Biju Patnaik University of Technology, Orissa
Rourkela

Syllabus
of
M.Tech

in

ELECTRICAL ENGINEERING

(Specialization: Energy Systems Engineering)

From 2014 -2015 Academic Session

Syllabus for Energy Systems Engineering

1st Semester

Theory (Compulsory)

Code	Subject	Contact Hours (L-T-P)	Credit
EYPC 101	Foundation for Energy systems Technology	4-0-0	4
EYPC 102	Power Generation, Transmission and Distribution	4-0-0	4
EYPC 103	Solar Energy Engineering	4-0-0	4

Professional Elective-I (any One)

EYPE 101	Energy Efficiency in Electrical Utilities	3-0-0	03
EYPE 102	Conventional Power Plant Engineering	3-0-0	03
EYPE 103	Fuel and Combustion Technology	3-0-0	03

Professional Elective-II (any One)

EYPE 104	Energy Efficiency in Thermal Utilities	3-0-0	03
EYPE 105	Energy system modelling and Analysis	3-0-0	03
EYPE 106	Power System Planning And Operation	3-0-0	03
Credits (Theory)			**18**

Practical/Sessionals

`EYPR 102	Energy Engineering Lab-1	0-0-3	04
EYPT 101	Pre-Thesis Work related Seminar	0-0-3	02
Credits(Practicals/Sessionals)			**06**
Total Semester Credits			**24**
Total Cumulative Credits			**24**

2nd Semester

Theory (Compulsory)

Code	Subject	Contact Hours (L-T-P)	Credit
EYPC 201	Wind and Small Hydro Systems	4-0-0	04
EYPC 202	Operation & Control of Electrical Energy Systems	4-0-0	04

Professional Elective-III (any One)

EYPE 201	Energy Generation from Waste	3-0-0	03
EYPE 202	Fuel Cell and Hydrogen Technology	3-0-0	03
EYPE 203	Instrumentation and Control in Energy Systems	3-0-0	03

Professional Elective-IV (any One)

EYPE 204	Power System Dynamics	3-0-0	03
EYPE 205	Materials and Devices for Energy Application	3-0-0	03
EYPE 205	Energy and Climate Change	3-0-0	03

Professional Elective-V (any One)

EYPE 206	Quantitative methods for energy management and planning	3-0-0	03
EYPE 207	Energy Economics	3-0-0	03
EYPE 208	System Identification and Adaptive Control	3-0-0	03
Credits (Theory)			**17**

Practical/Sessionals

EYPR 201	Energy Lab-1	0-0-6	04
EYCV 201	Viva Voce-1	0-0-3	02
EYPT 201	Pre-Thesis Work Related Seminar	0-0-3	02
Credits(Practicals/Sessionals)			**08**
Total Semester Credits			**25**
Total Cumulative Credits			**49**

3rd Semester

OE	**Open Electives (any ONE)**		

4th Semester

EYOE 301	Energy Scenario and Energy policy	3-0-0	03				
EYOE 302	Energy Audit and Management	3-0-0	03				
EYOE 303	Energy Efficient Buildings	3-0-0	03				
EYOE 304	Project Management	3-0-0	03				
Credits (Theory)			**03**	**Credits (Theory)**			**00**
Practical/Sessionals				**Practical/Sessionals**			
EYPT 301	Thesis Part - I	0-0-3	14	EYPT 401	Thesis Part - II	0-0-6	20
Credits (Practical/Sessional)			**14**	EYPT 402	Technical Seminar	0-0-3	02
Total Semester Credits			**17**	EYCV 401	VIVA voce-2	0-0-3	02
				Credits (Practical/Sessional)			**24**
				Total Semester Credits			**24**
				Total Cumulative Credits			**90**

FOUNDATION FOR ENERGY SYSTEMS TECHNOLOGY

MODULE-I:

Renewable Energy Alternatives:

Solar Photovoltaic conversion, Wave Energy and Ocean Thermal Energy Conversion, Wind Energy Conversion, Biomass Energy Conversion, Energy from Waste, Mini/Micro-hydel

MODULE-II:

Basic Concepts of Thermodynamics

First law and its application, second law and its application, Irreversibility and power generation cycles.

Basic Concepts of Heat transfer: Heat exchangers, overall heat transfer co-efficient, Design of single and multiple pass heat Exchangers, Heat Pipes, Heat Pumps and their applications in Solar Energy systems

Basic Concepts of Fluid Mechanics:

Basic Concepts**,** Flow through pipes, Fluid flow in solar water heaters

MODULE-III:

Combustion Process Overview: Basic physical laws governing combustion, air as a source of oxygen for combustion, combustion principles of solid-liquid-gaseous fuels, proximate and ultimate analysis of solid and gaseous fuels, Estimation of calorific values, combustion process, flame velocity, excess air requirements and estimation, flue gas analysis, combustion efficiency

Text Books /References:

1. RE Sonntag, C Borgnakke, GJ Van Wylen, *Fundamentals of Thermodynamics*, 6th Edition, (Wiley-India)

2. PK Nag, *Engineering Thermodynamics*, Third Edition (*Tata McGraw-Hill)*

3. YA Cengel and MA Boles, *Thermodynamics: An Engineering Approach*, 6th Edition (Tata McGraw-Hill)

4. SR Turns, *An Introduction to Combustion: Concepts and Applications*, 2nd Edition (McGraw Hill)

5. JB Jones and RE Dugan, *Engineering Thermodynamics*, PHI, New Delhi,

6. SP Sukhatme, *Solar Energy - Principles of thermal collection and storage*, 2nd edition, Tata McGraw-Hill, New Delhi

7. JA Duffie and WA Beckman, *Solar Engineering of Thermal Processes*, 2nd edition, John Wiley, NY

8. DY Goswami, F Kreith and JF Kreider, *Principles of Solar Engineering*, Taylor and Francis, Philadelphia

9. M. W. Zemansky, *Heat and Thermodynamics*, 4th Edn. McGraw Hill, 1968.

10. A. L. Prasuhn, *Fundamentals of Fluid Mechanics*, Prentice Hall, 1980

11. S. P. Sukhatme, *A Text book on Heat Transfer*, Orient Longman, 1979.

12. John Twidell and Tony Weir, "Renewable Energy Resources" Second Edition, Taylor and Francis (2006)

13. G. N. Tewari and M. K. Ghosal, Renewable Energy Sources: Basic Principles and Applications, Narosa Publishing House (2005)

POWER GENERATION, TRANSMISSION AND DISTRIBUTION

MODULE-I:

Generation:

Synchronous generator operation, Power angle characteristics and the infinite bus concept, dynamic analysis and modeling of synchronous machines, Excitation systems, Prime-mover governing systems, Automatic generation control; Power system stabilizer,

MODULE-II:

AC Transmission:
Overhead lines and cables, Transmission line equations, Regulation and transmission line losses, Reactive power compensation, Flexible AC transmission;
HVDC transmission:
HVDC converters, advantages and economic considerations, converter control characteristics, analysis of HVDC link performance, Multi-terminal DC system, HVDC and FACTS

MODULE-III:

Distribution:
Distribution systems (Radial and Ring Main systems), Conductor size, Kelvin's law, Performance calculations and analysis, Wiring installation in domestic and commercial buildings, Substation and feeder circuit design considerations, Distribution automation,
Power quality
Text Books /References:

1. Power Generation, Operation, and Control by Allen J. Wood and Bruce F. Wollenberg, John Wiley & Sons, 2003.

2. Power System Control and Stability by P. M. Anderson and A. A. Fouad, Wiley-IEEE Press, 2002

3. Electric Energy Systems Theory: An Introduction by Olle I Elgerad, T M H Edition, 1982

4. HVDC Transmission: Power Conversions Applications in Power Systems by Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee, Wiley – IEEE Press, 2009

5. Electric Power Transmission System Engineering Analysis and Design by Turan Gonen, CRC Press, 2009

6. Power system stability and control by P**.** Kundur. McGraw-Hill, 1994.

SOLAR ENERGY ENGINEERING

MODULE-I:
Solar Photovoltaic (SPV) Systems:
Source of radiation – solar constant– solar charts – Measurement of diffuse, global and direct solar radiation, Photovoltaic Effect, Multi-junction solar cell, Quantum well solar cell, thin film solar cells, Equivalent Circuit of the Solar Cell, Analysis of PV Cells: Dark and illumination characteristics, Figure of merits of solar cell, Efficiency limits, Variation of efficiency with band-gap and temperature, Efficiency measurements, Solar array, Voltage regulation, Maximum tracking**.**

MODULE-II:
Solar Thermal Systems:
Flat Plate Collectors, Energy balance principle, Overall Heat Loss Coefficient , heat transfer between Parallel surfaces , Heat capacity effect, Types of Flat Plate Collectors: Liquid Flat Plate Collectors, Air flat-plate Collectors-Thermal analysis, Evacuated tubular collectors, Solar Energy Storage, Collector tracking systems.

