Managing Risk in Hydro-Based Portfolios: the Brazilian Experience

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Markets, Investments and Risks in Hydro vs Thermal-Dominated Systems
The Energy Centre – U of Auckland Business School
Topics

• Brazilian system overview
• Hydrothermal scheduling
• Risks and challenges
• Tools for risk management
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The big numbers...

Surface area: 8 million km\(^2\)
(= continental US + 1/2 Alaska)
Population: 185 million
GDP: US$ 800 billion
Installed capacity (2006): 100 GW
Production (2006): 50 GW average
Peak load: 65 GW
Energy production sources

**Hydro (85%)**: large plants in cascade, in several river basins, with multiple weather patterns

**Thermal (15%)**: natural gas (combined and simple cycle); coal; heavy fuel; diesel; nuclear; sugarcane biomass cogen
Transmission network

Country is interconnected by 80,000 km of HV lines (>230 kV)

2200 MW interconnection with Argentina

Long transmission lines (> 1,000 km)

15,000 km of new lines added in the past five years

Auctions for the construction of grid reinforcements

Source: ONS, www.ons.org.br
G, T and D Sectors

• **Generation**
  - 11 major utilities + several smaller companies
  - 15% private (energy produced)
  - Total revenues (2005): US$ 13 billion

• **Transmission**
  - 35 companies (27 private)
  - Total revenues (2005): US$ 3 billion

• **Distribution**
  - 64 utilities
  - 80% private (energy consumed)
  - Total revenues (2005): US$ 27 billion
Investment needs

• For a GDP growth of 4%, it is necessary to install 3200 MW average of new firm energy per year
  ⇒ US$ 6 billion/year in investments

Main objective: to ensure an efficient capacity increase
Resources for generation expansion

**North (N):**
- Substantial hydro (170 GW); limited natural gas

**Northeast (NE):**
- Offshore natural gas and oil; LNG and coal imports; biomass (sugarcane); wind

**South (S):**
- Electricity and gas imports from Argentina; local coal; binational hydro plants; LNG

**Southeast (SE):**
- Hydro; Bolivian gas + local offshore gas fields (Campos and Santos); biomass (sugarcane)
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System dispatch

- The National System Operator (ONS) controls the production of all hydro and thermal plants
- Hydro plants are dispatched as a portfolio, to take advantage of hydrological diversity (export from “wet” to “dry” basins)
The Hydrothermal (HT) scheduling problem

• Formulated as a stochastic DP recursion
  – Objective: minimize the present value of expected operation cost (fuel cost for thermal plants + penalties for rationing) taking into account inflow uncertainty
  – State variables: reservoir storage levels and observed lateral inflows at each reservoir

• For a system with 50 hydro plants and an autoregressive lag-3 model, this results into 200 state variables ⇒ Discrete stochastic DP cannot be used (curse of dimensionality)
The SDDP scheme

• A stochastic dual dynamic programming algorithm (SDDP) is used to solve the dispatch problem
  – the future cost function (FCF) is represented by piecewise linear hyperplanes (Benders cut)
    • no discretization necessary
    • The hyperplane coefficients are the dual values of the dispatch problem (hence the name)
• The SDDP scheme has been applied to more than 40 countries in Latin America, Europe, Eurasia and Oceania
Spot price

- In addition to energy production schedule, the HT scheduling model calculates the system short-run marginal cost (SRMC)
  - Related to the opportunity cost of water (water value)
- The SRMC is used as a proxy of spot prices in all wholesale energy market (WEM) transactions
Although bus-level LMPs are calculated, a zonal system with 4 regions is used for WEM transactions.

