

ELECTRICITY MARKET

ENEE 365

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to provide fundamental knowledge of electricity market structures and deregulation, including market models, pricing, congestion management, and trading. It also highlights Nepal's power sector and its transition toward competitive electricity markets.

- 1 Electric Power Industry and Regulation (5 hours)**
 - 1.1 Structure of traditional power systems, vertically integrated structure, Regulated monopoly
 - 1.2 Issues and limitations of regulated systems, motivation of deregulation
 - 1.3 Privatization in power sector
 - 1.4 Timeline of deregulation in different countries and experiences

- 2 Fundamentals of Market Economics (6 hours)**
 - 2.1 Basic economic concepts: Supply and demand, market equilibrium, marginal cost; Trading mechanisms
 - 2.2 Market structures: Monopoly, duopoly, oligopoly, monopsony, duopsony, oligopsony and perfect competition
 - 2.3 Market efficiency, elasticity of demand, producer surplus and consumer surplus

- 3 Restructured Power System (10 hours)**
 - 3.1 Goals, constraints and pre-requisites of power sector restructuring, restructuring models: Monopoly at all levels, purchasing agency, wholesale competition, retail competition
 - 3.2 Unbundling: Key aspects, models of unbundling (Accounting, functional, legal, ownership)
 - 3.3 Restructured market entities: GENCO, TRANSCO, DISCO, ISO, retailers and traders, power exchange, consumers, prosumers
 - 3.4 Pool markets: Pool models and open access model, bidding mechanism; Bilateral markets, hybrid markets

- 4 Electricity Trading Mechanisms (6 hours)**
- 4.1 Supply and demand in electricity markets, electricity as commodity
 - 4.2 Day-ahead markets
 - 4.3 Real-time markets
 - 4.4 Forward and futures markets
 - 4.5 Market clearing: Market clearing price, gate closure
 - 4.6 Ancillary services: Frequency regulation, voltage control, reserves
- 5 Pricing in Deregulated Electricity Market (8 hours)**
- 5.1 Electricity pricing methods: Marginal cost pricing, average cost pricing
 - 5.2 Nodal pricing (Locational Marginal Pricing), zonal pricing
 - 5.3 Transmission pricing methods: Postage stamp method, MW-mile method, Incremental cost method
 - 5.4 Transmission open access
 - 5.5 Congestion, congestion management method: Market splitting, counter trade
- 6 Nepal Power Sector and Restructuring (10 hours)**
- 6.1 Overview of Nepal power sector
 - 6.1.1 Evolution of Nepal power sector, structure and major characteristics
 - 6.1.2 Institutional and regulatory framework
 - 6.2 Role of independent power producers
 - 6.3 Power development agreement (PDA) and power purchase agreement (PPA)
 - 6.4 Current market structure, characteristics and limitations
 - 6.5 Existing legal framework and need for improvement
 - 6.6 Deregulation and restructuring initiatives
 - 6.7 Cross-border market
 - 6.8 Prospects of Nepal power market: Competitive trading, expansion of cross-border trading, increased private sector participation
- Tutorial (30 hours)**
- 1. Unbundling of power sector: A comparative study of unbundling approaches in India and Nepal
 - 2. Study of the role of independent system operator in an established market
 - 3. Analysis of day-ahead and real-time market operation in India
 - 4. Challenges of storing electricity and its impact on market design
 - 5. Importance of frequency regulation and reserves in maintaining grid reliability
 - 6. Analyze LMP implementation in and established markets and discuss possibility of LMP in Nepal
 - 7. Compare postage stamp, MW-mile, and incremental cost methods in a realistic transmission system
 - 8. Study congestion issues in a market and evaluate different congestion management methods
 - 9. Analysis of role of IPPs on Nepal power sector

10. Study of cross-border power trade mechanism of NEA

Practical

(15 hours)

1. Case study and presentation on electricity as a commodity and its difference from other commodities
2. Presentation on different entities and their role in restructured power market
3. Assessment of the Nepali regulatory environment and organizational structures of power utilities
4. Case study on restructuring and operation Nepal's transmission sector
5. Presentation on current status of independent power producers in Nepal
6. Term paper on possibility of cross-border power trade with China