MODULE-III:

Applications of Solar PV and Solar Thermal Systems:

Centralized and decentralized SPV systems, Stand alone, hybrid, and grid connected SPV systems.

Solar Passive Heating and Cooling, Solar Thermal Power Plant, Solar Desalination, Solar Drying, Solar Cooking, Solar Greenhouse technology, Application of solar thermal energy in agriculture and space heating.

Texts Books/References:

1. SP Sukhatme, *Solar Energy: Principles of Thermal Collection and Storage*, Tata McGraw-Hill,1984

2. JA Duffie and WA Beckman, *Solar Engineering of Thermal Processes*, John Wiley, 1991

3. B Sorensen, *Renewable Energy*, (2nd Ed), Academic press, New York, 2000

4. Garg HP, J Prakash, *Solar Energy: Fundamentals and Applications*, Tata McGraw Hill, New Delhi, 1997
5. DY Goswami, F Kreith and JF Kreider, *Principles of Solar Engineering*,Taylor and Francis

6. GN Tiwari, S Suneja, *Solar Thermal Engineering System*, Narosa Publishing House, New Delhi, 1997

Text Books/ References:

1. AL Fahrenbruch and RH Bube, *Fundamentals of Solar Cells: PV Solar Energy Conversion*, Academic Press, New York, 1983

2. T Bhattacharya, *Terrestrial Solar Photovoltaic*, Narosa Publishers Ltd, New Delhi LD Partain (ed), *Solar Cells and their Applications*, John Wiley and Sons, Inc, New York, 1995

3. RH Bube, *Photovoltaic Materials*, Imperial College Press, 1998

4. HS Rauschenbach, *Solar Cell Array Design Handbook*, Van Nostrand Reinfold Company, New York, 1980

5. R Messenger and J Vnetre, *Photovoltaic Systems Engineering*, CRC Press *Stand Alone PV Systems: A Handbook of Recommended Design Practices*, Report No SAND 87-7023, Sandia National Lab USA
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6. F Kreith and JF Kreider, *Principles of Solar Engineering*, McGraw-Hill (1978)

7. J Twidell and T Weir, *Renewable Energy Resources*, Taylor and Francis (Ed), New York, USA, 2006

TEXT BOOKS

1. D. Yogi Goswami, Frank Kreith, Jan. F. Kreider, "Principles of Solar Engineering", 2nd Edition, Taylor & Francis, 2000, Indian reprint, 2003
2. Edward E. Anderson, "Fundamentals for solar energy conversion", Addison Wesley Publ. Co., 1983.

REFERENCE

1. Duffie J. A and Beckman, W .A., "Solar Engineering of Thermal Process", John Wiley, 1991.
2. G. N. Tiwari and M. K. Ghosal, "Fundamentals of Renewable energy Sources", Narosa Publishing House, New Delhi, 2007
3. *Energy Studies, Second Edition, by W. Shepherd and D. W. Shepherd, Imperial College Press, London, 2004.*

Text Books/References:

A. Rabl, Active Solar Collectors and Their Applications, Oxford University Press, New York, 1985
D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia,
2000
W. T. Welford, R. Winston, The Optics of Nonimaging Concentrators – Light & Solar Energy, Academic Press,
New York, 1978

1. Solar Energy of Thermal Processes, Second Edition, 1991, by JA Duffie and WA Beckman, John Wiley & Sons Inc.

2. Solar Energy, First Edition, 2002, by GN Tiwari, Narosa Publishing House.

3. Principals of Solar Engineering, Second Edition, 2000, by DY Goswami, F Krieth & JF Krieder, Taylor and Francis Inc.

ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

MODULE-I:

Electrical System: Electricity billing, Electrical Load Management and maximum demand control, Power factor improvement and its benefit, Selection and location of capacitors, Performance assessment of PF capacitors, Distribution and Transformer losses.

Electric Motors: Types, Losses in Electric Motors, motor efficiency, factors affecting motor performance, rewinding and motor replacement issues, energy saving opportunities with energy efficient motors

Lighting System: Light source, choice of lighting, luminance requirements, and energy conservation avenues

MODULE-II:

Compressed Air System: Types of air compressors, compressor efficiency, efficient compressor operation, compressed air system components, capacity assessment, leakage test, factors affecting the performance and savings opportunities

HVAC and Refrigeration system: Vapour compression refrigeration cycle, refrigerants, coefficient of performance, capacity, factors affecting refrigeration nd air-conditioning system performance and saving opportunities, vapour absorption refrigeration system - working principle, types and comparison with vapour compression system, saving potential

Fans and Blowers: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities.

Pumps and Pumping System: Types, performance evaluation, efficient system operation, flow control strategies and energy conservation opportunities.

Cooling Tower: Types and performance evaluation, Efficient system operation, flow control strategies, energy saving opportunities, Assessment of cooling tower

MODULE-III:

Diesel generating system: Factors affecting selection, energy performance assessment of diesel conservation avenues.

Energy Efficient Technologies in Electrical Systems: Maximum Demand Controllers, automatic power factor controllers, energy efficient motors, soft starters with energy saver, variable speed drives, energy efficient transformers, electronic ballast, occupancy sensors, energy efficient lighting controls, energy saving potential of each technology

TEXT BOOKS

1. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists,.
Logman Scientific & Technical, ISBN-0-582-03184, 1990.
2. Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.

REFERNECE

1. Larry C Whitetal, Industrial Energy Management & Utilization.
2. Power System Engineering 2nd Ed. D P Kothari, I J Nagrath, Tata McGraw-Hill Co 2008

3. Bureau of Energy Efficiency (BEE) : www.bee-india.nic.in
4. The Energy and Resource Institute (TERI): http://www.teriin.org/
1. Energy Efficiency for Engineers and Technologists, First Edition, 1990, by TD Eastop and DR Croft, Longman Group UK Ltd.

2. Industrial Energy Management and Utilization, 1988, by LC Wittie, P S Schmidt and D R Brown, Hemisphere Publishing Company.

3. Energy Management Hand Book, Third Edition, 1997, by W C Turner, The Fairmont Press Inc.

CONVENTIONAL POWER PLANT ENGINEERING

MODULE-I:

Steam Power Plants:
Steam power stations based on fossil fuels, Economy and thermal scheme of the steam power stations, Thermal power plant equipments - boilers, super heaters, super critical steam generator, economizers, feed water heater, condensers, combustion chamber and gas loop, turbines, cooling towers, etc.

MODULE - II:

Hydro Power Plants:
Catchment area, Reservoir, Dam, Head Gate, Spillways, Pen stock, Surge Tanks, Scroll case, Draft tubes and Tail Race, Power House, Classification of Hydroelectric Power Plants, Operational principle of Kaplan and Francis Turbine and Pelton wheel, Speed and Pressure Regulation, Work done, efficiency, Governors, Plant auxiliaries.

