Electricity Economics

- ~$1 trillion in total asset value
- 540,000 miles of transmission lines
- $247 billion annual revenues
- 131 million customers
- 3,200 utilities

Without electric power, the $10 trillion U.S. economy comes to a halt
Challenges to the Industry

- Reliability & Power Quality
- Generation Growth Exceeds Grid Expansion
- Regulatory Uncertainty
DMSP F15
14 August 2003
0129Z
~20 hrs before Blackout
DMSP F15
15 August 2003
0114Z
~7 hrs after Blackout

After
U.S. Transmission 10-Yr Plans*  

Source: NERC Reliability Assessment Reports  
*230-kV and Above
De-coupling of Investment

Source: EEI Statistical Yearbook and Energy Information Administration
Recent Major Blackouts

- West Coast ’96
- Northern California ‘01
- San Francisco ‘00
- Detroit ‘00
- Chicago ‘99
- New York ‘99
- Delaware ‘99
- Atlanta ‘99
- New Orleans ‘99
- Northeast ‘03
Cost of U.S. Power Failures

Cost in $ Billions/Year

- Aug. 1996: $25
- May, 2000: $50
- July, 2001: $119

Source: Electric Power Research Institute
TVA transmission transactions have grown over 1,000% since 1996

Many occurred during times of tight system resources
New Generation & Pipelines

Source: RDI, Power Map, March, 2003

Status
- Operating
- Proposed
- Under Constr

Cap (MW)
- 1,200 to 2,720
- 680 to 1,200
- 390 to 680
- 0 to 390
- -1,020 to 0

Plant Type
- CC/CT Cogen
- Comb Cycle
- Combust Turb

Crosses Only:
- Four 345-kV lines
- Two 500-kV lines

Gas Wellheads & Pipelines
Restructuring

Still a Matter of Perspective
Would We Use These Tracks . . .
... to Run These Trains?
To Meet the Challenges . . .

. . . the Industry Must:

- Expand transmission infrastructure
- Develop consistent, mandatory reliability rules
- Improve data & information exchange
Enter Virtual RTOs
What’s a vRTO?

A tightly coordinated group of transmission providers that:

• Offers nondiscriminatory service over a broad geographic area

• Facilitates a seamless power market

• Efficiently delivers reliable power while reducing consumer costs
vRTO Origins

“The coordinated congestion relief protocol outlined here provides a method with rules for exchange of information among system operators in an interconnected grid . . . The method requires nothing revolutionary.”

--William W. Hogan, et al, October 7, 1999
How a vRTO Would Work

• Coordinates congestion management & market operations of multiple RTOs, ISOs & other providers

• Coordination includes:
  - Information transfer
  - Grid modeling & operational data
  - Congestion management procedures
  - Interchange flows & market interfaces
  - Transmission planning & resource adequacy
  - Financial settlements
Laying the Foundation

• Common data & IT architecture are foundations for coordinated operations

• Glue for connecting RTOs, ISOs & other Transmission Providers:
  - Common power system model
  - Standard set of commercially significant flowgates
  - Standard definition of Cohesive Electrical Zones (CEZ)
  - Sharing of real-time data
    ◦ Network status, flow limits
    ◦ Dispatch decision (Portfolio Tags)
    ◦ Actual measurement data (e.g. flowgate flows)
vRTO - Common Data

• Same base case of entire interconnection updated with topology changes
• Same required set of flowgate constraints consistent with topology changes
• Same definition of impacted elements in adjoining systems (CEZs)
• Exchange of portfolios through E-tags
• Real-time line flows and limits for more accuracy in modeling flowgate constraints
vRTO Coordinated Operations

- Real-time Data Link
- Reliability Backstop (IDC)
- E-tags with Portfolios

Provider A
LMP Sys

Provider B
SCED* Sys

*Security-Constrained Economic Dispatch

EPRI Paper, 1/9/03; Product ID # 1007680. Call 1/800-313-3774 to order.
Provider A receives bid information from other RTOs/Providers

Other Providers receive bid information from the other RTOs/Providers

Flow gates

Economy Energy Bid Curve
Inter-Regional Convergence

- Each RTO/Provider supplies bid from energy sellers to other RTO/Provider interfaces, using LMP or SCED system lambda curve.

- Each RTO/Provider solves its LMP/SCED with all bids including those from neighboring areas.

- With iteration, an equilibrium solution is achieved.

- Resulting solution is close to global LMP solution in terms of total cost.
Coordinated Market = Lower Cost

- Each region has its own Dispatch/LMP system, iterating with others on dispatch
- Market prices will converge to “optimal” global market equilibrium in the interconnection
- Sellers receive market price
- Regions share congestion savings with one another under agreed formula
- Each Region’s customers will always have lower costs than they would in an isolated region
Converging on Optimal Solution

LMP A

Minimize \( C(x_A) + \sum C(e_B) \)
subject to:
\( h(x_A, e_B) = 0 \)
\( g(x_A, e_B | x_B) \leq T_{A_{\text{max}}} \)
\( g(x_A, e_B | x_B) \leq T_{B_{\text{max}}} \)

\( x_A \) Sys A’s bids
\( e_B \) bids from RTO B
\( T_A \) Sys A’s transmission lines

LMP A+B

Minimize \( C(x_A, x_B) \)
subject to:
\( h(x_A, x_B) = 0 \)
\( g(x_A, x_B) \leq T_{A_{\text{max}}} \)
\( g(x_A, x_B) \leq T_{B_{\text{max}}} \)

LMP B

Minimize \( C(x_B) + \sum C(e_A) \)
subject to:
\( h(x_B, e_A) = 0 \)
\( g(x_B, e_A | x_A) \leq T_{A_{\text{max}}} \)
\( g(x_B, e_A | x_A) \leq T_{B_{\text{max}}} \)

\( x_B \) Sys B’s bids
\( e_A \) bids from RTO A
\( T_B \) Sys B’s transmission lines

By introducing a set of LMP-derived CEZ bid price curves, an RTO/Provider can sell economy energy into other RTOs/Providers, thus enabling convergence towards the optimal global market solution.
Advantages of vRTO

• Lays the foundation (models, protocols, data)
• Minimizes risk of unintended consequences – regardless of future market path
• Supports expansion of transmission and information infrastructure
• Coordinates actions, regardless of market designs or policies, to achieve public benefits.
• Ensures a smooth transition to broad, seamless transmission service
vRTO: Linking Neighbors

*Planned
Summary vRTO Benefits

• Lower cost
• Technologically achievable
• Resolves regional differences
• Flexible—able to accommodate future rule changes