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	5	8
2	6	9
3	10	12
4	6	9
5	8	10
6	10	12
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Bigger, D. R., Hesamzadeh, M. R. (2014). The economics of electricity markets. John Wiley & Sons & IEEE Press.
2. Kirschen, D., Strbac, G. (2004). Fundamentals of power system economics. John Wiley & Sons.
3. Hunt, S. (2002). Making competition work in electricity (Latest Edition). John Wiley & Sons.
4. Stoft, S. (2002). Power system economics: Designing markets for electricity (Latest Edition). IEEE Press.
5. Rothwell, G., Gomez, T. (2000). Electricity economics: Regulation and deregulation (Latest Edition). IEEE Press.
6. National Energy Technology Laboratory (2013). Power market primers series.

ADVANCED POWER ELECTRONICS

ENEE 366

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to equip students with advanced knowledge of power electronic converter topologies, control methods, and soft-switching techniques, and to enhance their ability to analyze and apply power electronic converters in utility and industrial power system applications.

- 1 Modern Power Semiconductor Devices (5 hours)**
 - 1.1 Review of power electronic devices as switches, switching characteristics: static and dynamic characteristic and losses
 - 1.2 Preliminary design considerations for converters, thermal design
 - 1.3 Overview on SiC and GaN based devices
 - 1.4 Power IGBTs versus SiC and GaN devices
 - 1.5 Hard switching and soft switching

- 2 Power Electronic Converters (6 hours)**
 - 2.1 Synchronous rectification implementations
 - 2.2 PWM rectifiers and three-phase topologies (Vienna, PWM boost rectifiers)
 - 2.3 Power factor correction (PFC): Continuous versus discontinuous, bridgeless PFC

- 3 DC-DC Converters and Power Supplies (8 hours)**
 - 3.1 Steady-state analysis and design equations for buck, boost and buck-boost operation
 - 3.2 Isolated Topologies: Analysis of fly-back, forward converter, push pull, half bridge and full bridge converter operation
 - 3.3 Concept of switched mode DC and AC power supply, offline versus online uninterrupted power supply (UPS), role of DC–DC converters in power supplies

- 4 Soft Switching Techniques (5 hours)**
 - 4.1 Switching losses and need for soft switching
 - 4.2 Zero voltage switching (ZVS)
 - 4.3 Zero current switching (ZCS)

- 4.4 Resonant and quasi-resonant converters: LLC resonant converter, ZVS and ZCS quasi-resonant switch cell

5 DC-AC Converters (7 hours)

- 5.1 Three-phase inverters, zero and active vectors, relation between leg voltage, line voltage and common mode voltage
- 5.2 Dead time in inverters
- 5.3 Space vector PWM (SVPWM)
- 5.4 Multilevel inverter topologies: Overview on diode clamped (NPC), flying capacitor and cascaded h-bridge

6 Control of Power Electronic Converters (10 hours)

- 6.1 Modeling and control of DC-DC Converters
- 6.2 Closed-loop current control system of the AC/DC rectifiers: Voltage control operation, generation of firing angle
- 6.3 Modeling and control of three phase DC/AC converter: PLL, outer voltage and inner current control loops, PR controller

7 Applications of Power Electronics (4 hours)

- 7.1 Overview on power converters for solar PV applications
- 7.2 Overview of FACTS controllers and their objectives
- 7.3 Evolution of HVDC Power transmission; Topologies, components used in HVDC power transmission

Tutorial (30 hours)

- 1. Revision on switching loss calculation of power semiconductor devices
- 2. Thermal resistance and junction temperature calculation
- 3. Dead-time loss estimation for synchronous rectification
- 4. Inductor design for CCM, peak current in DCM, boundary mode condition associated with power factor correction
- 5. Flyback converter analysis & design
- 6. Switched mode power supply topology selection & design
- 7. Resonant frequency calculation
- 8. Design of LLC resonant tank parameters
- 9. Gain vs frequency characteristics derivation
- 10. Loss comparison: Hard vs soft switching
- 11. Space vector modulation: Derivation of switching time equations, sector identification numerical
- 12. Transfer function derivation, control-to-output gain analysis for boost dc-dc converter, duty cycle to output voltage control
- 13. PI controller design, stability analysis (Bode plot)
- 14. Inverters: DQ transformation basics
- 15. Output voltage and inner current control design

