Reliability and Risk

Marija Ilic
Carnegie Mellon University
milic@ece.cmu.edu
November 6, 02
Boulder, CO
Talk outline:

• I. Reliability-related risk management under regulation: The way it was

• II. Reliability and risk under industry restructuring
I. The basic problem of reliable electricity service: The way it was

• Long-term/planning approach: For the anticipated load growth, build generation mix to meet demand of native customers; reserves for managing outages shared with other utilities (CAs).

• Regional planning to ensure sufficient reserves
I. Operating Practices: The way it was

• Given anticipated demand patterns, generation is scheduled in an open-loop way to meet the forecast. This is done day ahead, and updated, hour ahead, 15 minutes ahead, etc.

• Small unanticipated changes in demand supplied in an automated way (AGC)

• Large changes (outages) managed by human experts and rules established from planning studies
Structure of a Power System

- Traditional Utility: Generation, Transmission, Load and System Operator
Electric System Time Line

The Physical System

Build
Operate

Decades/Years
Years/Months
Day
Hour
Minutes
Seconds
Cycles
1
5-5
5-1
<10
100

Maintain

Schedule

Operate

Unit Commitment

Economic Dispatch

Spinning Reserve Control

Frequency Control / Dynamics

Voltag Control

Energy
Ancillary

1 Shimon Awerbuch, Michael Crew, Paul Kleindorfer
Design, Operation and Control of Power System

• Objective: Produce, Deliver and Consume Electricity **Reliably** under **Normal** Operating Conditions with Possible Occurrence of **Plausible Contingency**

• Continual Balance of Supply and Demand
  – Lack of Practical Means of Storage
  – Long Distance Transmission
  – **Uncertainties** in **Load and Equipment**
Continual Balance between Supply and Demand under Normal Condition with Load Uncertainty

Energy Imbalance

Uncertainty
- Base
- Ramp
- Fluctuations

Demand (MW)

Time
7 a.m. - 8 a.m.
Hierarchical Control Structure in Order to Cope with Uncertainties

TERTIARY LEVEL ($N^T$) : More general decisions about settings

- Unit Commitment
- Feasibility Studies
- Transient Stability Studies
- Security Studies
- Optimization

Demand forecast for real/reactive power

SECONDARY LEVEL ($N^S$) : Decisions for equipment settings

AREA 1

- Supplementary Control Signal For the Area (AGC, AVC)

All real power tie-line flows of area 1

All real set points for all controllers in the area

Voltage set points for all controllers in the area

PRIMARY LEVEL ($N^P$) : Equipment

PRIMARY CONTROLLER 1 IN AREA 1

- Real Power Controllers
  - Generators
  - Phase Shifters

- Voltage Controllers
  - Generators
  - Shunt Capacitors/Inductors
  - On-Load Transformers

Real power output/frequency

Reactive power output/voltage
Computer Based Decision and Control by Regulated Utility

• Operation and Planning Based on Reliability Criteria
  • Generating, transmitting and distributing electric energy to captive consumers

• Operation and Planning as a Stochastic Optimization Problem
  • Reflecting the Cost of Supply and the Value of Investment in Generation and Transmission
Key Features under Regulation

• Operations and planning separate tasks
• Hierarchical operations and control based on temporal and spatial separation
• Generation and transmission planning done sequentially and statically; the worst case approach
• Average price reflecting total capital and O&M (not an actively used signal)
• Customer not an active decision maker
• No direct incentive for right technologies
II. Ongoing Changes

- Technological (cost-effective small and smart power supply, direct line flow control devices (FACTS), Internet, customer automation)

- Organizational (competitive power generation, electricity markets, customer choice, potential for PBR-based transmission businesses; open access)
Regional Electric Markets

Source: DOE Electricity 2002 Conceptual Design
Regional Electric Markets

Suppliers

Market on Top of Physical System

Generation

Wholesale Customers

Wholesale Markets

High Voltage Line

Distribution System

Retail Markets

Ancillary Services Markets

System Operator

Transmission Services Market(s)

End-Use Consumption

Source: DOE Electricity 2002 Conceptual Design
Interaction between Market and Physical System

Transmission Owners

Grid Operator

Generator

Bilateral Contracts

Loads

Market for Energy

Bid
Functional Unbundling of Regulated Utilities

- **Power Supplier**
- **Power User**
- **Power Seller**
- **Power Purchaser**

- **Transmission System**
- **Operating Authority**
- **Market Tools**
- **OASIS**

*OASIS: Open Access Same-time Information System*
Electric System Time Line: Market and Physical\(^1\)

1 Shimon Awerbuch, Michael Crew, Paul Kleindorfer
Key Features Under Competition

• Power supply, delivery and consumption separate functional and/or corporate entities (own objectives)
• Decentralized decision making under uncertainties
• Active use of price signals (temporal and spatial)
• Potential for valuing right technologies
• Issues with reliability and long term system evolution
Decentralized Decisions

• Qualitatively Different Mode
  – Multi-stage, Decentralized Decisions
• Smart Components and Smart Control
  – Supplier
  – User
  – Transmission
• Role of Information Technology (IT) and Research
Qualitatively Different Mode

• Suboptimal operation in static sense
• Potentially optimal long-term, given uncertainties (result of distributed stochastic optimization); multi-stage decision making
• System operating closer to the acceptable operating limits for which it was designed
• Conjecture: IT tools will play critical role in facilitating iterative interplay among different entities
Smart Power Suppliers

- Profit maximization and risk management
- Decentralized stochastic optimization
- Value of a given technology and its dependence on industry structure
- Relating physical characteristics and financial decisions (unit commitment and financial commitments)
- Sizing, technology, purpose (backup, ancillary, energy)
Smart Transmission Networks

• Owners not the same as real-time operators
• Two cases 1) Transmission remains a fixed ROR-based business; 2) Transmission is a PBR-based business
• Conjecture: The IT tools (software) play critical role in making this a viable business
Smart End Users

• Energy price responsive demand
• Various technologies available
• Complex to implement in current industry structure (separation of whole-sale and retail markets, no incentives for peak-shaving, no direct environmental incentives)
• Micro-grids?? Economics, implementation?
Dynamic investments

• Need for relating operations and long-term commitments (and investments)
• How should a transmission provider decide between serving a short-term request or paying penalty for not serving a long-term pre-committed market requests?
IT-related Questions

• Type of data required to be made public for reliable and adequate industry (by the EIA, FERC, NERC)
• Design of internet-based information structures
• (Network) data aggregation for transparency; from hierarchical to open access
• Embedded software to implement smart suppliers, users and delivery services
Flexible OASIS

• Once the models/software exist for making the transmission providers smart, one employs internet to provide the relevant information on-line

• System users observe the status of the system, and internalize into their distributed objectives

• This is how coordination takes place
Open Research Problems

• Develop tools for going from sequential operations/planning to interactive iterative decision making over variety of time horizons

• Rate at which information is provided, type of information critical

• Many counterexamples possible to show market failure related to lack of adequate information
Distributed Power Systems

• The power grid evolution from strong EHV large power plants to a much weaker EHV grid and very many distributed power suppliers closer to the users
• Smart wires, users and suppliers interacting through IT
• Distributed reliability provision
• Question: How does one get from here to there?
• Possible answer: Protocols instead of standards??
Summary:

• The industry is headed toward decentralized management of various risks (physical and financial)
• Much work remains to be done to develop sustainable risk management (building extra capacity at the value, for example)
• Commodities hard to store economically (such as electricity) pose a particularly hard challenge
• One possible solution: Reliability as a private property, reliability insurance.