Nuclear power plants:
Fission & fusion, Chain Reaction, controlled chain reaction, Various types of Nuclear Reactors (Boiling water, pressurized water, heavy water, breeder), Location and layout of nuclear power plant

MODULE-III:

Gas turbine power stations, Integrated Gasification Combined Cycle (IGCC), Indirect Fired Combined Cycle (IFCC), Combined cycle power plants, Internal combustion engine plant for peak load, standby and start up.

Text Books/References:

1. “Power Plant Engineering” by F.T.Morse, D.Van.Nostran, Newyork, 1953

2. “Power Plant Engineering” by P.K.Nag, Tata McGraw Hill 2008

3. “Power Plant Technology” by M.M.EI- Wakil , McGraw Hill 1984
4. Vopat

TEXT BOOK
1. Thomas C. Elliott ,”Standard Hand Book of Power Plant Engineering”
REFERENCE
1. E L Wakil, “Power Plant Engineering”, McGraw-hill Book Co, N.Y. 2001
2. Arora and Domkundwar, A course in Power Plant Engineering, Dhanpat Ra, N. Delhi. 2003
*3. Nag, P.K., “Power Plant Engineering**”**, 2nd Edition, TMH, 2001*

FUEL AND COMBUSTION TECHNOLOGY

MODULE-I:

Fuels and Fuel Analysis
Solid, liquid and gaseous fuels, Coal as a source of energy, Gasification and liquefaction of coal and lignite, Principle of combustion, Petroleum and its derived products, Testing of liquid fuels, Petroleum refining processes, Inter-conversion of fuels.

MODULE-II:
Combustion Thermodynamics & Furnaces
Calculation of heat of formation & heat of combustion, First law analysis of reacting systems, Combustion Stoichiometry, theoretical & actual combustion processes, Air fuel ratio.
Industrial furnaces, Process furnaces, Kilns, Batch & continuous furnaces,

MODULE-III:
Combustion Appliances
Flame, Flame Structure, Ignition and Igniters, self & forced ignition, Ignition temperature, flame propagation, deflagration, detonations, flame front.
Combustion appliances for solid, liquid and gaseous fuels, Gas burners- Functional requirement of burners – Gas burner Classification –Stoker firing –pulverized system of firing

TEXT BOOKS
1. S.P. Sharma & Chander Mohan, "Fuels & Combustion", Tata McGraw Hill Publishing Co. Ltd., 1984
2. Dr. Samir Sarkar, "Fuels & Combustion", Orient Longman, Second edition, 1990.
REFERENCES
1. Blokh A.G, "Heat Transmission in Steam Boiler furnaces", Hemisphere Publishing Corpn.ISBN-089-116-626-2
2. Gupta O.P, "Elements of Fuels, Furnaces & Refractories", 3rd edition, Khanna Publishers, 1996.
3. Combustion Fundamentals by Roger A. Strehlow – McGraw-Hill
4. Combustion Engineering and Fuel Technology by Shaha A.K. – Oxford and IBH.
5. Principles of Combustion by Kenneth K. Kou – John Wiley & Sons.

ENERGY EFFICIENCY IN THERMAL UTILITIES

MODULE-I:
Boilers: Types, combustion in boilers, performance evaluation, analysis of losses, feed water treatment, blow down, energy conservation opportunities.
Steam System: Properties of steam, assessment of steam distribution losses, steam leakages, steam trapping, condensate and flash steam recovery system, identifying opportunities for energy savings.
Furnaces: Classification, general fuel economy measures in furnaces, excess air, heat distribution, temperature control, draft control, waste heat recovery
MODULE-II:
Insulation and Refractories: Insulation types and application, economic thickness of insulation, heat saving and application criteria, refractory types, selection and application of refractories, heat loss
FBC Boilers: Introduction, mechanism of fluidized bed combustion, advantages, types of FBC boilers, operational features, retro-fitting of FBC system to conventional boilers, saving potential.
MODULE-III:
Cogeneration: Definition, need, application, advantages, classification, saving potential.
Waste Heat Recovery: Classification, advantages and applications, commercially viable waste heat recovery devices, saving potential.
TEXT BOOKS

1. George Polimeros, Energy Cogeneration Hand Book for Central Plant Design, Industrial Press inc, Newyork, 1981

2. M.M.EI- Wakil, Power Plant Technology, McGraw Hill, 1984

3. Chapters in a number of books on Power Plant Engineering and Thermodynamics
4. Eastop, T.D. & Croft D.R, "Energy efficiency for engineers and Technologists", 2nd Edition, Longman Harlow, 1990.
5. O'Callaghan, Paul W, "Design and Management for energy conservation", Pergamon,1993.

REFERENCES

1. Osborn, peter D, "Handbook of energy data and calculations including directory of products and services", Butterworths, 1980.
2. Charles H.Butler, Cogeneration, McGraw Hill Book Co., 1984.
3. Horlock JH, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford, 1987
4. IEEE Bronze Book: IEEE Standard 739-1984 – Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities, IEEE Publications, 1996.
5. A.P.W. Thumann: Plant Engineers and Managers Guide to Energy conservation, 7e, UNR, 1977.
6. H. Partab, Art and Science of Utilisation of Electrical Energy, Pritam, 1985.
7. S.C. Tripathy, Electric Energy Utilization and Conservation, Tata McGraw Hill, 1991.
8. W.C. Turner, Energy Management Handbook, 2e, Fairmont press, 1993.
9. UNESCAP- Guide Book on Promotion of Sustainable Energy Consumption (www.unescap.org/enrd/energy)
10. Bureau of Energy Efficiency (BEE) : www.bee-india.nic.in

11. The Energy and Resource Institute (TERI): http://www.teriin.org/
13. The efficient use of steam – Oliver Lyle, (HMSO London)
15. The Efficient use of steam generation – General editor – P.M.Goodall
18. Practical Heat Recovery – Boyen J.L. (John Wiley, New York, USA1976)

ENERGY SYSTEM MODELING AND ANALYSIS

MODULE-I:
Modeling overview:
Input output analysis, steps in model development, examples of models. Quantitative Techniques: Interpolation-polynomial, Lagrangian. Curve-fitting, Systems Simulation-information flow diagram, solution of set of nonlinear algebraic equations, successive substitution, Newton Raphson Method
Analysis of System load curve, plant load factor, availability, Loss of load Probability calculations for a power system.

MODULE-II:
Optimisation :
Objectives/constraints, problem formulation. Unconstrained problems- Necessary & Sufficiency conditions, Constrained Optimisation- Lagrange multipliers, constrained variations, Kuhn-Tucker conditions. Linear Programming - Simplex tableau, pivoting, sensitivity analysis. Dynamic Programming. Search Techniques- Univariate / Multivariate. Case studies of optimisation in Energy systems problems. Dealing with uncertainty probabilistic techniques. Trade-offs between capital & energy using Pinch Analysis.

MODULE-III:
Basic concept of econometrics and statistical analysis:
The 2-variable regression model; The multiple regression model; Tests of regression coefficients and regression equation, Econometric Energy Demand Modeling,Econometric techniques used for energy demand analysis, Methodology for Energy Forecasting- Sectoral Energy Demand Forecasting, Load Forecasting -Time series, Econometric, end use techniques.

Text/References

1. S.S.Rao Optimisation theory and applications, Wiley Eastern, 1990
2. S.S. Sastry Introductory methods of numerical analysis,Prentice Hall, 1988
3. P. Meier Energy Systems Analysis for Developing Countries, Springer Verlag, 1984
4. R.de Neufville, Applied Systems Analysis, Mcgraw Hill, International Edition, 1990
5. Beveridge and Schechter,Optimisation Theory and Practice,Mcgraw Hill, 1970
6. B.K. Hodge: Analysis and Design of Energy Systems, Prentice Hall, 1990.
7. W.J. Gajda and W.E. Biles: Engineering Modeling and Computation, Houghton Mifflin, 1980.
8. R.W.Haywood, Analysis of Engineering Cycles, 4th Edition, Pergamon Press, Oxford, 1991.
9. H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.
10. T.M. O' Donovan, Short Term Forecasting: An introduction to the Box Jenkins Approach, Wiley, Chichester,1983.
11. Wood, A.J., Wollenberg, B.F., Power Generation, operation & control, John Wiley, New York, 1984.