The main transmission network has 3500 buses and 5000 circuits.
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Average energy inflow – Southeast region
Average storage level – Southeast region
Average spot price – Southeast region

Rs/MWh

May-05  Jun-05  Jul-05  Aug-05  Sep-05  Oct-05  Nov-05  Dec-05  Jan-06  Feb-06  Mar-06  Apr-06  May-06  Jun-06  Jul-06  Aug-06  Sep-06  Oct-06  Nov-06  Dec-06
Storage scenarios – Southeast region
Spot price scenarios – Southeast region
The spot price distribution is skewed
Low prices for a long time, punctuated by “spikes”
Challenges for new capacity

- Because of price volatility, it is very risky for any generator (hydro or thermal) to enter the system as a merchant plant
- The uncertainty is compounded by the variability of load growth

![Graph showing GW medium capacity with GDP scenarios]

- [High - Base]: 2700 MW average
- [Base – Low]: 700 MW average
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• Volatility of spot prices
• Tools for risk management
  ▪ Contract auctions
  ▪ Forward contracts for hydro
  ▪ Call option contracts for thermal plants
Supply contracts

• All consumers (free and regulated) should be 100% contracted
  – Verified ex-post, for the cumulative energy consumption in the previous year

• Although contracts are financial instruments (forward or call options), they must be “backed” by a firm energy “certificate”
100% contract + firm energy $\Rightarrow$ expansion

Load increase

Genco

Firm supply $\geq$ Demand

New generation

Should be 100% contracted; looks for a genco or a trader

Has to cover contract with firm energy; thus invests in...
Contract auctions

• Discos contract energy through auctions
  – Discos are responsible for load forecast; avoids government planners’ “optimism”
  – Contracts reduce risks for investors; lower prices

• Free consumers can contract as they wish, as long as they remain 100% covered
  – Free consumers are 25% of the market
  – They serve as “checks and balances” for the regulated sector
Auction results 2004-2006

- 5 auctions; US$ 50 billion in contracts
Next auctions are scheduled for May 2007

205 candidate projects; 25 thousand MWs
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Risks of forward contracts for hydro plants

• For thermal plants, forward contracts are Ok
  – Hedge against low spot prices
  – If the spot price is high, the plant will dispatch; the worst expense is the fuel cost

• However, significant risks remain for hydro
The production of individual hydro plants is quite variable; long periods in which the plant may be “short” on the contract.
Solution: spatial hedging

Idea: total hydro production is more stable
The spatial hedging scheme (MRE)

- All hydro plants are “shareholders” of a “hedge fund” called MRE
- The total hydro production is assigned to MRE
- It is then allocated to each plant as an “energy credit”, in proportion to the shares, not to the physical production
- The energy credits are used for the WEM clearing
Hydro plants have a two-sided risk:
if they contract too little, they will “starve” in wet periods;
if they contract too much, they are “hurt” by high spot prices in dry periods.
Solution 2a: Contract adjustment in a crisis

• In case of rationing, the contracted amount of all plants is reduced in the same % as the load curtailment
  – Alleviates exposure to very high prices in crisis situations; risks are transferred to consumers
Solution 2b: Optimize energy contracted

- For each candidate contract amount, calculate price that ensures the required return on investment
  - e.g. “Value at Risk” on IRR: Pr [IRR > target] > 95%
  - Stochastic optimization model (OptFolio)

- Select energy amount that maximizes plant competitiveness in auctions
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Auctions for “Call option” contracts

- “Call option” contract auctions for thermal plants have been used since 2005
  - Plants bid both the “premium” (fixed annual revenue) and the “strike price” (used as the variable operating cost in the HT dispatch)
- Bids are compared with basis on the estimated benefit for consumers
  - [low premium, high strike] x [high premium, low strike]
- Objective: transfer benefits (and risks) of hydrothermal optimization to consumers
Conclusions

• Load growth uncertainty and spot price volatility create important risks for generation investors, in particular for hydro plants

• These risks can be handled by a set of technical, regulatory and financial instruments:
  – Stochastic optimization for hydrothermal dispatch
  – “Competition for the market” (long-term contract auctions)
    • Discos are responsible for load forecasts
  – “Spatial hedging” and forward contract optimization for hydro plants
  – Call option contracts for thermal plants