Assessment of the economic viability of balancing from Norwegian hydro from the perspective of a single power producer

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What is meant by "balancing"?

1. Handle varying renewable power generation
   - Spot market
   - Capacity markets
   - Transmission lines

2. Handle deviation from day-ahead
   - Intra-day markets

3. Real-time balance
   - Reserves: procurement, activation
   - FCR, FRR, RR
What is meant by "balancing"?

- Handle varying renewable power generation
- Handle deviation from day-ahead
- Real-time balance
  - Reserves: procurement, activation, FCR, FRR, RR
- Spot market
- Capacity markets
- Transmission lines
- Intra-day markets
- Hydropower
Research questions

1) Will investments in Norwegian hydropower be profitable?
   – New/upgraded facilities, pumped storage
   – Share of income in different markets?
   – Bilateral arrangements?

2) How will hydropower be operated in the future?
A possible mind-map

Norwegian hydropower: Operation and profitability

- Hydropower infrastructure
- Norwegian prices
  - Formal market access
  - Transmission capacity
  - Nordic system

European prices

- Competing flexible technologies
- Renewable generation
- Thermal power: capacity and costs

To be studied

Local optimization variables

Power system setting

Needs for balancing, and competition

Future / scenario
A possible mind-map

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Future / scenario
Market access

- **Today**
  - Nordic market (spot, Elbas, balancing energy)
  - European day-ahead price coupling (75% of total)
  - Elbas (intraday): Nordic + Baltic + NL + GE

- **European integration process**
  - Florence Forum for regulators (2008), TM/roadmap
  - Day-ahead, intraday, balancing, capacity allocation, connections
  - Ongoing process: EC / ACER / ENTSO-E / …
  - Network codes

- **Forward-looking: 2030, 2040, 2050**
  - Difficult to foresee
  - Best guess: Full integration in the long run?
Network code development process

- Legislation
- Comitology
- EC
- ACER
- ENTSO-E

**NC on markets**
- CACM
  - Day-ahead
  - Intraday
  - Capacity calculation
- EB
  - TSO cooperation
  - Balancing energy
  - Procurement reserves
  - Netting
- FCA
  - Forward capacity calculation
Figure

A possible mind-map

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Environmental constraints

To be studied

Local optimization variables

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Future / scenario
Figure

http://www.statnett.no/Global/Dokumenter/Prosjekter/Nettutviklingsplan%202013/Nettutviklingsplan%202013.pdf

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A possible mind-map

Norwegian hydropower: Operation and profitability

Hydropower infrastructure

Norwegian prices

Environmental constraints

To be studied

Local optimization variables

Transmission capacity

Nordic system

Power system setting

European prices

Formal market access

Competing flexible technologies

Renewable generation

Thermal power: capacity and costs

Needs for balancing, and competition

Future / scenario
European prices 2030 and beyond

- Affected by many factors
  - Thermal power capacity and costs
  - Renewable generation
  - Prices for fuel prices and CO2
  - Nuclear power policy
  - Flexible technologies
  - …

- Several markets: day-ahead, intraday, balancing energy, …

- In project
  - WP1: Different Scenarios for 2050
  - IAEW (European day-ahead prices, more markets for Germany)
  - ECN
A possible mind-map

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- Environmental constraints

Local optimization variables

European prices

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Power system setting

To be studied

Needs for balancing, and competition

Future / scenario
Flexible technologies
(dealing with varying vind/solar)

- Large-scale reservoir hydropower
- Gas-power
- More flexible coal- and nuclear-power
- Netting / transmission grid enhancement

- Storages
  - Local pumped storage
  - Power to gas
  - Batteries
  - Thermal

- Demand flexibility
A possible mind-map

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Needs for balancing, and competition

Future / scenario
Goals in WP3 of Hydrobalance

■ Analyze
  – Expected payback for investors in hydropower capacity
  – Shares from different markets

■ Simulate future hydropower operation
  – Design methodology (multi-market)
  – Case-studies of specific water-courses
Plan: Apply the model PRODRISK
(… and possibly SHOP)

- One of SINTEF's optimization tools for hydropower
- Local producer / river system
- Time-resolution: minimum 1 hour
- Horizon: e.g. 1 year
- Prices and inflow are stochastic variables: inputs to model
Challenge: Future-year prices

- **Spot prices**
  - For future year: 2050
  - Several 2050-scenarios
  - Uncertainty and variation for renewable generation

- **Prices in several markets**
  - Procurement of reserves (several types)
  - Day ahead
  - Intra-day (several trading hours)
  - Activation of reserves / balancing energy (several types)
  - ...
Trading in multiple markets
2013-prices in German market

Intra-day prices (€ / MWh)

Spotprices (€ / MWh)

\[ y = 1.0084x + 0.3473 \]
\[ R^2 = 0.8212 \]

Source:
Prices downloaded from EPEX
Illustration made by SINTEF
Analyze future year profitability in DA

Scenario 2050 (WP1)

Assumptions

Model simulation (IAEW/ECN)

DA-prices Norway, ...

PRODRISK

Optimal operation

Profitability
Analyze profitability for investment

Investment in pumped storage

- Scenario 2050 (WP1)
- Model simulation (IAEW/ECN)
- Assumptions
- DA-prices Norway, ...
- PRODRISK
- Optimal operation
- Profitability
Challenge: Multi-market optimization

- Prices
  - One per hour in PRODRISK
  - Several for each hour in reality

- Presently, we do not have the multi-market optimization tool for hydropower

- A set of strategies can still be evaluated
Strategies to be evaluated

- Analyze operation towards
  1) Spot-market prices
  2) Prices in other markets (intra-day, balancing)

- Sequential sub-optimal approach
  - Simulate participation in all markets
  - As difference between solutions for each market

\[
\begin{align*}
X_t^{spot} &= X^{PRO}(p_t^{spot}) \\
X_t^{intra} &= X^{PRO}(p_t^{intra}) - X^{PRO}(p_t^{spot}) \\
X_t^{bal} &= X^{PRO}(p_t^{bal}) - X^{PRO}(p_t^{intra})
\end{align*}
\]

- Reserve capacity (MW): parameter, try different values
- Reservoir content updates needed
Next steps in WP3

- Finalize review on markets
- Calculate future prices (cooperation)
  - Scenarios
  - Markets
- Calculate optimal operation (PRODRISK, SHOP)
  - Design/test methodology
  - Case study; site
- Evaluate profitability of investment for different scenarios