POWER SYSTEM PLANNING AND OPERATION

MODULE-I:

Demand Forecasting and Generation Planning: Sector-wise peak demand and energy forecasting by trend and econometric projection methods.

Probabilistic models of generating unit outage performance and system load, Evaluation of loss of load and loss of energy indices, Probabilistic production costing, Inclusion of renewable energy sources in the reliability analysis.

MODULE-II:

Interconnected Systems: Multi-area reliability analysis, Power pool operation and power/energy exchange contracts, Quantification of economic and reliability benefits by pool operation.

MODULE-III:

Optimal Generation Expansion Planning : Formulation of least cost optimization problem incorporating the capital, operating and maintenance costs of candidate plants of different types (thermal, hydro, nuclear, renewables etc) and minimum assured reliability constraints, Optimization techniques for solution by linear, nonlinear and dynamic programming approaches, Case studies.

Text Books /References:

1. Power Generation, Operation, and Control by Allen J. Wood and Bruce F. Wollenberg, John Wiley & Sons, 2003.

2. Power System Control and Stability by P. M. Anderson and A. A. Fouad, Wiley-IEEE Press, 2002

3. Electric Energy Systems Theory: An Introduction by Olle I Elgerad, T M H Edition, 1982

4. HVDC Transmission: Power Conversions Applications in Power Systems by Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee, Wiley – IEEE Press, 2009

5. Electric Power Transmission System Engineering Analysis and Design by Turan Gonen, CRC Press, 2009

6. Power system stability and control by P**.** Kundur. McGraw-Hill, 1994.

WIND AND SMALL HYDRO SYSTEMS

MODULE-I:

Wind Energy Fundamentals

Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics,Power Content, Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz's Limit, Turbulence.

Classification of wind turbines
Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control, Pitch Control and Gear Coupled Generator type wind turbines.

MODULE-II:
Modern Wind Turbine Control
Gear Coupled Generator Wind Turbine, Direct Rotor Coupled Generator Wind Turbine**,** Excited Rotor Synchronous Generator / PMG Generator, Control Rectifier, Capacitor Banks, Step Up / Boost Converter (DC-DC Step Up), Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current), Transformer, Safety Chain Circuits, Doubly Fed Induction Generator and Power Control

MODULE-III:
Small Hydro and Hybrid Systems:
Overview of micro mini and small hydro, Site selection and civil works, Penstocks and turbines, Speed and voltage regulation, Investment issues, load management and tariff collection, Distribution and marketing issues, Hydro based stand-alone / hybrid power systems, Control of hybrid power systems, case studies

TEXT BOOKS
1. S. Rao & B. B. Parulekar, "Energy Technology", 4th edition, Khanna publishers, 2005.
2. Wind energy Handbook, Edited by T. Burton, D. Sharpe, N. Jenkins and E. Bossanyi, John Wiley & Sons, 2001
3. Wind and Solar Power Systems, Mukund. R. Patel, 2nd Edition, Taylor & Francis, 2001
4. L .L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
5. *D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press*
REFERENCES
1. Anna Mani & Nooley, "Wind Energy Data for India", 1983.
2. IS 875 Part IV and IS 1893 semics D+STDS mareials STDS IS 226 (IS 2862, ASTMS 36, BS 4360 GR 43D and A).
3. Logan (EARL),"Turbo Machinery Basic theory and applications", 1981.

1. Wind Energy Explained – Theory, Design and Application by J. F. Manwell, J. G. McGowan and A. L. Rogers, John Wiley & Sons, Ltd., 2002

2. Aerodynamics of Wind turbines by Martin O. L. Hansen, Earthscan, 2008.

3. Wind Turbine Control Systems- Principles, Modelling and Gain Scheduling Design by Fernando D. Bianchi, Hernan De Battista and Ricardo J. Mantz, Springer, 2007

4. Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes by Adam Harvey, Andy Brown and Priyantha Hettiarachi ITDG,1993.

5. Guide on How to Develop a Small Hydropower Plant by Maria Laguna, ESHA,2004

6. Good & Bad of Mini Hydro Power edited by Roman Ritter, GTZ, 2009

OPERATION & CONTROL OF ELECTRICAL ENERGY SYSTEMS

MODULE-I:
Real Time Monitoring of Power Systems : State Estimation, Topological observability Analysis, Security Analysis of Power Systems, Economic Dispatch & Unit Commitment

MODULE-II:

Control of Power & Frequency : Turbine -Governor Control Loops, Single Area and Multi-Area Systems Control, Effect of high penetration of Wind & Other Renewable/Distributed Generation on P-F Control
Control of Voltage & Reactive Power: Generator Excitation Systems, & Automatic Voltage Regulators, Transformer Tap Changes Controls, Voltage Control in Distribution Networks using New Power Electronic Devices

MODULE-III:
Introduction to Market operations in Electric Power Systems : Restructured Power Systems, Short Term Load Forecasting, Power Trading through Bilateral, Multilateral Contracts and Power Exchanges, Role of Distributed Generators in market Operations.

TEXT BOOKS

1.Wood, A.J. and B.F. Wollenberg, Power Generation Operation and Control, Wiley - Interscience Publication, Second Ediction (2003).
2. O.I. Elgard, Electric Energy Systems Theory : An Introductuion, Tata McGraw Hill Publication, Second Edition, 1982
3. Shahidepour, M. et al, Market Operationhs in Electric Power Systems, Wiley Interscience & IEEE Publication, 2002.
4. Bhattacharya et al, Operation of Restructured Power Systems, Kluwer Academic Publishers, 2001

ENERGY GENERATION FROM WASTE

MODULE-I:
Solid Waste Sources Solid Waste Sources, types, composition, Properties, Municipal Solid Waste: Physical, chemical and biological properties , Waste Collection and, Transfer stations, Waste minimization and recycling of municipal waste, Segregation of waste, Size Reduction , Managing Waste, Status of technologies for generation of Energy from Waste
Waste Treatment and Disposal Aerobic composting, incineration, Furnace type and design, Medical waste /Pharmaceutical waste treatment Technologies, incineration, Environmental impacts, Measures to mitigate environmental effects due to incineration

MODULE-II:
Land Fill method of Solid waste disposal Land fill classification, Types, methods and Sitting consideration, Layout and preliminary design of landfills: Composition, characteristics, generation, Movement and control of landfill leachate and gases, Environmental monitoring system for land fill gases
MODULE-III:
Energy Generation from Waste
Bio-chemical Conversion: Sources of energy generation, Anaerobic digestion of sewage and municipal wastes, Direct combustion of MSW-refuse derived solid fuel, Industrial waste, agro residues,
Anaerobic Digestion: Biogas production, Land fill gas generation and utilization,
Thermo-chemical conversion: Sources of energy generation, Gasification of waste using Gasifiers , Briquetting, Utilization and advantages of briquetting, Environmental benefits of Bio-chemical and Thermo-chemical conversion

Text Books/References:
1. Nicholas P. Cheremisinoff. Handbook of Solid Waste Management and Waste Minimization Technologies. An Imprint of Elsevier, New Delhi (2003).

2. P. Aarne Vesilind, William A. Worrell and Debra R. Reinhart. Solid Waste Engineering. Thomson Asia Pte Ltd. Singapore (2002)

3. M. Dutta , B. P. Parida, B. K. Guha and T. R. Surkrishnan. Industrial Solid Waste Management and Landfilling practice. Narosa Publishing House, New Delhi (1999).

