, water, land pollution due to emission for thermal power plant. Environmental pollution limits guidelines for thermal power plant pollution control. Various pollution control equipment's such as dust collector, bag filter, electrostatic separator, working principle and selection criteria, designing the pollution control system, methods and limitation. Water pollution in thermal power plant, physical and chemical methods of pollution control, Land pollution, effect of land pollution, measurement of land pollution. Limitations and advantages of pollution control systems. Hydrothermal plant environmental assessment, hydrothermal plant and rehabilitation measures for hydrothermal plant. Nuclear power plants and environmental pollution, pollution control measures.

Module 03: Pollution due to Vehicles and Utilities (1.0 Credits)

Pollution due to vehicles and utilities, methods to control emission from vehicle, boilers, furnaces etc, International Standards for quality of air and norms for exhaust gases. Effect of hydroelectric power stations on ecology and environment.

Module 04: Environmental and Pollution Control Laws (1.0 Credits)

United Nations Framework Convention on Climate Change (UNFCC), Protocol, Conference of Parties (COP) 19 Clean Development Mechanism (CDM), Prototype Carbon Funds (PCF) Carbon Credits and it's trading, Benefits to developing countries, Building a CDM project.

Learning Outcomes:

After completing this course, student should be able to:

1) learn interactions between the environment and energy conversion systems, with particular reference to pollution processes (both chemical and thermal) and to the impacts related to power plants.

2) Students will be provided with fundamentals required for the understanding of most important solutions and techniques to limit the effects of the use of power plants, with reference to the actual knowledge and to engineer responsibilities in this field.

REFERENCE BOOKS:

[1] Management of Energy Environment Systems -W.K.Foell (John Wiley and Sons).

[2] Energy Management and Control Systems -M.C.Macedo Jr. (John Wiley and Sons).

[3] Environmental Impact Analysis Handbook -J.G.Rau, D.C.Wood (McGraw Hill).

[4] Energy and Environment – J.M. Fowler, (McGrawHill)

[5] Environmental Impact Assessment, Clark D. Brain, Biesel Donald
[6] EIA for Developing Countries, Biswas Asit. K.
[7] EIA Guidelines 1994, Notification of Govt. of India Impact Assessment
[8] Methodologies & Procedures.
[9] Environmental Impact Assessment W. Canter (IInd Edition)
[10] Auditing for Environmental Quality Leadership Willing, T-Johan
[11] Environmental Audit Mhastear A. K.
[12] Hugh Barton and Neol Brudes, A Guide to local Environmental Auditing, EarthscanPublications Ltd. (1995)

ii. Data Analytics [4.0 Credits]

Module-01: Basic data & variables (C-1, L- 10, 5 -S/ D/ T)

Significance of Data, Analyzing Data, Identify Types of Data Variables, summarizing data, Identify Measures of central tendency, Describe Measures of spread, Identify Skew-ness of data distribution, Data Collection and Management Framework, Data Collection, Data Dictionary, Outlier Treatment, Missing Value Imputation. Standardization of scores, Standard Deviation, Standard Scores Data distribution, Normal Distribution, Hypothesis Testing- Developing Null and Alternative Hypotheses, Type I and Type II Errors One-Tailed Tests About a Population Mean Two-Tailed Tests About a Population Mean. Introduction to Data Structure in R

Module 02: Analysis of data (C-1.5, L- 15, 5-S/ D/ T)

What is Regression? Covariance & Correlation, features of r (correlation), Testing the significance of the correlation coefficient, Types of regression analysis, Purpose of regression analysis, Purpose of regression analysis, R2 coefficient determination, Coefficient of determination (R2) and Adjusted R2, Multiple Linear Regression, Typical Applications of Regression Analysis, Residual Analysis. Multi-collinear, Hetero-skedasticity. Case Study with R.

