Energy price risk management
Energy price risk management

... from a three year perspective
Contents

- Risk
- Deregulation
- Markets
- Blackouts
- Weather
- Spikes
- Conclusions
The possibility of incurring loss (or gain)

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Wheel of misfortune

General fraud (1991)

Speculation by Nick Leeson (1995)


Interest rate speculation (1998)

Questionable trades (1996)

Real estate losses (1994)

Bad investments & creative accounting (2001)

Retail price cap & wholesale price spike (2001)

Oil forward-futures “hedge” (1993)

Counterparty defaults (1998)

Accounting fraud (1998)

Asbestos cases settlement (1995)

Real estate losses (1994)

$3.8 bln

$0.3 bln

$1.3 bln

$1 bln

$0.24 bln

$0.3 bln

$1.3 bln

$5.3 bln

$8.9 bln

$40 bln

$10 bln

$1.1 bln

$1.3 bln

$0.3 bln

$40 bln

$1.3 bln

$10 bln

$8.9 bln

$40 bln

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Enron: Problematic practices

- Accounting: “Financial engineering” with SPEs
  - hedging transactions
  - creative accounting
- Leveraging
  - financing operations
- Bad investments
  - eg. power plant in Dabhol, India
- Enron’s “culture”
  - profits, more profits, even more profits
Enron: Special Purpose Entities (SPEs)

Enron records gains from transactions with SPEs but does not consolidate SPEs’ debt on its balance sheet.
DEREGULATION

- Europe
  - England & Wales, Scandinavia, Spain, The Netherlands, Germany, Poland, Austria, …

- The Americas
  - USA: CA, PA, NJ, CT, TX, …
  - Chile, Argentina, …

- Asia/Pacific basin
  - Australia & New Zealand, …
  - Japan, …
Liberalization

- Privatization
- Acquisitions by foreign companies
  - Polish EC Kraków bought by French EdF
  - German HEW, Bewag & VEAG bought by Swedish Vattenfall
- Mergers
  - PreussenElektra + Bayernwerke → E.On
  - RWE + VEW → RWE
- New Actors
  - Marketers (qualified energy brokers)
- Increase in efficiency and standards of service
- Constant battle for the CUSTOMER
What do the customers have of it?

- Higher quality of services
- Choice of supplier
- Lower prices (?)
Average electricity prices for industrial customers in Germany

Prices without VAT and electricity tax. From January 2001, prices included KWG and EEG fees.

2) Delivery only to distributors. 3) Former area of Bayernwerk AG 4) Former area of PreussenElektra AG 5) Merged with RWE
Stages of liberalization

- **S-1**: State monopolies
- **S-2**: Declaration of competition
- **S-3**: Deregulation
- **S-4**: Tranquility
- **S-5**: Mergers and effects of market power
- **S-6**: Private monopolies
Opening of the EU market

- **Directive 96/92/EC** of the European Parliament
  - common rules for the production, transmission and distribution of electricity

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>All EU companies free to choose electricity supplier</td>
</tr>
<tr>
<td>2004</td>
<td>All EU companies free to choose gas supplier</td>
</tr>
<tr>
<td>2005</td>
<td>All EU consumers free to choose electricity and gas suppliers</td>
</tr>
</tbody>
</table>
Electricity market opening - current plans

United Kingdom
Sweden
Spain
Portugal
Netherlands
Luxembourg
Italy
Ireland
Greece
Germany
France
Finland
Denmark
Belgium
Austria

2000
2003
2007

0% 20% 40% 60% 80% 100%
MARKETS

Wholesale market structure

- Bilateral Contracts
- Futures, Forward and Option Markets
- Day-Ahead Market
- Balancing Market

Financial
Physical delivery

OTC Power Exchange ISO
European power exchanges

UK Pool/UK PX, APX, Power EX, IPE (1992, …)  
Nord Pool (1993)  
APX (1999)  
PolPX (2001)  
Powernext (2001)  
EXAA (2002)  
PolPX (2001)  
EEX/LPX (2000)  
Omel (1998)
European power exchanges – timeline