4. Amalendu Bagchi. Design, construction and Monitoring of Landfills. John Wiley and Sons. New York. (1994)

5. M. L. Davis and D. A. Cornwell. Introduction to environmental engineering. Mc Graw Hill International Edition, Singapore (2008)

6. C. S. Rao. Environmental Pollution Control Engineering. Wiley Eastern Ltd. New Delhi (1995)

7. S. K. Agarwal. Industrial Environment Assessment and Strategy. APH Publishing Corporation. New Delhi (!996)

8. Sofer, Samir S. (ed.), Zaborsky, R. (ed.), "Biomass Conversion Processes for Energy and Fuels", New York, Plenum Press, 1981

9. Hagerty, D.Joseph; Pavoni, Joseph L; Heer, John E., "Solid Waste Management", New York, Van Nostrand, 1973

10. George Tchobanoglous, Hilary Theisen and Samuel Vigil Prsl: Tchobanoglous, George Theisen, Hillary Vigil, Samuel, "Integrated Solid Waste management: Engineering Principles and Management issues", New York, McGraw Hill, 1993

1. C Parker and T Roberts (Ed), *Energy from Waste - An Evaluation of Conversion Technologies*, Elsevier Applied Science, London, 1985

2. KL Shah, *Basics of Solid and Hazardous Waste Management Technology*, Prentice Hall, 2000

3. M Datta, *Waste Disposal in Engineered Landfills*, Narosa Publishing House, 1997

4. G Rich et.al, *Hazardous Waste Management Technology*, Podvan Publishers, 1987

5. AD Bhide, BB Sundaresan, *Solid Waste Management in Developing Countries*, INSDOC, New Delhi,1983

FUEL CELL AND HYDROGEN TECHNOLOGY

MODULE-I:

Fuel Cell Basics Fuel cell definition, Difference between batteries and fuel cells, fuel cell history, components of fuel cells, principle of working of fuel cells Fuel cell thermodynamics - second law analysis of fuel cells, efficiency of fuel cells fuel cell electrochemistry - Nernst equation, Electrochemical kinetics, Butler-Volmer equation
Fuel cell types Classification by operating temperature/electrolyte type, Fuel Cell Performance, Activation, Ohmic and Concentration over potential

MODULE-II:
Fuel cell design and components Cell components, stack components, system components Overview of intermediate/high temperature fuel cells - Solid oxide fuel cells (SOFC), Molten carbonate fuel cells (MCFC), Phosphoric acid fuel cells (PAFC) Polymer Electrolyte fuel cells ,Heat and mass transfer in polymer electrolyte fuel cells, water management in PEFCs, Current issues in PEFCs, Direct methanol fuel cells (DMFC) - Electrochemical kinetics methanol oxidation, Current issues in MFCs, Fuel crossover in DMFCs, Water management in DMFCs, high methanol concentration operation, limiting current density

MODULE-III:
Hydrogen Energy Hydrogen: Its merit as a fuel, Applications
Hydrogen production methods Production of hydrogen from fossil fuels, electrolysis, thermal decomposition, photochemical and photo-catalytic methods
Hydrogen storage methods Metal hydrides, metallic alloy hydrides, carbon nano-tubes, sea as source of deuterium

1. Kettani, M.A., Direct energy conversion, Addison-Wesley, Reading, Mass, 1970
2. Angrist S.W. ,Direct Energy Conversion. 4th Ed. Allyn And Bacon, Boston, 1982
3. Green M.A. ,Solar Cells, Prentice-Hall, Englewood Cliffs, 1982
4. Hand book Batteries and Fuel Cells. Linden, McGraw Hill, 1984.

Text Books/Reference:

1. J Larminie and A Dicks, *Fuel Cell Systems Explained*, 2nd Edition, Wiley,2003

2. Xianguo Li, *Principles of Fuel Cells*, Taylor and Francis, 2006

3. S Srinivasan, *Fuel Cells: From Fundamentals to Applications*, Springer €

4. O'Hayre, SW Cha, W Colella and FB Prinz, *Fuel Cell Fundamentals*, Wiley, 2005

5. A Faghri and Y Zhang, *Transport Phenomena in Multiphase Systems*, Elsevier 2006

1. Hand Book of Batteries and Fuel cells, 3rd Edition, Edited by David Linden and Thomas. B. Reddy, McGraw Hill Book Company, N.Y. 2002
2. Principles of Fuel Cells, by Xianguo Li, Taylor & Francis, 2006
3. Fuel Cells, Principles and Applications, Viswanathan, B. and Scibioh, Aulice M, Universities Press, 2006

INSTRUMENTATION AND CONTROL IN ENERGY SYSTEM

MODULE-I:
Basic measurement concepts: Measurement errors, Transducer classification, Static and dynamic characteristics of transducers
Instruments for measuring temperature, pressure, velocity and flow, heat flux, liquid level and concentration in energy systems
Characterization of combustors, Flue gas analysers, Exhaust gas analysers, Solar energy measurement requirements and instruments, Net Metering
Meteorological data measurements, Energy auditing instruments, Energy audit kit, humidity measurement,

MODULE-II:
Instruments for monitoring electrical parameters, Analysis of power system measurements. Analog signal conditioning, A/D and D/A converters, Digital data processing and display, Computer data processing and Data acquisition system.

MODULE-III:
Feedback control system, Stability and transient analysis of control systems, Application of PID controllers, General purpose control devices and controller design

Air pollution sampling and measurement of particulates, SOx, NOx, CO, O3, hydrocarbons.

TEXT BOOKS

1. D.V.S Murty, Transducers and Instrumentation, Prentice-Hall of India Pvt. Ltd. 1995

2. C.S. Rangan, G.R. Sarma, and V.S,V. Mani, Instrumentation Devices and Systems, TMH Ltd. New Delhi, 1983

3. B.C. Nakra and K.K. Chaudhry, Instrumentation Measurement and Analysis, TMH Ltd. New Delhi, 1985.

4. N.H. Afgan, Measurement Techniques in Power Engineering, Hemisphere Publishing Corporation, 1985

5. Alexander D, Khazan, Transducers and their Elements, PTR Printice Hall, 1994

1. A. K. Sawhney. Puneet Sawney: A course in Mechanical Measurements and Instrumentation. Dhanpat Rai &Co 2002

2. Bechwith. Marangoni. Lienhard: Mechanical Measurements Fifth edition. Addison-Wesley 2000

REFERENCES

1. J.P. Holman: Experimental methods for engineers Sixth edition, McGraw-Hill .1994.

POWER SYSTEM DYNAMICS

Module-I (15 Hours)

Power System Stability Problems: Basic concepts and definitions, Rotor angle stability, Synchronous machine characteristics, Power versus angle relationship, Stability phenomena, Voltage stability and voltage collapse, Mid-term and long-term stability, Classification of stability.

Small Signal Stability: State space concepts, Basic linearization technique, Participation factors, Eigen properties of state matrix, small signal stability of a single machine infinite bus system,

Module-II (15 Hours)

Studies of parametric effect: effect of loading, effect of K_A, effect of type of load, Hopf bifurcation, Electromechanical oscillating modes, Stability improvement by power system stabilizers. Design of power system stabilizers.

Large Perturbation Stability: Transient stability: Time domain simulations and direct stability analysis techniques (extended equal area criterion)

Energy function methods: Physical and mathematical aspects of the problem, Lyapunov's method, Modeling issues, Energy function formulation, Potential Energy Boundary Surface (PEBS): Energy function of a single machine infinite bus system, equal area criterion and the energy function, Multimachine PEBS.

Module-III (15 Hours)

Sub Synchronous Oscillations: Turbine generator torsional characteristics, Shaft system model, Torsional natural frequencies and mode shapes, Torsional interaction with power system controls: interaction with generator excitation controls, interaction with speed governors, interaction with nearby DC converters, Sub Synchronous Resonance (SSR): characteristics of series capacitor – compensated transmission systems, self – excitation due to induction generator effect, torsional interaction resulting in SSR, Analytical methods, Counter measures to SSR problems.