Logistic Regression Basics, Generalized Linear Model (glm), What is logistic regression? Types of logistic regression analysis, Applications of logistic regression analysis, Prerequisite / when & why binary logistic regression. What is clustering? , When to use cluster analysis? Application of cluster analysis, Types of cluster analysis , K means (In detail), What is decision tree? Why decision tree? Types of decision tree Constructing decision tree, Random forest and CART (In detail) Case Study with R.

Module 03: Analysis tools and programming (C-1.5, L- 15, 5 -S/ D/ T)

Introduction to analytics & different terms of analytics. Need of Analytics. Analytics vs analysis, Intelligence vs Data Science, Data Analyst Vs Business Analyst, Types of Analytics, Tools for Analytics Latest. Trends of analytics Business Analytics in Practice-Asset Health Analytics, Supply Chain Analytics, Operational Analytics, HR Analytics, Financial Analytics, Marketing Analytics, Text Analytics.

What is Time series, Components of Time Series, Techniques for forecasting- Simple Moving Average, Weighted Moving Average, Simple Exponential Smoothing, Double Exponential Smoothing, Triple Exponential Smoothing, Time Series Models Comparison, Use Cases, Industry Applications, Basic Concepts (acf, pacf, AR, MA), ARMA Model, ARIMA Model ,Industry Applications.Case Study with R
What is R? Data science & R, Components of R, Installing R, Using command line in R, Introduction to R Studio (IDE),Finding Help & solving issues in R, Data types in R, Program Structure in R, Flow Control : For loop, If condition, While conditions and repeat loop ,Debugging tools, Concatenation of Data, Combining Vars , cbind, rbind, Sapply, apply, tapply functions, Built - in functions in R, File operations in R, Reading file, Writing to a file, Importing and exporting a file, Vectors, Lists, Scalars, Data Frames, Matrices, Arrays, Factors, Use of data structures in different conditions

Learning Outcomes:

After completing this course, student should be able to:

1) Students will demonstrate proficiency with statistical analysis of data.

2) Students will develop the ability to build and assess data-based models.

3) Students will execute statistical analyses with professional statistical software.

4) Students will demonstrate skill in data management.

Reference Books:

1. Fundamentals Of Mathematical Statistics, Gupta & Kapoor, Fourth Edition, Sultan Chand Publication
2. Time Series Analysis & Its Application, Shumway & Stuffer, Fourth Edition, Springer
3. Statistical Inference, Shrivastav, First Edition, Phi
4. Design And Analysis Of Experiments, Duglass C Mongtomery, Ninth Edition, Wiley
5. Hands On Programming With R, Garrett Gorelumund, First Edition, Oreilly Publisher
6.Essential Of R For Data Analysis,PBR Books, First Edition, PBR Books,
7. Basic Statistics, Mohonty, P.K., irst Edition, Sceintific Publisher
8. Fundamental Of Applied Statistics, Gupta & Kapoor, Fouth Edition, Sultan Chand & Sons
9. Basic Statistics For Business & Economics, Lind & Marchal, First Edition, Tata Mcgraw Hill
10. Operations Research, Mohonty, P.K., First Edition, Sceintific Publisher

iii. Advanced Solar Photovoltaic Systems [4.0 Credits]

Module 01: Solar Radiation (1.0 Credit)

Nature of Solar Radiation, Global, Beam and Diffuse Radiation, Hourly, Daily and Seasonal variation of solar Radiation, Estimation of Solar Radiation, Measurement of Solar Radiation.

Module 02: Photo Thermal Systems (1.0 Credit)

Flat Plate Collector, Hot Air Collector, Evacuated Tube Collector, Parabolic, Compound Parabolic and Fresnel Solar Concentrators, Central Receiver System, Thermal Analysis of Solar Collectors Performance of Solar Collectors, Solar Water Heating Systems (Active and Passive), Solar Space Heating and Cooling Systems, Solar Industrial Process Heating Systems, Solar Dryers and Desalination Systems, Solar Thermal Power Systems.

