LIVING IN INTERESTING TIMES

- The business has never been more exciting
- Restructuring presents a range of unprecedented opportunities and set of daunting challenges
- Problems require interdisciplinary approaches
OUTLINE

- The growing importance of electricity
- Evolving role of transmission services
- The 2003 U.S. Blackout
- Some key challenges and opportunities
- Training needs
CRITICAL IMPORTANCE OF ELECTRICITY

- Energy is the lifeblood of modern society
- The importance of electricity is on the rise
- Efficient and environmentally sensitive electricity services are key requirements for each nation’s global competitiveness
electricity will continue to substitute for less efficient and less productive energy forms (index is 100 for the year 1900)

energy / GNP ratio
electricity as a percentage of total energy consumed

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U.S. ELECTRIC ENERGY SALES AND CO$_2$ EMISSIONS

Source: Energy Information Administration, U.S. Department of Energy
IMPACTS OF ELECTRICITY

- The National Academy of Engineering, the U.S.’s most prestigious collection of outstanding engineers, named electrification -- the development of the vast networks of electricity that power the world -- the most important of the twenty engineering achievements that have had the greatest impact on the quality of life in the 20th century
IMPACTS OF ELECTRICITY

- Electricity ranked ahead of the automobile, airplane, safe and abundant water, electronics, computers and space exploration.

- The widespread electrification implemented in the 20th century gave us power for our cities, factories, farms and homes, forever changing the lives of people.
THE UNIQUE CHARACTERISTICS

- Lack of large-scale storage
- Extreme *perishability* of electricity: *just-in-time* manufacturing process
- *Obligation to serve* requirement: no analogue to the busy signal in communications systems
THE VERTICALLY INTEGRATED UTILITY INDUSTRY STRUCTURE

- customers
- customer service
- distribution
- transmission
- generation

IPP

self-generation

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THE VERTICALLY INTEGRATED UTILITY INDUSTRY STRUCTURE

- IPP
- generation
- transmission
- distribution
- customer service
- customers
- self-generation
KEY DEVELOPMENTS IN RESTRUCTURING

- **PURPA**
- **EPACT**
- FERC Orders No. 888/889
- FERC Order 2000
- SMD NOPR

- 1978
- 1992
- 1996
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004

- **California crisis**
- **ENRON bankruptcy**
- **Megablackout**
THE TRANSMISSION “COP”

transmission services
markets
system reliability

interrelated
market operation
system security
system operations

ISO

transmission expansion
generation investment
THE ISO AND TRANSMISSION CUSTOMERS

LSE

power marketers/brokers

ISO

generation companies
THE EVOLUTION TO RTOs

- ISO
- RTO
- ideal RTO
- actual RTO

specified in FERC Orders No. 888/889

FERC Order 2000

FERC SMD NOPR

WMP Whitepaper

1996 | 1999 | 2002 | 2003
Transmission systems developed primarily to meet the demands of each utility’s native load customers.

Major stages of transmission development:
- Connection of remote generating resources to load centers
- Interconnection of utilities for reliability
- Construction of ties to support inter-utility transactions
Transmission owning utilities provided *bundled* transmission and generation services through:
- full or partial requirements services
- integration agreements

Limited amount of *transmission only* services was provided to
- embedded transmission dependent utilities
- embedded qualifying facilities or QFs

In the competitive wholesale electricity markets, unbundled transmission service is taking on a *common carrier* role.
"COMMON CARRIER" TRANSMISSION SERVICE

transmission system

- self generation
- EWG
- QF
- broker / marketer
- IPP
- utility generation
- other utility
The blackout, whose costs estimates range from 6.5 to 12.9 billion US $, exposed the weaknesses of the North American transmission infrastructure.
Largest single blackout ever in North America

Area covering 8 U.S. states and one Canadian province impacted: total population 50 million

61,800 MW load lost

34,000 miles of transmission and 290 units affected during the cascade of events

Five major independent system operators’ territories involved
SPECIFIC FACTORS CAUSING THE BLACKOUT

- “Inadequate situational awareness”
- Failure of timely vegetation management
- Heavy congestion
- Cascading outages of lines
- Cascading outages of generators
- Unexpected loop flows
"INADEQUATE SITUATIONAL AWARENESS"

- No single entity had a complete picture of what was going on.
- Lack of recognition or understanding of the deteriorating conditions in the network.
- Lack of procedures to ensure that operators were continually aware of the functional state of their critical monitoring tools.
- Inability to be aware of the failure of the IT system.
CONTROL AREAS

MAP OF CONTROL AREAS

- MAPP
- WECC
- NPCC
- MAAC
- ECAR
- SERC
- FRCC
- ERCOT
- SPP

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ORGANIZATIONAL COMPLEXITIES IN THE MIDWEST

- 4 reliability councils, 5 ISO’s and 6 reliability coordinators were involved in the blackout.
- There are 18 inter-control-area interfaces across the PJM/MISO reliability coordinator boundary.
- MISO’s and PJM’s lack of information resulted in no effective security control actions to respond to the fast evolving situation.
MAJOR PROBLEM: LACK OF REACTIVE POWER

- Reactive power is critically important in the maintenance of the desired voltage profile throughout the interconnected network.
- As transmission lines get loaded more heavily, they consume increasing amounts of reactive power resulting in insufficient reactive power levels at the load buses.
- Inadequate supply of reactive power results in declining voltages and may, in the limit, lead to voltage collapse.
MAJOR PROBLEM: LACK OF REACTIVE POWER

base case

3000 MW transfer – 500 MW per line

example by Pete Sauer
MAJOR PROBLEM: LACK OF REACTIVE POWER

one line out

3000 MW transfer – 600 MW per line
MAJOR PROBLEM: LACK OF REACTIVE POWER

two lines out
3000 MW transfer – 750 MW per line

limit reached
MAJOR PROBLEM: LACK OF REACTIVE POWER

three lines out
3000 MW transfer – 1000 MW per line

voltage rating of 99% - still OK
limit reached
MAJOR PROBLEM: LACK OF REACTIVE POWER

West

6000 MW
1000 MVR
9000 MW
1757 MVR

| 1.00 PU |

East

6000 MW
1000 MVR
3000 MW
1200 MVR

| 0.97 PU |

voltage rating of 97% - starting to fall

limit reached

four lines out

3000 MW transfer – 1500 MW per line
MAJOR PROBLEM: LACK OF REACTIVE POWER

West

East

voltage collapse at the East load

five lines out

voltage rating of 77%

limit reached
THE BLACKOUT CHALLENGES

- Modernization of transmission grid
- Change of protection philosophy including proper coordination of relay devices in an interconnected system
- Training of control center operators
KEY RECOMMENDATIONS FROM THE BLACKOUT INVESTIGATION

- Strengthen the institutional framework for reliability management in North America
- Integrate a “reliability impact” consideration into the regulatory decision-making process
- Strengthen reactive power and voltage control practices in all NERC regions
- Assess IT risk and vulnerability at scheduled intervals