Restructured Power Systems - Web course

COURSE OUTLINE

The restructuring of power industry has changed the way of operation of the power systems. Along with the secured and reliable operation of power systems, the economic efficiency has become an equally important consideration.

Unlike the knowledge of conventional operation of power systems, understanding the restructured power systems requires basic knowledge of electrical engineering, power systems, and also the economics.

This course is intended to provide a comprehensive treatment towards understanding of the new dimensions associated with the power systems.

The course will initially bring out the differences between the conventional power system operation and the restructured one. Before tackling taxing issues involving techno-commercial solutions, the course will prepare a background with fundamentals of microeconomics.

The design of power markets and market architectural aspects will be discussed next. With this foundation, the changes in operational aspects with new operational challenges like congestion management and ancillary service management will be elaborated.

Efficient pricing of transmission network usage is a must to bring economic efficiency in the power market operation. These issues will follow next.

There will be separate modules on Genco bidding strategies and market power with mitigation techniques. Towards the end, the discussion on restructuring experiences of different countries all around the world will be provided.

Also, there will be exclusive module on reform practices in developing countries with special focus on Indian power system.

The course will be enriched with solved examples in order to illustrate various concepts. Also, case studies on deeply researched topics will be provided.

The emphasis of the course will be on bringing out new concepts in a simple and lucid manner.

COURSE DETAIL

Sl. No	Topic	No. of Hours
1	Introduction to restructuring of power industry.	01
2	Fundamentals of Economics.	03
3	The Philosophy of Market Models.	05
4	Transmission Congestion Management.	05

NP-TEL

NPTEL

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Electrical Engineering

Pre-requisites:

1. Basic electrical engineering.
2. Basic knowledge of power systems.

Coordinators:

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5	Locational Marginal Prices (LMP) and Financial Transmission Rights (FTR).	**05**
6	Ancillary Service Management.	**04**
7	Pricing of transmission network usage and loss allocation.	**05**
8	Market power and generators bidding.	**04**
9	US and European market evolution.	**04**
10	Reforms in Indian power sector.	**04**
	Total	**40**

Detailed Syllabus for a Course on Restructured Power Systems:

Module 1: Introduction to restructuring of power industry

1. Introduction

2. Reasons for restructuring / deregulation of power industry

3. Understanding the restructuring process

   a. Entities involved
   b. The levels of competition
   c. The market place mechanisms
   d. Sector-wise major changes required

4. Introduction to issues involved in deregulation

5. Reasons and objectives of deregulation of various power systems across the world

   a. The US
   b. The UK
   c. The Nordic Pool
   d. The developing countries

6. Conclusion

Module 2: Fundamentals of Economics

1. Introduction

2. Consumer behaviour

   a. Total utility and marginal utility
   b. Law of diminishing marginal utility
   c. Consumer surplus
   d. Consumer equilibrium
   e. Market demand curve
   f. Demand elasticity

3. Supplier behaviour

   a. Law of diminishing marginal product
   b. Supply functions
   c. Supplier equilibrium
   d. Supplier surplus
   e. Supplier elasticity

4. Market equilibrium

    a. Global welfare
    b. Deadweight loss

5. Short-run and Long-run costs

6. Various costs of production

    a. Total cost (TC)
    b. Average fixed cost (AFC)
    c. Average variable cost (AVC)
    d. Average cost (AC)
    e. Marginal cost (MC)

7. Relationship between short-run and long-run average costs

8. Perfectly competitive market

    a. The firm's supply decision under perfect competition

Module 3: The Philosophy of Market Models

1. Introduction

2. Market models based on contractual arrangements

    a. Monopoly model
    b. Single buyer model
    c. Wholesale competition model
    d. Retail competition model

3. Comparison of various market models

4. Electricity vis-à-vis other commodities

    a. Distinguishing features of electricity as a commodity
    b. Four pillars of market design
        i. Imbalance
        ii. Scheduling and Dispatch
        iii. Congestion Management
        iv. Ancillary Services

5. Market architecture

    a. Timeline for various energy markets
    b. Bilateral / forward contracts
    c. The spot market
        i. Discriminatory or non-discriminatory pricing?
        ii. Simple bids or complex bids
        iii. Day-ahead and real-time market
    d. Models for trading arrangements
        i. Integrated or centralized model
        ii. Decentralized model
        iii. Comparison between trading arrangement models
    e. ISO or TSO model