Module 03: Photovoltaic Systems (1.0 Credit)

Solar Cells and Panels, Performance of Solar Cell, Estimation of Power Obtain from Solar Power, Solar Panels PV Systems, Components of PV Systems, Performance of PV Systems, Design of PV Systems, Applications of PV Systems, Concentrating PV Systems, PV Power Plants, Power Plant with Fuel Cells

Module 04: Design, Modeling and Economic Analysis of Solar Energy Systems (1.0 Credit)

F Chart Method, φ-F Chart method, Utilizability Modeling and Simulation of Solar Energy Systems, Life Cycle Analysis of Solar Energy Systems, Time Value of Money, Evaluation of Carbon Credit of Solar Energy Systems,

Learning Outcomes:

After completing this course, student should be able to:

1) Explain the principles that underlie the ability of various natural phenomena to deliver solar energy

2) Outline the technologies that are used to harness the power of solar energy

3) Discuss the positive and negative aspects of solar energy in relation to natural and human aspects of the environment.

4) understand the different components of a solar photovoltaic systems.

5) choose type of solar PV system suitable for application.

6) design the PV array configuration, inverter and BOS components for given application.

REFERENCE BOOKS:

[1] J. A. Duffie and W.A. Beckman: Solar Engineering of Thermal Process

[2] S. A. Kalogirou: Solar Energy Engineering

iv. Wind Energy Systems [4.0 Credits]

Module 01: Wind Energy Fundamentals (1.0 Credit)

Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics, Power Content, Class of wind turbines, Atmospheric Boundary Layers, Turbulence.

Wind Measurements, Analysis and Energy Estimates: Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz's Limit, Turbulence Analysis

Aerodynamics Theory: Airfoil terminology, Blade element theory, Blade design, Rotor performance and dynamics, Balancing technique (Rotor and Blade), Types of loads; Sources of loads

Module 02: Wind Turbines Technology and Components of MW series WTGs (1.0 Credit)

Wind turbines types: Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control, Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator

Wind Turbine Technology and Components of WTG: 1) Gear Coupled Generator Type [Const. Speed]

2) Direct Coupled Generator Type [Variable Speed Variable Frequency]: Multipole Synchronous / PMG Generators, Gear Coupled Generator Wind Turbine Components and their construction.

Electronics Sensors/Encoder/Resolvers, Wind Measurement: Anemometer and Wind Vane, Grid Synchronization System, Soft Starter, Switchgear [ACB/VCB], Transformer, Cables and assembly. Compensation Panel, Programmable Logic Control, UPS, Yaw and Pitch System: AC Drives, Safety Chain Circuits, Generator Rotor Resistor controller (Flexi Slip), Differential Protection Relay for Generator, Battery/Super Capacitor Charger and Batteries/ Super Capacitor for Pitch System, Transient Suppressor / Lightning Arrestors, Oscillation & Vibration sensing.

Direct Rotor Coupled Generator (Multipole) [Variable Speed, Variable Freq.]

Excited Rotor Synch. Generator/PMG Generator, Control Rectifier, Capacitor Banks, Step Up / Boost Converter (DC-DC Step Up), Grid Tied Inverter, Power Management, Grid Monitoring Module (Voltage and Current), Transformer, Safety Chain Circuits

Doubly Fed Induction Generator and Power Control

Module 03: Modern Wind Turbine Control and Monitoring System (1.0 Credit)

Details of Pitch System and Control Algorithms, Protections used and Safety Consideration in Wind turbines, Wind Turbine Monitoring with Error codes, SCADA and Databases: Remote Monitoring and Generation Reports, Operation and Maintenance for Product Life Cycle, Balancing technique (Rotor & Blade), FACTS control and LVRT & New trends for new Grid Codes.

Module 04: Concept of Wind Farms and Project Cycle and Cost Economics (1.0 Credit)

Project planning, Site selection, Project execution, Operation and maintenance, Environmental concerns: Pollution free power; Noise; birds; Aesthetics; Radio waves interference; Rainfall

Cost Economics: Wind resource assessment and R & D costs, Fixed and variable costs, Value of wind energy, Life cycle costing and cash flow of wind power projects, Wind project owners / developers, Wind energy market.