Voltage stability, System oscillations

References:

1.Prabha. Kundur, *Power system stability and control*, Tata McGraw-Hill, 1994

2.P. Sauer and M. Pai, *Power system dynamics and stability*, Prentice Hall, 1998.

MATERIALS AND DEVICES FOR ENERGY APPLICATIONS

MODULE-I:

Device fabrication technologies: diffusion, oxidation, photolithography, sputtering, physical vapor deposition, chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), hot wire CVD (HWVD), etc.

Introduction to material characterization, Scanning electron microscopy (SEM), Transmission electro-microscopy (TEM),X-ray diffraction (XRD), Raman spectroscopy, Atomic force microscopy (AFM)

Spectral response of solar cells, quantum efficiency analysis, dark conductivity, I-V characterization.

Introduction to physics of semiconductor devices and basics of solar cells

MODULE-II:

High efficiency solar cells: PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III-V, II-VI thin-film solar cells (GaAs, Cu(In,Ga)Se2, CdTe) Nano-, micro- and poly-crystalline Si for solar cells, mono-micro silicon composite structure, crystalline silicon deposition techniques, material and solar cell characterization, advanced solar cell concepts and technologies (Porous Si layer transfer, Metal induced crystallization etc.). Amorphous silicon thin-film (and/or flexible) technologies, multi-junction (tandem) solar cells, stacked solar cells. Conjugated polymers, organic/plastic/flexible solar cells, polymer composites for solar cells, device fabrication and characterization.

MODULE-III:

Materials and devices for energy storage: Batteries, Carbon Nano-Tubes (CNT), fabrication of CNTs, CNTs for hydrogen storage, CNT-polymer composites, ultra-capacitors etc. Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells.

Text/Refrences

1. Solar cells: Operating principles, technology and system applications, by Martin A. Green, Prentice-Hall Inc,Englewood Cliffs, NJ, USA, 1981.
2. Semiconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
3. Solid State electronic devices, Ben G. Streetman, , Prentice-Hall of India Pvt. Ltd., New delhi 1995.
4. Carbon nanotubes and related structures: New material for twenty-first century, P. J. F. Harris, Cambridge University Press, 1999.
5. Thin-film crystalline silicon solar cells: Physics and technology, R. Brendel, Wiley-VCH, Weinheim, 2003.
6. Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial college press, 2001.
7. Organic photovoltaics: Concepts and realization, C. Barbec, V. Dyakonov, J. Parisi, N. S. Saricifttci, Springer-Verlag 2003.
8. Fuel cell and their applications, K. Kordesch, G. Simader, VCH, Weinheim, Germany, 1996.
9. Battery technology handbook, edited by H.A. Kiehne, Marcel Dekker, New York, 1989

ENERGY AND CLIMATE CHANGE

MODULE I:

Energy Scenario and Energy Policy:

Global Energy Scenario: Energy consumption pattern in various sectors, Impact on economy, India`s Energy Scenario, Urban and Rural energy consumption patterns, Impact of Energy on Development, Energy Infra structure in India, India's Solar Energy Mission Programmes , Targets and Present Status

Review of Energy policies of various countries**, I**ndian Electricity Plan, Integrated Energy Policy and Programmes of India, Review of Odisha Solar Policy

MODULE II:

Impact of Energy Projects on Environment:

Overview of global environmental problems, Environmental degradation due to Energy production and use, Pollution due to thermal power stations , Environmental aspects of Wind Energy Farms ,Environmental aspects of Nuclear power generation, Nuclear waste disposal, Impact of Hydro power generation on Ecology and Environment,

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.

Guidelines for Environmental impact assessment (EIA) of Energy Projects

MODULE III:

Climate Change Concerns and Climate Change Policy Issues:
Green House Gas Emissions, Depletion of Ozone layer, Global Warming, Climate Change Concerns, Climate Change in India, Kyoto protocol, Clean Development Mechanism [CDM], Carbon Fund, Concept of Carbon credit

Impact of Climate Change on Glaciers, Rivers and Water Resources, Climate Change Policy Issues in Himalayas, International Status of Climate Change Policies, Indian Action Plan on Climate Change

Text Books /References

1. EH Thorndike, *Energy and Environment: A Primer for Scientists and Engineers*, Addison-Wisley Publishing Company
2. R Wilson and W J Jones, *Energy, Ecology and the Environment*, Academic Press Inc

3. DW Davis, *Energy: Its Physical Impact on the Environment*, John Wiley and Sons

4. *Energy and the Challenge of Sustainability, World Energy assessment*, UNDP, N York, 2000

5. AKN Reddy, RH Williams, TB Johansson, *Energy after Rio, Prospects and challenges*, UNDP, United Nations Publications, New York, 1997

6. N Nakicenovic, A Grubler and A McDonald (Ed), *Global Energy Perspectives,* Cambridge University Press, 1998

7. NH, Ravindranath, K Usha Rao, B Natarajan, P Monga, *Renewable Energy and Environment – A Policy Analysis for India*, Tata McGraw Hill, 2000

8. JM Fowler, *Energy and the Environment*, 2nd Ed, McGraw Hill, New York, 1984

9. T widell and T Weir, *Renewable Energy Resources*, E and F N Spon Ltd, London, 1986

10. ER Berman, *Geothermal Energy*, Noyes Data Corporation, New Jersey

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 & Environment – J.M. Fowler, (McGrawHill)

QUANTITATIVE METHODS FOR ENERGY MANAGEMENT AND PLANNING

MODULE-I:
A review of probability concepts, Forecasting and decision making in view of multi-variant techniques, Linear programming, Graphical solution, Simplex method, Duality and post-optimality analysis, Integer programming

MODULE-II:
Optimal technology mix in micro and macro level energy planning exercises, Sequencing, Queuing theory, Networks, PERT and CPM,

MODULE-III:
Decision theory, Markov analysis, Non linear programming, Decision making with uncertainty, decision

making with multiple objectives, Deterministic and probabilistic dynamic programming, Regression analysis.

Text/References

1. Operations Research, An Introduction, Sixth Edition, 2000, by HA Taha, Prentice-Hall of India Pvt. Ltd.

2. Quantitative Techniques in Management, First Edition, 1997, by ND Vohra, Tata McGraw-Hill Publishing Company Ltd, New Delhi

ENERGY ECONOMICS

MODULE I:

Introduction: Law of demand, Elasticities of demand, Theory of firm: Production function, output maximization, cost minimization and profit maximization principles. Theory of market, National income and other macroeconomic parameters

Basic concepts of Energy Economics Calculation of unit cost of power generation from different sources with examples, Ground rules for investment in Energy sector, Payback period, NPV, IRR and Benefit-cost analysis with example

3. Socio-economic evaluation of Energy Conservation Programmes Net Social Benefit incorporating Free riding concept and Rebound effects, Energy-GDP elasticity

MODULE II:

Overview of Energy Policies National energy policy in the last plan periods, Energy use and Energy supply, Overview of renewable energy policy and the Five Year Plan programmes, Basic concept of Input-Output analysis, Concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy

MODULE III:

Models and Analysis of Energy Demand Analysis of Environmental Pollution through decomposition of different sectors using I-O model, Interdependence of energy, economy and environment, Modeling concepts and application of SIMA model and I-O model for energy policy analysis, Simulation and forecasting of future energy demand consistent with macroeconomic parameters in India. Basic concept of Econometrics and statistical analysis (Multiple Regression), Econometrics techniques used for energy analysis and forecasting with case studies from India

Text Books/References:

1. EA Diulio, *Macroeconomic Theory*, Schaum's Outline Series, 2nd Ed, McGraw-Hill Publishing Company (1990)

2. R Loulou, P R Shukla and A Kanudia, *Energy and Environment Policies for a sustainable Future*, Allied Publishers Ltd, New Delhi, 1997