6. Conclusions

Module 4: Transmission Congestion Management

1. Introduction:

    a. Definition of congestion
    b. Reasons for transfer capability limitation
    c. Importance of congestion management in deregulated environment
        i. Effects of congestion
    d. Desired features of congestion management schemes

2. Classification of congestion management methods

    a. Basis for classification
    b. Non-market methods
    c. Market methods

3. Calculation of ATC

a. Definition of various terms
   i. ATC
   ii. TTC
   iii. TRM
   iv. CBM

b. ATC calculation using PTDF and LODF based on DC model
   i. DC Load flow model
   ii. Power Transfer Distribution Factor (PTDF)
   iii. Calculation of PTDF using DC model
   iv. ATC calculation using PTDF
   v. Line Outage Distribution Factor (LODF)
   vi. ATC calculation using PTDF and LODF

c. Calculation of ATC using AC model

4. Non-market methods

a. Capacity allocation on first come first served basis
b. Capacity allocation based on pro-rata methods
c. Capacity allocation based on type of contract

5. Market based methods

a. Explicit auctioning
b. Coordinated auctioning

6. Nodal pricing

a. OPF based congestion management
   i. DC OPF
   ii. OPF with load elasticity
   iii. AC OPF
   iv. Interpretation of Lagrange multipliers

b. Implications of nodal pricing

7. Inter-zonal Intra-zonal congestion management

8. Price area congestion management

a. Algorithm
b. Illustrative example

9. Capacity alleviation method

a. Re-dispatching
b. Counter-trade
c. Curtailment

10. Comparison and conclusion

Module 5: Locational Marginal Prices (LMP) and Financial Transmission Rights (FTR)

1. Mathematical preliminaries

a. Convexity
b. Duality
c. Perturbation analysis
d. Sensitivity analysis
e. KKT necessary conditions for optimality

2. Fundamentals of locational marginal pricing

a. Concept
b. Illustrative examples
c. Generic formulation

3. Lossless DCOPF model for LMP calculation

a. Formulation
b. LMP derivation
c. Reference node independency

4. Loss compensated DCOPF model for LMP calculation

a. Model 1
    i. Formulation
    ii. LMP derivation
    iii. Reference node independency

b. Accuracy comparison of both the models

5. ACOPF model for LMP calculation

6. Introduction to Financial Transmission Rights

7. Risk Hedging Functionality Of financial Transmission Rights

8. Simultaneous feasibility test and revenue adequacy

9. FTR issuance process

a. FTR auction
    i. Auction formulation
    ii. Auction pricing
    iii. Time differentiation of FTR products

b. FTR allocation
    i. Direct allocation
    ii. Auction revenue rights

10. Treatment of revenue shortfall

11. Secondary trading of FTRs

12. Flow Gate rights

a. FTR Vs FGR

13. FTR and market power

14. FTR and merchant transmission investment

15. Summary

Module 6: Ancillary Service Management

1. Introduction to ancillary services

2. Types of ancillary services

3. Classification of ancillary services

4. Load-generation balancing related services

a. Frequency regulation
b. Load following
c. Spinning reserve services

5. Voltage control and reactive power support services

a. Different sources of reactive power
    i. Generators
    ii. Synchronous condensers
    iii. Capacitors and inductors
    iv. SVCs
    v. STATCOMs

b. Comparison between different sources of reactive power

c. Issues in reactive power management

6. Black start capability service

7. How to obtain ancillary services?

a. Mandatory provision of ancillary services
b. Markets for ancillary services

8. Co-optimization of energy and reserve services

9. International comparison

a. England and Wales
b. Nordic countries
c. CAISO
d. NYISO
    i. Loss of opportunity cost
e. Australia

10. Summary

Module 7: Pricing of transmission network usage and loss allocation

1. Introduction to transmission pricing

a. What is power wheeling?
b. Issues involved

2. Principles of transmission pricing

3. Classification of transmission pricing methods

4. Rolled-in transmission pricing methods

a. Postage stamp method
b. Incremental postage stamp method
c. Contract path method
d. MW-Mile method
    i. Distance based
    ii. Power flow based
e. Power flow tracing
    i. Proportionate sharing principle
    ii. Graph theoretic approach
    iii. Simultaneous equations approach
f. Equivalent bilateral exchange method
g. Z bus cost allocation method

5. Marginal transmission pricing paradigm

a. Short-run marginal cost pricing
b. Complementary charge
c. Long-run marginal cost pricing

6. Composite pricing paradigm

a. Two part tariff

7. Merits and de-merits of different paradigms

8. Debated issues in transmission pricing

9. Introduction to loss allocation

a. Why loss allocation is contentious?