Learning Outcomes:

After completing this course, student should be able to:

1. get conceptual knowledge of the technology, economics and regulation related issues associated with wind and alternative sources of energy
2. get ability to analyse the viability of wind and alternative energy projects
3. get capability to integrate various options and assess the business and policy environment regarding wind and alternative energy projects
4. get advocacy of strategic and policy recommendations on usage of wind and alternative energy

REFERENCE BOOKS:

[1] Anna Mani: Wind Energy Data for India

[2] C-Wet: Wind Energy Resources Survey in India VI

[3] S. Rangrajan : Wind Energy Resources Survey in India V

[4] Sathyajith Mathew: Wind Energy

[5] Prepared by WISE: Wind Power in India (5000MW BY 2015)

[6] B.H.Khan: Non-Conventional Energy Sources

v. Waste to Energy [4.0 Credits]

Module 01: Basics (1.0 Credit)

Definition of chemical and physical properties and characteristics of MSW a Fuel Comparison to conventional fuels (coal, oil, and natural gas), Resource characterization and assessment, Principles of thermochemical conversion processes: Pyrolysis,Gasification, and Combustion

Module 02: Combustion and Gasification Technology (1.0 Credit)

Description of main combustion technology, Design of combustion, Co-firing, Energy conversion systems and CHP

Description of main gasification technology, Design of gasification, Definition of synthesis gas (producer gas), Co-gasification and IGCC

Module 03: Pyrolysis Technology (1.0 Credit)

Description of main pyrolysis technology, Slow pyrolysis for char production, Fast pyrolysis for bio-oil production, Bio-oil upgrading

Module 04: Introduction to Energy from Waste (MSW) (1.0 Credit)

Characterization and classification of waste as fuel – agrobased, forest residues, industrial waste, **Municipal solid waste, Waste to energy options:** combustion (unprocessed and processed fuel), gasification, anaerobic digestion, fermentation, pyrolysis; **Understand the properties** (physical, chemical, and biological) commonly associated with Municipal Solid Waste (MSW) and integrate them into waste management calculations

MSW segregation technologies and byproducts; Landfill technology and limitations

Conversion devices: combustors (Spreader Stokes, Moving grate type, fluidized bed), gasifier, digesters. Briquetting technology: Production of RDF and briquetted fuel.

Properties of fuels derived from waste to energy technology: Producer gas, Biogas, Ethanol and Briquettes, Comparison of properties with conventional fuels. Power generation using waste to energy technologies: Cl and Sl engines. IGCC and IPCC concepts. Landfills: Gas generation and collection in landfills, Introduction to transfer stations. Comparison with non-energy options like Vermiculture, Composting.

Evaluate specific process parameters critical to the design of non-landfill treatment processes (e.g. thermal destruction efficiencies; flue gas desulphurization requirements)

Apply process science and engineering (PSE) knowledge in describing key issues regarding emissions, treatment and performance of non-landfill technologies.

Learning Outcomes:

After completing this course, student should be able to:

1. Describe the components of solid waste management and the laws governing it.
2. Discuss solid waste collection systems, route optimization techniques and processing of solid wastes.
3. Understand the concept of pyrolysis and the production of different products by using pyrolysis.
4. Explore different types of biomass gasification techniques and understand Biochemical conversion of biomass for energy.
5. Explore different types of biomass combustion techniques and their working operations
6. Describe the basic concepts of biogas and explore Biogas plant technology and their applications.
7. Outline the design, operation, and maintenance of different methods of treatment.
8. Conclude the recent trends in reuse of solid waste

Reference Books

[1] Waste-to-Energy: Technologies and Project Implementation" by Marc J Rogoff Dr and Francois Screve.
[2] Waste to Energy Conversion Technology (Woodhead Publishing Series in Energy)" by Naomi B Klinghoffer and Marco J Castaldi
[3] Waste to Energy: Opportunities and Challenges for Developing and Transition Economies (Green Energy and Technology)" by Avraam Karagiannidis
[4] Waste to Energy" by Sethi Amrinder Singh

vi. Energy Storage [4.0 Credits]