3. J Parikh, *Energy Models for 2000 and Beyond*, Tata McGraw-Hill Publishing Company Ltd, New Delhi,1997

4. Energy Economics -A.V.Desai (Wieley Eastern)

Energy Economics - Simple Payback Period, Time Value of Money, IRR, NPV, Life Cycle Costing, Cost of Saved Energy, Cost of Energy generated, Examples from energy generation and conservation,

SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL

Module-I (15 Hours)
Introduction and overview of Systems Identification, Adaptive Control and applications. Parameter Estimation: Least Square, Generalized and Recursive Least Square, Estimator properties including error bounds and convergence, MES, ML and MAP estimators, Nonlinear Least Squares. Model Structures and Predictors.
Module-II (15 Hours)
Recursive Identification of Linear dynamic systems: RLS, ELS, IV, RML, Stochastic Approximation, Extended Kalman Filter, generalized prediction error framework and its application to ARMA and state models, convergence analysis, Time varying parameters. Nonlinear System Identification. ; Adaptive schemes. Adaptive control theory. Applications. Situations when constant Gain feedback is insufficient. ; Robust control. ; The adaptive control problem. ; The model following problem. MRAS based on stability theory. Model following when the full state is measurable.
Module-III (15 Hours)
Direct MRAS for general linear systems. Prior knowledge in MRAS. MRAS for partially known systems. Use of robust estimation methods in MRAS. ; The basic idea. Indirect self-tuning regulators. Direct Self-tuning regulators. Linear Quadratic STR. Adaptive Predictive control. Prior knowledge in STR.; Linear-in-the-parameters model. Least squares estimation. Experimental conditions. Recursive estimators. Extended least squares. Robust estimation methods (dead zone, projection).Implementation issues. ; Nonlinear System Identification Techniques
Essential Readings:

1. K.J. Astrom and B. Wittenmark, *Adaptive Control*, Addison, Pearson 2006.

2. L. Ljung, *System Identification Theory for the user*, Prentice-Hall, 2007.

Supplementary Reading:

1. K.S. Narendra and A.M. Annaswamy, *Stable Adaptive Systems*, Prentice-Hall, 1989.

2. Landau and Zito, *Digital Control Systems: Design, Identification and Implementation*, Springer, 2006

ENERGY SCENARIO AND ENERGY POLICY

MODULE I:
Global Energy Scenario
Role of energy in economic development and social transformation: Energy & GDP, GNP and its dynamics, Overall Energy demand and availability, Energy Consumption in various sectors and its changing pattern, Exponential increase in energy consumption and Projected future demands, Depletion of energy sources and impact of exponential rise in energy consumption on economies of countries and on international relations, Energy Security, Energy Consumption and its impact on environment, International Energy Policies of G-8 Countries, G-20 Countries, OPEC Countries, EU Countries. International Energy Treaties (Rio, Montreal, Kyoto), INDO-US Nuclear Deal, Energy Crisis: Transition from carbon rich and nuclear to carbon free technologies, parameters of transition.

MODULE II:
Indian Energy Scenario
Energy resources & Consumption: Commercial and noncommercial forms of energy, Fossil fuels, Renewable sources including Bio-fuels in India, their utilization pattern in the past, present and future projections of consumption pattern, Sector wise energy consumption, Impact of Energy on Economy, Energy and Environmental policies,

MODULE III:
Power Sector Restructuring:
Power sector reforms and restructuring, Energy Conservation Act-2001 & its features, Electricity Act-2003 & its features. Framework of Central Electricity Authority (CEA), Central & State Electricity Regulatory Commissions (CERC & SERCs)
Energy Pricing & Impact of Global Variations.

References:

1. Mohan Munasinghe, Peter Meier. Energy Policy analysis and Modelling: Cambridge University Press1993.

2. Stephen W, Sawyer and John R. Armstrang State Energy Policy: Westview Press.

3. Gerand J. mangone Energy Policies of the world: Elsevier.

4. Rene Codoni, Hi-Chun Park and K.V. Ramni (ed.), Integrated Energy Planning Vols I, II and III, Asian and Development Centre Kaule Lumpur 1985.

1. J. Goldemberg, T.B. Johansson, A.K.N. Reddy and R.H. Williams: Energy for a Sustainable World, Wiley Eastern, 1990.
2. IEEE Bronze Book: Energy Auditing, IEEE Publications, 1996.
3. P. Chandra: Financial Management Theory and Practice, Tata McGraw Hill, 1992.
4. Annual Energy Planning Reports of CMIE, Govt. of India.
5. Amlan Chakrabarti: Energy Engineering and Management, PHI, Eastern Economy Edition, 2012
6. A.K.N. Reddy and A.S. Bhalla: The Technological Transformation of Rural India, UN Publications, 1997.
7. A.K.N. Reddy, R.H. Williams and J.B. Johanson: Energy After Rio-Prospects and Challenges, UN publications, 1997.
8. P. Meier and M. Munasinghe: Energy Policy Analysis & Modeling, Cambridge University Press, 1993.
9. R.S. Pindyck and D. L. Rubinfeld: Economic Models and Energy Forecasts, 4e, McGraw Hill, 1998.

Reference Books:

1. Energy for a sustainable world: Jose Goldenberg, Thomas Johansson, A.K.N.Reddy, Robert Williams (Wiley Eastern).
2. Energy policy for : B.V.Desai (Weiley Eastern),
3. Modeling approach to long term demand and energy implication : J.K.Parikh.
4. Energy Policy and Planning : B.Bukhootsow.
5. TEDDY Year Book Published by Tata Energy Research Institute (TERI),
6. World Energy Resources : Charles E. Brown, Springer2002.
7. 'International Energy Outlook' -EIA annual Publication
8. Heat and Thermodynamics – M.W. Zemansky (McGraw Hill Publication)
9. Principles of Energy Conversion: A.W. Culp (McGraw Hill International edition.)
10.BEE Reference book: no.1/2/3/4.

ENERGY AUDIT AND MANAGEMENT

MODULE I:

General Philosophy and need of Energy Audit and Management, Definition and Objective of Energy Management, General Principles of Energy Management, Energy Audit: Need, Types, Methodology and Approach.Energy Management Approach, Understanding Energy Costs, Bench marking, Energy performance, Matching energy usage to requirements, Maximizing system efficiency, Optimizing the input energy requirements.

MODULE II:

Procedures and Techniques

Data gathering : Level of responsibilities, energy sources, control of energy and uses of energy, Facts, figures and impression about energy /fuel and system operations, Past and Present operating data, Special tests, Questionnaire for data gathering.

Analytical Techniques: Incremental cost concept, mass and energy balancing techniques, inventory of Energy inputs and rejections, Heat transfer calculations, Evaluation of Electric load characteristics, process and energy system simulation.

Evaluation of saving opportunities: Determining the savings in Rs, Noneconomic factors, Conservation opportunities, estimating cost of implementation.

Energy Audit Reporting: The plant energy study report- Importance, contents, effective organization, report writing and presentation.

MODULE III:
Energy Policy Planning and Implementation
Key Elements: Force Field Analysis, Energy Policy-Purpose, Perspective, Contents and Formulation.
Format and Ratification, Organizing: Location of Energy Manager, Top Management Support,Managerial functions, Role and responsibilities of Energy Manager, Accountability, Motivation of employees, Requirements for Energy Action Planning. Information Systems: Designing, Barriers, Strategies, Marketing and Communicating Training and Planning. Instruments for Audit and Monitoring Energy and Energy Savings, Types and Accuracy, Energy Balance sheet and Management Information System (MIS)

Reference Books:
1. Energy Management: W.R.Murphy, G.Mckay (Butterworths).
2. Energy Management Principles: C.B.Smith (Pergamon Press).
3. Efficient Use of Energy : I.G.C.Dryden (Butterworth Scientific)
4. Energy Economics -A.V.Desai (Wieley Eastern)
5. Industrial Energy Conservation : D.A. Reay (Pergammon Press)
6. Energy Management Handbook – W.C. Turner (John Wiley and Sons, A Wiley Interscience Publication)
7. Industrial Energy Management and Utilization – L.C. Witte, P.S. Schmidt, D.R. Brown (Hemisphere Publication, Washington)
8. Industrial Energy Conservation Manuals, MIT Press, Mass, 1982
9. Energy Conservation guide book Patrick/Patrick/Fardo (Prentice Hall)
10. Handbook on Energy efficiency –
11. ASHRAEE Energy Use (4 Volumes)
12. CIBSI Guide –Users Manual (U.K.)
8. CRC Handbook of Energy Efficiency – CRC Press.