10. Classification of loss allocation methods

a. Pro-rata methods
b. Incremental methods
c. Power flow tracing based allocation

11. Comparison between various methods

12. Summary

Module 8: Market power and generators bidding

1. Attributes of a perfectly competitive market

2. The firm's supply decision under perfect competition

3. Imperfect competition

    a. Monopoly
    b. Oligopoly
        i. Cournot model
        ii. Bertrand model
    c. Electricity markets under imperfect competition

4. Market power

    a. Sources of market power
    b. Effect of market power
    c. Identifying market power
        i. HHI Index
        ii. Entropy coefficient
        iii. Lerner index
    d. Market power mitigation
        i. Effects of contract for differences
        ii. Role of demand side bidding

5. Financial markets associated with electricity markets

    a. Forwards
    b. Futures
    c. Options
    d. Swaps

6. Introduction to optimal bidding by a generator company

    a. Bidding in real markets

7. Optimal bidding methods

    a. Game theory
    b. Markov decision process
    c. Genetic algorithm
    d. Equilibrium analysis
    e. Conjectural variation
    f. Bayesian analysis

8. Summary

Module 9: US and European market evolution

1. Introduction

2. US markets

    a. Historical developments
    b. Market design philosophy
    c. Uniform market pricing model
    d. Zonal market pricing model

3. The ERCOT market

    a. Market structure
    b. Bilateral market
    c. TCR market
    d. Ancillary service market
    e. Real time energy market
    f. ERCOT market design challenges
        i. Congestion management
        ii. Revenue adequacy
        iii. Inappropriate price signals

4. Towards Standard Market Design (SMD)

    a. Need for SMD
    b. Defining characteristics of SMD
    c. Locational marginal prices (LMP)
    d. Multi-settlement system
        i. Day-ahead energy market
        ii. Real-time market
        iii. Virtual bidding

iv. Benefits of multi-settlement system
e. Transmission rights market
f. Ancillary service market
g. Bilateral contracts

5. PJM market

a. Scheduling timeline
b. Day-ahead energy market
c. Real-time market
i. Overview of real time LMP calculation
ii. Description of LMP model
iii. LMP calculation
iv. Settlements
d. PJM market milestones

6. The Nordic power market

a. Earlier scenario
b. Transition towards unified Nordic Power Market
c. Various Markets in Nordic Pool
d. The Market activity time-line
e. Interaction between Market and System Operators
f. The Nordic Spot Market
g. Determination of System Price
h. The Price Area Congestion Management Technique
i. The Balancing Market
j. System Operational Issues
i. The Real Time Market
ii. The Imbalance Settlements
iii. The Congestion Management in Real Time
k. Point-of-Connection Transmission Tariff
l. Financial Markets
i. Contract-for-Difference (CfD)

7. Comparison of power markets

Module 10: Reforms in Indian power sector

1. Introduction

2. Framework of Indian power sector

a. Historical Developments
b. The Institutional Framework
c. Operational Demarcation of the Power System
d. National and Transnational Grids

3. Reform initiatives during 1990-1995

a. The Independent Power Plants
b. Orissa Reform Model
c. Accelerated Power Development and Reforms Program (APDRP)
d. Public-Private Partnership
e. Other Developments

4. The availability based tariff (ABT)

a. Why was ABT necessary?
b. The Mechanism
c. Working of the mechanism
d. Effects of ABT
e. Intra-state ABT

5. The Electricity Act 2003

a. Provisions in the generation sector
b. Provisions in the transmission sector
c. Provisions in the distribution sector
d. Power trading
e. Other important changes

6. Open Access issues

a. Operational Practices
b. Transmission pricing
c. Loss allocation
d. Reservation of Transmission Capacity and Congestion Management
e. Reactive power support
f. Explanation of practices using illustrative example

7. Power exchange

a. The auction
b. The congestion management
c. Administration of physical delivery
d. Timeline of activities

8. Reforms in near future

References:

Text:

1. *Fundamentals of Power System economics* Daniel Kirschen and Goran Strbac, John Wiley & Sons Ltd, 2004.

Reference:

1. *Making competition work in electricity* Sally Hunt, John Wiley & Sons, Inc., 2002.

2. *Operation of restructured power systems* Kankar Bhattacharya, Jaap E. Daadler, Math H.J Bollen, Kluwer Academic Pub., 2001.