1992 '93 '96 '98 '99 '00 '01 …

NordPool (N) (Spot + Futures)
NordPool (N+S) (Spot)
APX (Spot)
EEX (Futures)
UK PX (Spot)
APX (Spot)
IPE (Futures)
PowerEX (Spot + Futures)
PoIPX (Futures)

UK Pool

Omel (Spot)
NordPool (+Fin)

LPX (Spot)
EEX (Spot)
UK PX (Futures)
PoIPX (Spot)
NordPool (+DK)
Europe: Concocting a third way

Controlled market with competitive “ornaments”

Source: Cambridge Energy Research Associates
US: Energy restructuring at a crossroads

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Source: Cambridge Energy Research Associates
The making of California’s electricity crisis

- Market structure
- Market fundamentals
- Market power
- Regulatory and political inaction
## California crisis timeline

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>May-June 2000</td>
<td>ISO’s real-time price reached $750 ten times</td>
</tr>
<tr>
<td>June 28</td>
<td>PX’s day-ahead price (NP15) reached $1,099</td>
</tr>
<tr>
<td>July 1</td>
<td>CAISO lowers the price cap from $750 to $500</td>
</tr>
<tr>
<td>Aug. 7</td>
<td>CAISO further reduced the price cap to $250</td>
</tr>
<tr>
<td>Nov. 1</td>
<td>FERC issued an order, proposing a “soft cap” of $150</td>
</tr>
<tr>
<td>Jan. 8, 2001</td>
<td>Gov. Gray Davis declared deregulation a “colossal and dangerous failure” and proposed state intervention</td>
</tr>
<tr>
<td>Jan. 11</td>
<td>CAISO issued first <strong>Stage 3 alert</strong></td>
</tr>
<tr>
<td>Jan. 17-18</td>
<td><strong>Rolling blackouts</strong></td>
</tr>
<tr>
<td>Apr. 6</td>
<td>Pacific Gas &amp; Electric filed bankruptcy seeking court protection; reported <strong>$8.9 bln losses</strong></td>
</tr>
</tbody>
</table>
Was demand higher?

Annual and weekly seasonality clearly visible
Demand forecasting

Detecting seasonality
- correlation, spectral analysis

Removing seasonality and ARMA modeling
- differencing, moving average method, seasonal volatility technique, fitting a sum of sinusoids

Seasonal ARIMA (SARIMA) modeling

Detecting periodic correlation
- see poster by Ewa Broszkiewicz et al.

Periodic ARMA (PARMA) modeling
CalPX load: periodogram before and after seasonality reduction

Before

365 days
7 days

After

2.33 days
3.5 days

“Harmonics” indicate that the data exhibits a 7-day cycle, which is not sinusoidal
Deseasonalized load returns can be modeled by ARMA time series

Deseasonalized load returns

Only short range dependence
Modeling electricity loads in California: ARMA models with hyperbolic noise

J. Nowicka-Zagajek, R. Weron

Residuals
Stable CDF
Gaussian CDF

Heavier than Gaussian

Lighter than Levy-stable

Semi-log scale
ARMA models
with hyperbolic noise cont.

\[
f(x; \alpha, \beta, \delta, \mu) = \frac{\sqrt{\alpha^2 - \beta^2}}{2\alpha \delta K_1(\delta \sqrt{\alpha^2 - \beta^2})} \exp\left\{-\alpha \sqrt{\delta^2 + (x - \mu)^2} + \beta (x - \mu)\right\},
\]

where \( \delta > 0 \) is the scale parameter, \( \mu \in \mathbb{R} \) is the location parameter and \( 0 \leq |\beta| < \alpha \). The latter two parameters—\( \alpha \) and \( \beta \)—determine the shape, with \( \alpha \) being responsible for the steepness and \( \beta \) for the skewness.
Actual load and day-ahead out-of-sample forecasts: 1–2.2001
Errors of the day-ahead out-of-sample forecasts: 1–2.2001