Text Books/References
1. LC Witte, PS Schmidt, DR Brown, *Industrial Energy Management and Utilization*, Hemisphere Publication, Washington, 1988

2. *Industrial Energy Conservation Manuals*, MIT Press, Mass, 1982

3. IGC Dryden, Butterworths (Ed), *The Efficient Use of Energy*, London, 1982
4. WC Turner (Ed), *Energy Management Handbook*, Wiley, New York, 1982

5. *Technology Menu for Efficient energy use- Motor drive systems*, Prepared by National Productivity Council and Center for Environmental Studies- Princeton University, 1993

6. Frank, Kreith, Ronald E West *Hand Book of Energy Efficiency*, CRC Press

7. Bureau of Energy Efficiency Study Material for Energy Managers and Auditors Examination Paper I to IV

8. BG Desai, BS Vaidya DP Patel and R Parman, Savings Electricity in Utility Systems of Industrial Plants Efficient use of electricity in industries

9. *Instructions to Energy Auditors*, Vol - I and Vol - II National Technical Information Services US Deptt of Commerce Springfield, VA 22161

10. *Energy Auditing*, The Fairmont Press Inc Published by Atlanta, Georgia

TEXT BOOKS

1. Eastop T.D & Croft D.R, Energy Efficiency for Engineers and Technologists,. Logman Scientific & Technical, ISBN-0-582-03184, 1990.

2. Reay D.A, Industrial Energy Conservation, 1stedition, Pergamon Press, 1977.

REFERNECE

1. Larry C Whitetal, Industrial Energy Management & Utilization.

2. Power System Engineering 2nd Ed. D P Kothari, I J Nagrath, Tata McGraw-Hill Co 2008

1. Bureau of Energy Efficiency (BEE) : www.bee-india.nic.in
2. The Energy and Resource Institute (TERI): http://www.teriin.org/
3. Energy and Buildings – Efficiency, Air Quality and Conservation by Joseph B.Utrick, Nova Science Publishers, Inc, New York, 2009
4. Investment Grade Energy Audit by Shirley J.Hansen and James W.Brown, The Fairmount Press, INC, 2005

ENERGY EFFICIENT BUILDINGS

MODULE I:

Climate and shelter – Historic buildings – Modern architecture – Examples from different climate zones – Thermal comfort – Solar geometry and shading – Heating and cooling loads –Energy estimates and site planning – Integrative Modeling methods and building simulation.

MODULE II:

Passive solar heating – Direct gain – Thermal storage wall – Sunspace – Convective air loop – Passive cooling – Ventilation – Radiation – Evaporation and Dehumidification – Mass effect – Design guidelines.

MODULE III:

Energy conservation in building: Day lighting – Water heating and photovoltaic systems Air conditioning – HVAC equipments – Computer packages for thermal design of buildings and performance prediction – Monitoring and instrumentation of passive buildings – Control systems for energy efficient buildings – Illustrative passive buildings – Integration of emerging technologies – Intelligent building design principles.

Various Energy Efficiency Rating Systems for Buildings- LEEDS, BEE & GRIHA Rating Systems

Energy Conservation Building Code – 2007 (2008 Edition)

TEXT BOOKS

1. Sodha M.,Bansal, N.K., Bansal,P.K., Kumar, A.. and Malik, M.A.S.,"Solar Passive Buildings", Pergamon Press, 1986.

2. Koenigsberger, O.H., Ingersoll, T.G., Mayhew Alan and Szokolay, S. V., "Manual of Tropical Housing and Building part 1: Climatic Design", OLBN 0 00212 0011,Orient Longman Limited, 1973.

REFERENCES

1. Bureau of Indian Standards, I.S. 11907 –1986 Recommendations for calculation of Solar Radiation Buildings, 1986.

2. Givoni,B., "Man, Climate and Architecture", Elsevier, Amsterdam, 1986.

3. *Smith, R. J., Phillips, G.M. and Sweeney, M. "Environmental Science", Longman Scientific and Technical, Essex, 1982.*

References:

1. J.A. Clarke, Energy Simulation in Building Design (2e) Butterworth 2001.
2. J.K. Nayak and J.A. Prajapati Hadbook on Energy Conscious Buildings, Solar Energy Control MNES, 2006.
3. Energy Conservation Building Codes 2006; Bereau of Energy Efficiency.
4. J.R. Williams, Passive Solar Heating, Ann Arbar Science, 1983.
5. R.W. Jones, J.D. Balcomb, C.E. Kosiewiez, G.S. Lazarus, R.D. McFarland and W.O. Wray, Passive Solar Design Handbook, Vol.3, Report of U.S. Department of Energy

(DOE/CS-0127/3), 1982.
6. M.S. Sodha, N.K., Bansal, P.K. Bansal, A.Kumar and M.A.S. Malik. Solar Passive Building, Science and Design, Pergamon Press, 1986.
7. J.L. Threlkeld, Thermal Environmental Engineering, Prentice Hall, 1970.

PROJECT MANAGEMENT

TO BE INSERTED

Energy Laboratory-1

The experiments to be carried out by the M.Tech students in Semester-I will be identified from the following broad areas. However, based on the latest Research, Development and Testing requirements of the Energy Industry, new areas will be identified by the Centre and experiments will be designed and introduced for the students as and when required so that the Students develop expertise as per the current needs of Industry and R&D institutions

1.Solar Radiation Data Monitoring and Analysis:

Sunshine hour duration, Direct Solar Radiation, Global Solar Radiation, Diffuse Solar Radiation, Net radiation [W/m2], Outgoing radiation [W/m2] , Infra red radiation, Diffuseradiation from global and direct radiation at a given zenith angle

2.Solar Photo Voltaics: Current-voltage characteristics of Solar Cell, Efficiency Variation of Solar cell, Performance variation of solar photo cell at different light intensities,; Determination of power produced by a solar photo voltaic system, Performance Evaluation of a Solar Photo voltaic lighting system and its components: inverter, charge controller and battery, Performance evaluation of a solar photovoltaic water pump.

Energy Laboratory-1I

The experiments to be carried out by the M.Tech students in Semester-II will be identified from the following broad areas. However, based on the latest Research, Development and Testing requirements of the Energy Industry, new areas will be identified by the Centre and experiments will be designed and introduced for the students as and when required so that they develop expertise as per the current needs of Industry & R&D institutions

1. Solar Thermal Measurements and Analysis : Experimental study of thermal performance of Solar water heater, Evacuated tube Solar Collector, Solar Still, Thermal Performance of Solar drying System , Thermal testing of a box type Solar Cooker, Concentrator Type and Community Solar Cookers , Designing and Testing of Innovative Solar thermal Systems

2.Energy Performance of Buildings: **Solar Passive buildings :** Testing & Performance evaluation of Solar air heating systems: Solar Trombe wall, Thermo siphoning Heating Panels, Attached green houses; Lighting Measurements & Analysis, Measurement and analysis of heat gain and air-conditioning load in a building, day lighting in a building: sky luminance, daylight from illumination from window and skylight

3. Energy Audit: Thermal energy audit: Measurement of variables such as, temperature, pressure, air flow, etc of selected energy equipments and analysis; Electric Energy Audit: Measurement of basic parameters in electric power systems i.e. current, voltage, resistance, power factor, power and energy

4. Wind Energy Measurements: Wind speed, Wind Direction, Data Measurement and Analysis, Performance evaluation of Wind Energy System, Wind Potential Assessment