Investing in hydropower system flexibility

Application of decision support tools to a real case in Norway

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Agenda

• Motivation
• Decision support tools
• Investment case(s)
• Assumptions about the future
  • Market prices
  • Inflows
• Model based results
  • Production revenue
  • Reduced economical consequences of planned or forced outages.
Motivation

• Increased amount of new renewables in the European system
• Value of flexibility and storage will increase
  • Norwegian hydro is one such provider of flexibility
• Marked based system
• Individual producer decide on investment and upgrading based on their own assumptions about the future
• Presentation about how some of SINTEFs models are used in the investment decision process
  • Real case from Lyse Kraft and the Røldal Suldal-kraftverkene (RSK) system
Decision support tools

• Price forecasting
  • Fundamental market model: EMPS or FanSi

• Revenue calculations
  • SDDP based model: ProdRisk
  • A new detailed simulator (ProdRisk-SHOP)
Investment cases
Future market prices

• Basic price scenario from fundamental market model
  • Detailed model of North European system
  • Stage 2030
  • Typical time resolution 3 hours

• Results:
  • Prices referred to 2030 for each time period for different weather years
  • Weather years used to correlate prices with local inflow

• Value of flexibility given by uncertainty and variation
  • Prices from model vs observed uncertainty?
Price properties - volatility

- Price period (3 hour)
- Daily
- Weekly
- 4-Weekly
- Yearly (30 scenarios)

HydroCen

Historical 2010-2021

2020-2021

HydroCen
Scaling of price volatility

A price series $P(t)$ (with 3h-resolution) with average price $\bar{P}$ og period averages $\langle P \rangle_{\text{period}}$ the variations $\delta P$ on each time scale are given by:

- $\delta P_y(t) = \langle P \rangle_{\text{year}}(t) - \bar{P}$
- $\delta P_{4w}(t) = \langle P \rangle_{\text{4weeks}}(t) - \langle P \rangle_{\text{year}}(t)$
- $\delta P_w(t) = \langle P \rangle_{\text{week}}(t) - \langle P \rangle_{\text{4weeks}}(t)$
- $\delta P_d(t) = \langle P \rangle_{\text{day}}(t) - \langle P \rangle_{\text{week}}(t)$
- $\delta P_{3h}(t) = P(t) - \langle P \rangle_{\text{day}}(t)$

$\Rightarrow P(t) = \bar{P} + \delta P_y(t) + \delta P_{4w}(t) + \delta P_w(t) + \delta P_d(t) + \delta P_{3h}(t)$

The price variations may then be scaled on each time scale with different factors $f$:

- $P_{\text{skalert}}(t) = \bar{P} + f_y \delta P_y(t) + f_{4w} \delta P_{4w}(t) + f_w \delta P_w(t) + f_d \delta P_d(t) + f_{3h} \delta P_{3h}(t)$
Future inflows

- Based on historical observations
- Adjustment to include climate change
  - Basic correction factors from a Nordic Climate project
    Climate and Energy Systems - CES | Icelandic Meteorological office (vedur.is)
  - Yearly average volume
  - Yearly profile
  - Volatility (variation at different time scales: day, week, month and year)
  - Several "possibilities" for climate change
Inflow properties - volatility

![Graph showing volatility for different time scales: Daily, Weekly, 4-Weekly, Yearly (30 scenarios). Different markers represent Historical, HADAM, and Example scaling.](image)
Model based simulation results

• Production revenue
  • 90 optimizations

• Reduced economical consequences of planned or forced outages.
  • 482 optimizations / simulations
Increase in production revenue
Economical consequences of forced outages

Current system

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Investment case J

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A new detailed simulator (ProdRisk-SHOP)