Transmission Complexities and Probabilistic Modeling

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With a Competitive Power Market, Operators & Planners Face More Uncertainties

- Generation location, capacity and inservice dates
- Weather uncertainties over wider areas
- Market operation not predictable as central dispatch
- Inter-regional wholesale power transaction patterns can change from season to season and hour to hour
Transmission Limits

• High dimensional problem
  – Large interconnection models require ~40,000 buses & ~50,000 lines, and ~3,000 generators with ~120 control areas
  – Each line has a capacity limit
  – The system must withstand of loss of any one line or generator (~53,000 contingencies)
  – 53,000 x 50,000 = 2,650,000,000 possible constraints

• Reliable operation requires an operating point that satisfy these 2.65 billion constraints
Past Practice for Operators

• With ample reserve capacities in the transmission grid before deregulation, only a limited number of critical contingencies and constraints had to be handled
• Transmission planners studied typical peak load and off peak conditions and derived sets of operating boundaries, called “Nomograms” to guide operators
• Control centers run contingency analysis of the current operating point to check the current limits
Traditional Nomograms - An Example

- Usually for a specific load flow case
- May show a set of curves that vary with some conditions

![Graph showing simultaneous transfer limits](image)
Past Practice Not Adequate

- After deregulation, transmission investment not kept up with load and generation
- Many more bottlenecks showing up
- With more long-distance power transfers, no single existing control center can perform contingency analysis for entire interconnection
- NERC solution since 1998:
  - Electronic Tags (E-tags) to identify all transactions
  - Interchange Distribution Calculator (IDC) to perform Transmission Loading Relief (TLR)
Eastern Interconnection in Four Areas
Keeping Track of the “State” of the Power Market

- Each E-Tag specifies a MW transfer from a source (blue dot) to a sink (red dot) (each is a control area) for the current hour
- TagNet aggregates all E-Tags into Net Exports
- The values of the regional net exports place the position of the Light-Bulb

E-Tags are schedules, not physical flows

Net Exports

<table>
<thead>
<tr>
<th>G1</th>
<th>G2</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 3000</td>
<td>- 3000</td>
</tr>
<tr>
<td>+ 4000</td>
<td>- 500</td>
</tr>
<tr>
<td>+ 2000</td>
<td></td>
</tr>
<tr>
<td>= 9000</td>
<td>= -3500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G3</th>
<th>G4</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 1000</td>
<td>+ 500</td>
</tr>
<tr>
<td>- 2000</td>
<td>- 4000</td>
</tr>
<tr>
<td>= -1000</td>
<td>- 1000</td>
</tr>
<tr>
<td></td>
<td>= -4500</td>
</tr>
</tbody>
</table>

Again, G1+G2+G3+G4 = 0
TagNet Display for Eastern Interconnection (Updated Hourly)

Bubble Diagram for Tagdump Dump Date: 6/4/2001 Start Hour ends at 14:00 Central showing Hr 1 (14:00)
Flows <= 10 MW are not shown

Blue bubble = exporting
Red bubble = importing

The four Net Export values (12260, -2806, -3234, -6220) define the position of the Light-bulb for the Eastern Interconnection
TagNet Display Pilot of Community Activity Room for Eastern Interconnection

- July 2, 2002
- August 1, 2002
- August 6, 2002

Bubble Diagrams
CAR Painting
Summer 2000 Market Activities

North to South Net Schedules (May thru Sept 2000)

Max = 10,366

467 hours >= 8000 MW

Max = -2401

Zero values represent missing data

Date (MMDDYY)
Summer 2001 Hourly A1, A2, A3 Net Exports (May thru Oct)

G1 > 0
G2 > 0
G3 > 0
Summer 2001 Market Activities
Hourly Schedules From May 2001 through Oct 2001
Summer 2002 Market Activities

Hourly Schedules Summer 2002

Period from 5/6/02 to 9/10/02

Date

MW

5/4/02 6/1/02 6/29/02 7/27/02 8/24/02 9/21/02

North to South
West to East
Duration Curves of N-S Schedules

Duration Curve of N-S Schedules Exceeding Different Congestion Index (CI)
June 13 - Aug 31, 2002

What is the simultaneous N to S Transfer Limit? It may be getting smaller because of load growth!

Congestion Index (CI) is the sum of post-contingency MW overloads or kV violation below voltage limits.

S - N Flows Increasing in Duration
CAR Painter computes the current hour’s max N-S and S-N transfer limits (dynamic nomogram). This scatter plot shows the actual hourly schedule with the max N-S or the max S-N transfer limit in the same direction as the actual schedule.

These hours have N-S schedules exceeding the max transfer limit (all points to the right of the 45 degree line.)

Median = 4700 MW
Duration Curves of W-E Schedules

Duration Curve of W-E Schedules Exceeding Different Congestion Index (CI)
June 13 - Aug 31, 2002

Congestion Index (CI) is the sum of post-contingency MW overloads or kV violation below voltage limits.

What is the simultaneous W to E Transfer Limit? It may be getting smaller because of load growth!
ACHIEVED TRANSFER LIMITS

Correlation of W-E Schedules with W-E Transfer Limits at Cl=100
(6/13/02 - 8/31/02)

CAR Painter computes the current hour’s max N-S and S-N transfer limits (dynamic nomogram). This scatter plot shows the actual hourly schedule with the max N-S or the max S-N transfer limit in the same direction as the actual schedule.

These hours have N-S schedules exceeding the max transfer limit (all points to the right of the 45 degree line.)
Simultaneous N-S and W-E Schedules for Summer 2001

Scenarios Studied

- 5/1/01 to 10/31/01
- Scenarios Studied

North to South Schedules (MW)

West to East Schedules (MW)
Hourly TagNet Simultaneous Schedules Compared with PSAST Studied Scenarios

Period from 5/6/02 to 9/10/02

Heavier West to East flows and more South to North this summer!
July 2, 2002 Bubble Diagram Hour 12

Bubble Diagram for Tagdump Dump Date: 7/2/2002 Start Hour ends at 12:00 Central showing Hr 1 (12:00)

Flows <= 10 MW are not shown.
Aug 6, 2002 Bubble Diagram Hour 12

Bubble Diagram for Tagdump Dump Date: 8/6/2002 Start Hour ends at 12:00 Central showing Hr 1 (12:00)
Flows <= 10 MW are not shown.
Lessons Learned

• Wholesale power transactions vary greatly
  – Year to year
  – Month to month
  – Day to day
  – Hour to hour

• Transmission constraints will likely get worse

• Better forecasts on wholesale power transactions can lead to greater reliability and cheaper energy prices
Need for Better Weather Forecasts

• **Short Term Forecasting**
  – Better accuracy for demand forecasts

• **Wholesale power transaction forecasts (difficult problem) depend on:**
  – Weather effect
  – Forced outages of power plants
  – Schedule outages of power plants
  – Regional demands

• **Mid Term Forecasting (1 to 3 months)**
  – Demand forecasting
  – Maintenance scheduling
  – Power purchases / sales
  – Hydro scheduling
  – Fuel scheduling