Practical**(15 hours)**

1. Thermal simulation of buck converter with power loss and efficiency calculation
2. Simulation of open loop control of single and three phase uncontrolled rectifier
3. Simulation of open loop control buck, boost and buck-boost converters
4. Simulation of H bridge inverter and implementation of unipolar and bipolar modulation
5. Study of open loop control of three-phase inverter with 180° conduction mode
6. Generation of space vector PWM
7. Simulation of closed loop control of DC-DC converters

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	5	6
2	6	8
3	8	10
4	5	6
5	7	10
6	10	14
7	4	6
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Mohan, N., Undeland, T. M., Robbins, W. P. (2003). Power electronics: Converters, applications and design (Latest Edition). John Wiley & Sons.
2. Erickson, R. W., Maksimovic, D. (2004). Fundamentals of power electronics. Kluwer Academic Publishers.
3. Wu, B. (2006). High-power converters and AC drives. Wiley-IEEE Press.
4. Blaabjerg, F. (Ed.). (2018). Control of power electronic converters and systems (Vol. 2). Academic Press.
5. Rashid, M. H. (1999). Power electronics: Circuits, devices, and applications (Latest Edition). Prentice-Hall.
6. Krein, P. T. (1998). Elements of power electronics (Latest Edition). Oxford University Press.
7. Bose, B. K. (2020). Power electronics and motor drives: Advances and trends. Academic Press.

WIND ENERGY CONVERSION SYSTEMS

ENEE 367

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to equip students with a solid understanding of aerodynamic principles and statistical methods required for wind energy resource assessment and energy capture. The course also focuses on the electrical control of modern wind energy conversion systems and provides analytical tools to address challenges related to grid integration and compliance with utility standards.

- 1 Wind Power Basics and Aerodynamics (8 hours)**
 - 1.1 Historical development and current global/national status of wind energy.
 - 1.2 Wind Nature: Wind profile, boundary layer, terrain effects and Himalayan topographic impacts
 - 1.3 Wind turbine aerodynamics: Actuator disc model, Betz limit, thrust and torque coefficients
 - 1.4 Tip speed ratio (TSR), blade element theory basics and aerodynamic power control (Pitch versus Stall regulation)

- 2 Wind Resource Assessment & Forecasting (9 hours)**
 - 2.1 Wind measurement techniques: Anemometry, light detection and ranging (LIDAR), and sonic detection and ranging (SODAR)
 - 2.2 Statistical modeling: Rayleigh and Weibull probability density functions
 - 2.3 Wind rose diagrams, turbulence intensity, and wind shear
 - 2.4 Modern assessment tools: Wind atlas analysis and application program (WASP) and wind mapping
 - 2.5 Wind power forecasting: Short-term and long-term forecasting using artificial intelligence, machine learning (AI/ML) data models

- 3 Technology of Wind Energy Conversion Systems (10 hours)**
 - 3.1 Turbine classifications: Horizontal axis wind turbine (HAWT) versus vertical axis wind turbine (VAWT), fixed-speed versus variable-speed concepts
 - 3.2 Squirrel cage induction generators (SCIG) and soft starters
 - 3.3 Doubly fed induction generators (DFIG): Operating principle, stator/rotor-side converters, and active/reactive power control

- 3.4 Permanent magnet synchronous generators (PMSG): Full-scale converters, gearless (Direct-drive) systems
- 3.5 Maximum power point tracking (MPPT) algorithms for wind turbines

4 Interconnection Topology (10 hours)

- 4.1 Wind power in standalone mode: Need of dispatchable generation or storage to manage fluctuating generation and load
- 4.2 Hybrid topology: Wind power with other technologies (Diesel power plant, Hydro power plant and solar and battery for isolated operation)
- 4.3 Grid connection of WECS: Interfacing mechanism, point of common coupling (PCC)
- 4.4 Power quality issues: Reactive power balance, voltage sags, flicker, harmonics, and filtering
- 4.5 Grid codes and compliance: Protection requirements, fault ride through (FRT) / low voltage ride through (LVRT) capabilities, recommended practices
- 4.6 Nepal context: Grid connection guidelines for WECS and transmission line right of way (ROW) challenges