- CAISO forecast
- ARMA(1,6) forecast

**New Year’s**

**President’s Day**
# Errors of the day-ahead out-of-sample forecasts: 1–2.2001

<table>
<thead>
<tr>
<th>Forecasting approach</th>
<th>CAISO</th>
<th>ARMA(1, 6)</th>
<th>Adaptive ARMA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Error</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSE</td>
<td>208.34</td>
<td>304.14</td>
<td>318.50</td>
</tr>
<tr>
<td>MAE</td>
<td>10.52</td>
<td>9.86</td>
<td>9.87</td>
</tr>
<tr>
<td>MAPE (%)</td>
<td>1.7799</td>
<td>1.6642</td>
<td>1.6682</td>
</tr>
</tbody>
</table>

**January 1–February 28**

<table>
<thead>
<tr>
<th>MSE</th>
<th>ARMA(1, 6)</th>
<th>Adaptive ARMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>190.28</td>
<td>89.00</td>
<td>88.36</td>
</tr>
<tr>
<td>10.08</td>
<td>7.39</td>
<td>7.31</td>
</tr>
<tr>
<td>1.7087</td>
<td>1.2401</td>
<td>1.2282</td>
</tr>
</tbody>
</table>

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If it wasn’t the demand then maybe it were the “gas pains”!
Natural gas prices

Source: NG Daily Index
Electricity prices in 2000 – nominal and gas price adjusted

Source: California PX
Other causes

- Precipitation in Columbia river basin lower by 40%
- Little generation investment in the last 10 years
- Execution of market power by the producers
  - bidding strategies, cooperative “games”

*see poster by Agnieszka Wyłomańska*
“That’s why I never walk in front”
BLACKOUTS

- System load (throughput)
  - optimized to get the maximum out of the system
  - high load means small operating margins
  - has impact on interactions and component failures

- Tradeoff between load and risk of failure
  - at system level
  - for system components
DMSP F15
14 August 2003
0129Z
~20 hrs before Blackout
DMSP F15
15 August 2003
0114Z
~7 hrs after Blackout
2003 Blackout timeline

- 12:05:44 – 1:31:34 PM: 3 generator trips (shutdowns) causing flow pattern changes
- 2:02 PM: transmission line disconnects in SW Ohio due to fire under the line
- 3:05:41 – 3:41:33 PM: transmission lines disconnect between E Ohio and N Ohio; reasons unknown
- 3:45:33 – 4:08:58 PM: remaining transmission lines disconnect from E into N Ohio
2003 Blackout
- the domino effect
2003 Blackout timeline cont.

- 4:08:58 – 4:10:27 PM: transmission lines into NW Ohio disconnect, and generation trips in central Michigan

- 4:10:00 – 4:10:38 PM: lines disconnect across Michigan and N Ohio, generation trips off line in N Michigan and N Ohio, and N Ohio separates from Pennsylvania

- Power immediately reversed direction and began flowing in a giant loop counterclockwise from PA to NY to Ontario and into Michigan
2003 Blackout timeline cont.

- 4:10:40 – 4:10:44 PM: four transmission lines disconnect between Pennsylvania and New York
2003 Blackout timeline cont.

- 4:10:41 PM: line disconnects and generation trips in N Ohio
- 4:10:42 – 4:10:45 PM: transmission paths disconnect in N Ontario and New Jersey, isolating the NE portion of the Eastern Interconnection
- 4:10:46 – 4:10:55 PM: New York splits east-to-west; New England (except SW Connecticut) and the Maritimes separate from New York and remain intact
4:10:50 – 4:11:57 PM: Ontario separates from New York west of Niagara Falls and west of St. Lawrence; SW Connecticut separates from New York and blacks out

4:13 PM: cascading sequence essentially complete

More than 60 mln customers affected!
2003 Blackout
- the cascade effect
Modeling blackouts

- North American Electricity Reliability Council (NERC) data
  - Analyzed by Carreras, Dobson, Newman & Poole
  - 15 years of data (1984-98)
  - 427 blackouts
  - On average 28.5 per year, waiting time of 12 days

- Three measures of blackout size
  - Energy unserved (MWh)
  - Amount of power lost (MW)
  - Number of customers affected
What is the distribution of blackout sizes?