Module 01: Fundamentals of Energy Storage Systems (1.0 Credit)
Introduction and Fundamentals of energy storage, energy density, power density; Electrochemical storage components; Supercapacitors; Hydraulic storage; Flywheels; Compressed air energy storage; Pumped Hydro Storage, Transportation, mobile applications; Power electronics and grid connected systems; Grid stability and grid management, concept of load dispatch centre, effect of renewable integration in to grid. Overview of energy storage technologies: Thermal, Mechanical, Chemical, Electrochemical, Electrical. Efficiency of energy storage systems. Electrical energy storage: Batteries, Super capacitors, Superconducting Magnetic Energy Storage (SMES), charging methodologies, SoC, SoH estimation techniques. Hydrogen production and storage, fuel cells.

Module 02: Types of Energy Storage Systems (1.0 Credit)
Mobile storage system: electric vehicle, G2V, V2G.Hybrid Energy storage systems: configurations and applications. Storage for renewable energy systems: Solar energy, Wind energy, pumped hydro energy, fuel cells. Energy storage in Microgrid and Smart grid. Energy Management with storage systems, increase of energy conversion efficiencies by introducing energy storage.

Module 03: Operation and Maintenance of Energy Storage Systems (1.0 Credit)
Simulation of energy storage systems and its management, smart park, Electric Vehicle charging facility, HESS in microgrid and smart grid, microbial fuel cell, hydrogen fuel cell and so on.

Module 04: Other Energy Storage Systems and Econometric Analysis of Energy Storage Systems (1.0 Credit)
Performance advantages and disadvantages of lead acid batteries, Inadequacy of existing technologies, Next generation of li-based batteries, Battery Management System (BMS), Electric Vehicles battery considerations. Hybrid Charging (grid and solar photovoltaic). ROI and Project Analysis involving Energy Storage Systems.

Learning Outcomes:

After completing this course, student should be able to:

1. Discuss the scientific principles underpinning the operation of energy storage systems.

2. Resolve the intermittency of renewable energy sources such as solar and wind by utilizing problem solving skills in energy storage engineering and grid integration.

3. Work with a team to apply energy storage knowledge to develop and conduct a project.

Reference Books:

1) Energy Storage: Fundamentals, Materials and Applications by Robert A. Huggins; Springer, 2010.
2) Electric Energy Storage Systems: Flexibility Options for Smart Grids, by Pio Lombardi, Przemyslaw Komarnicki, and Zbigniew Antoni Styczynski, Springer 2017.
3) Energy Storage Systems, by S. Kakac, BirolKilkis, 1989
4) Energy Storage for Sustainable Microgrid, by David WenzhongGao, Academic Press Elsevier, 2015.
5) A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN - 978-1-84919-219-4), 2011.
6) A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN - 13:9789380090122), 2011.

4) Course 04: [2 credits]

Publication Ethics.

Total 30 class hours. Designed and prescribed by BOS or Adopt as per the course designed by the Centre for publication Ethics, SPPU. Research Centre to Conduct the course. Research Centre can have their own course to be run and evaluate. OR Can adopt payment basis publication ethics online run by Centre for Publication ethics, SPPU.

Learning Outcomes:

After completing this course, student should be able to:

1) Understand and define the concepts of integrity and ethics

2) Understand the ideas of values, ethics and morality in a multicultural context

3) Understand how universal values can be uncovered by different means, including scientific investigation, historical research, or public debate and deliberation (what some philosophers call a dialectic method)

4) Understand and discuss the idea of moral relativism and the challenges it poses to universal values

5) Understand the relationship between ethics and society

6) Define and give examples of ethical leadership, Understand leaders' ethical responsibilities.

7) Perceive the value of cultures, identities, histories and points of view other than one's own

8) Learn choosing right publication journal for the research outcome.

9) learn steps in choosing

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