5 Economics, Policy and Environment (8 hours)

- 5.1 Economics of wind power: Capital costs, operation and maintenance and levelized cost of energy (LCOE) calculations
- 5.2 Tariff structures, feed-in tariffs (FiT), and power purchase agreements (PPA) in Nepal
- 5.3 Institutional framework: Role of AEPC and Department of Electricity Development (DoED)
- 5.4 Environmental and social impacts: Noise propagation, shadow flicker, avian (bird) impacts, and life-cycle assessment
- 5.5 Emerging trends: Brief introduction to Offshore wind farms and airborne wind energy

Tutorial (30 hours)

1. Aerodynamic limits and TSR optimization – Calculate the theoretical power available in the wind for a given rotor diameter and air density, then determine the actual power output using the Betz limit
2. Wind resource statistical analysis – Utilize site-specific data to derive Weibull parameters (k and c) and apply the wind shear exponent to extrapolate wind speeds from measurement height (LIDAR/SODAR) to turbine hub height
3. Electromechanical conversion (DFIG versus PMSG)– Compare the efficiency and control topologies of doubly fed induction generators versus permanent magnet synchronous generators, focusing on the role of back-to-back converters in active/reactive power control
4. Hybrid wind power– Design a dispatch strategy for a wind-solar-battery-diesel hybrid system for isolated operation in rural Nepal, focusing on the point of common coupling (PCC) and frequency regulation during fluctuating loads

5. Grid code compliance and LVRT– Analyze turbine responses to voltage sags and frequency deviations to meet NEA standards, specifically calculating the reactive power injection required during low voltage ride through (LVRT) events
6. Techno-economic and environmental appraisal– Perform a levelized cost of energy (LCOE) calculation based on Nepal’s current feed-in tariffs (FiT) while drafting mitigation strategies for noise propagation and shadow flicker

Practical

(15 hours)

1. Wind data analysis: Use software tool to plot Weibull distributions and calculate average power density from raw meteorological data
2. Aerodynamic simulation: Simulate the C_p versus tip speed ratio λ curve for a given turbine blade profile using software
3. WECS electrical modeling: Model a DFIG-based variable-speed wind turbine in software and observe active/reactive power responses to changing wind speeds
4. Wind hybrid topology sizing: Use software tool to size and optimize a wind-solar-battery hybrid system for a remote Nepalese village
5. Grid fault analysis: Simulate a 3-phase fault on a grid-tied PMSG system to observe LVRT capability

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	8	12
2	9	12
3	10	12
4	10	12
5	8	12
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Abad, G., Rodríguez, M. A., Poza, J., Canales, E. (2011). Doubly fed induction machine: Modeling and control for wind energy generation. IEEE Press.
2. Ackermann, T. (2012). Wind power in power systems. John Wiley & Sons.
3. Heier, S. (2014). Grid integration of wind energy conversion systems. John Wiley & Sons.
4. Masters, G. M. (2013). Renewable and efficient electric power systems. Wiley-IEEE Press.

HYDROELECTRIC MACHINES AND SYSTEMS

ENEE 368

Lecture : 3
Tutorial : 2
Practical : 1

Year : III
Part : II

Course Objectives:

The objective of this course is to provide fundamental knowledge of hydroelectric power development and plant planning. It introduces essential concepts needed to understand hydroelectric machines and hydromechanical equipment. Students will learn to classify hydro power plants, evaluate environmental and regulatory requirements and perform techno-economic analysis for hydro plant capacity and unit sizing.

1 Hydropower Development (3 hours)

- 1.1 Classification of hydroelectric plants
- 1.2 Types of hydro projects: Run-of-river, pondage, storage, pumped storage
- 1.3 Peaking and frequency regulation capability
- 1.4 Regulatory and clearance requirements
- 1.5 Environmental protection law in hydropower

2 Techno-Economic Planning of Hydropower Plants (6 hours)

- 2.1 Identification and layout of hydropower
- 2.2 Plant capacity, unit size and spare capacity
- 2.3 Hydrograph, flow-duration curve and energy estimation
- 2.4 Economic evaluation: Capital cost, generation cost
- 2.5 Financial analysis: NPV, IRR, benefit-cost ratio, levelized cost of energy, marginal cost of electricity
- 2.6 Tariff structure and policy considerations
- 2.7 Optimization of plant capacity and pumped storage economics