Source: Carreras et al. (2002)

Slope ~ –1.7
Modeling blackouts cont.

There seems to be a critical loading at which
- sharp increase in average number of failures is observed
- power tail distribution of blackout sizes forms

power system has Self-Organizing Criticality (SOC) dynamics ?!
- cascade models
Modeling blackouts cont.

- Waiting times have exponential tails
  - blackouts can be modeled by a Poisson process
  - like the risk process in insurance
  - Extreme Value Theory

- Power system is a network
  - What type of a network should it be?
  - Can we construct such networks?
  - What is the critical loading?
Important for energy at a range of time scales

Daily
- Highly anomalous temperatures at a location
- Widespread anomalous temperatures

Multiple days
- Hurricanes
- Persistent heat events

Seasonal
- Much colder winter than normal
- Excessively wet/dry winter in Scandinavia, Pacific Northwest
Role of weather in power sector

- **Electricity – Demand**
  - Weather is a measure of demand
    - Quasi-linear for non-extreme
    - “Hockey stick” for extreme heat

- **Electricity – Supply**
  - Impacts efficiency of power plants
  - Fuel for power supply: Hydro, Wind, Solar
  - Severe weather can impact power transmission
    - Wind-induced power outages
Relationship of load to temperature – Cinergy 1996

“Hockey stick”

Max Daily Load (MW)

Degrees Fahrenheit

Courtesy of BTU Brokers
Temperatures vs. system price

Temperaturer i storbyer i Sverige 2000

Grader i Celcius

NOK/MWh

Jan  Feb  Mar  Apr  Mai  Jun  Jul  Aug  Sep  Okt  Nov  Des

Stockholm
Göteborg
Stockholm normal
Göteborg normal
Elspot systempris

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PJM – power price vs. maximum temperature

On-Peak Price ($/MWh)

Max Daily Temp (°F)

Jan-97 May-97 Sep-97 Jan-98 May-98 Sep-98
SPIKES

Days since 2.1.1998 until 17.3.2000

$/MWh

Cinergy (left scale)
COB (right scale)

1998

1999
Anatomy of the 1998 Cinergy spike

- **The setup**: Federal sells call options for 50 $/MWh; “Sleeve deal” provides credit guarantees
- **End of June 1998**: an early heat wave hits the Midwest; more than 20 power plants are off-line for maintenance or down due to storm damage
- **June 22-24**: prices (“into Cinergy”) rise from 180 to 550 $/MWh
- Marketers anticipating price squeeze buy up power bidding prices higher
Anatomy of the 1998 Cinergy spike cont.

- Options **get called** amid high prices at Cinergy
- **Federal Energy defaults** on call options; Springfield announces that it will not perform on these options
- On the night of June 24th a tornado damages a 900 MW nuclear power plant
- Prices continue to rise and reach **7500 $/MWh** in real-time trading; purchasers suffer large losses
July 1999 Cinergy price spike

- Weather Situation
  - Last part of July – hottest temperatures in several years
  - Widespread record highs
  - Heat indices:
    - 115°F (Chicago)
    - 118°F (South Bend)
July 1999 Cinergy price spike cont.

- Energy demand
  - Record high demands in Ohio River area
- Reduced plant efficiency
  - High air/water temperatures caused generating units to run at lower efficiencies due to reduced effectiveness of cooling systems
- Other contributing energy factors
  - Strained transmission grids and flow cuts due to high energy demand
  - Market psychology
July 1999 Cinergy price spike — end results

- Power outages due to insufficient capacity
- Reduced power to interruptible customers
- Record high power prices

Hourly max: $9500

Daily Average OVER $1700!
WE’VE GOT TO FIND A BETTER WAY TO HANDLE PEAK DEMAND...
Conclusions ... from a three year perspective

- Power markets are different
  - than other commodity or financial markets
  - from each other
- New modeling, forecasting, pricing methods are needed
- “Blackout-free” design of power networks is necessary
- There still is work for everyone in the room