3 Hydraulic Turbines: Classification, Selection and Application (8 hours)

- 3.1 Head, discharge and site parameters
- 3.2 Types of turbines: Francis, Kaplan, Pelton, impulse and reaction
- 3.3 Specific speed and turbine selection criteria
- 3.4 Selection procedure for large and small hydro
- 3.5 Design concept of hydraulic turbines
- 3.6 Pump as turbine (PAT) concept

- 4 Turbine Regulation, Governing and Hydraulic Transients (4 hours)**
- 4.1 Turbine regulating characteristics
 - 4.2 Hydraulic transients and surge phenomena
 - 4.3 Governing systems: Mechanical and electro-hydraulic
 - 4.4 PID control concepts in turbine governors
- 5 Turbine Performance, Testing and Specifications (5 hours)**
- 5.1 Turbine performance curves and hill charts
 - 5.2 Model testing
 - 5.3 Shop and pre-commissioning field tests
 - 5.4 Performance guarantees and technical specifications
 - 5.5 Performance testing at site/commissioning tests
- 6 Hydro Generators Characteristics (6 hours)**
- 6.1 Types and configurations of hydro generators (Synchronous and Asynchronous)
 - 6.2 Electrical characteristics: Voltage, reactance, efficiency
 - 6.3 Mechanical characteristics: Bearings, cooling, flywheel effect
 - 6.4 Stability considerations
 - 6.5 Generator standards and grid requirements
- 7 Excitation Systems and Stability (5 hours)**
- 7.1 Types of excitation systems
 - 7.2 Steady-state and transient requirements
 - 7.3 Power system stabilizer (PSS)
 - 7.4 Excitation control and limiters
 - 7.5 VAR control system and redundancy of equipment
- 8 Generator Testing, Protection and Recent Trends (5 hours)**
- 8.1 Factory test, field testing and performance testing of generators
 - 8.2 Excitation system testing
 - 8.3 Monitoring and protection systems
 - 8.4 Modern hydro power practices: GIS, digital control systems
 - 8.5 Recent trends in electro-mechanical systems
- 9 Operation and Maintenance of Hydroelectric Machines (3 hours)**
- 9.1 Operation procedure of hydroelectric machine
 - 9.2 Types of maintenance and maintenance schedule
 - 9.3 Maintenance of major mechanical and electrical equipment
 - 9.4 Maintenance guidelines and standards

Tutorial**(30 hours)**

1. Calculation of hydro power, estimation of annual energy generation, capacity factor and load factor calculation, comparison of run-of-river versus storage plant performance
2. Determination of optimum unit size, capital cost estimation and generation cost calculation,
3. Economic, financial analysis numerical problems
4. Tariff calculation and breakeven analysis
5. Turbine selection problems
6. Design problems for small hydropower plants
7. Numerical problems on speed regulation
8. Water hammer and surge tank calculations (Basic level)
9. PID parameter tuning concepts (Theoretical concepts)
10. Interpretation of Hill charts and performance curves, efficiency calculations, Model vs prototype similarity laws
11. Case study on plant failure

Practical**(15 hours)**

1. Resource assessment of hydropower plant
2. Determination of installed capacity
3. Selection of turbine type
4. Basic designing of hydro turbines
5. One-day field study on hydroelectric machines and system

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Mark distribution*
1	3	5
2	6	8
3	8	10
4	4	5
5	5	5
6	6	8
7	5	7
8	5	7
9	3	5
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Nigam, P. S. (2008). Handbook of hydroelectric engineering. Nem Chand and Bros.
2. Vershney, R. S. (2010). Hydropower structures. Nem Chand and Bros.
3. Gulliver, J. S., Arndt, E. A. (1991). Hydropower engineering handbook (Latest Edition). McGraw-Hill.
4. Mosonyi, E. (1965). Water power development (Vols. 1–2) (Latest Edition). Akademiai Kiado (Hungarian Academy of Sciences).
5. Kausal, M. L., Chauhan, G. (2009). Planning and design of small hydroelectric projects (Publication No. 305). Central Board of Irrigation and Power.