Balancing of variable wind and solar production in Continental Europe with Nordic hydropower –

A review of simulation studies

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Workshop on Hydro Scheduling in Competitive Electricity Markets

PhD study: Balancing wind and solar power production in Northern Europe with Norwegian hydropower (2014 -2017)

- **The overall objective is to develop methodology and models for assessing the potential value of the Norwegian hydro power resources for balancing of variable wind and solar production. The sub objectives are:**
  - **Develop a scheme for systematically categorization of variability of wind and solar production for different time horizons**
  - **Develop a data model with high spatial and temporal resolution for different scenarios of wind and solar production in Northern Europe**
  - **Establish a possibility for analyses of several markets (day-ahead, intraday, balancing)**
  - **Assess the value of application of Norwegian hydro power and storage for balancing of large shares of wind and solar production in future Northern Europe power production**

Background

- The European power system is expected to gradually increase its share of production from variable resources like wind and solar and to phase out fossil fuel based production.
- In periods with limited production from the wind turbines and the solar plants, demand has to be covered from other types of production.
- In other periods the production from wind and solar plants may exceed the demand and the energy can be stored for future use.
- Norway has ca half of the reservoir capacity in Europe - can provide Europe with some of the future needed flexibility.

About the review

- **The objective:** to identify the state-of-the-art related to the need for balancing and storage for scenarios of large shares of wind and solar production in the Northern Europe, and the possibility for using the Nordic hydropower for balancing the variability and uncertainty. Identify the research gap.

- **Questions studied:**
  1. The need for balancing and storage in the future power system
  2. How can the Nordic power system be further developed to cover a larger share of the need for balancing and storage?
  3. Consequences of different market solutions
  4. Changes in operation patterns of the Nordic hydropower system

12 paper reviewed

1. Korpås M, et.al. Balancing of Wind Power Variations using Norwegian Hydro Power. Wind Engineering 37(1), 2013
2. Aigner T, et. al, The Effect of Large-Scale Wind Power on System Balancing in Northern Europe, IEEE Transaction on Sustainable Energy 3(4), 2012
3. Farahmand H, et.al, Nordic hydropower flexibility and transmission expansion to support integration of North European wind power, Wind Energy (2014),
4. Amelin M, et.al (2009) Balancing of wind power and hydro power in Northern Sweden, Elforsk report 09:88,
5. Kiviluoma J et.al, Impacts of wind power on energy balance of a hydro dominated system. In: Proc. Of European Wind Energy Conference, Greece, 2006.
6. Holttinen H et.al Imbalance costs of wind power for a hydropower producer in Finland" Wind Engineering, 36(1), 2012
7. Harby, A, et.al . Pumped Storage Hydropower. Transition to Renewable Energy Systems, 2013
8. Jaehnert S, et.al. Transmission expansion planning in Northern Europe in 2030 – Methodology and analyses Energy Policy 61 (2013)
9. Aigner T. System Impacts from Large Scale Wind Power. PhD Thesis NTNU. 2014
10. Trötscher T, et.al A power market model for studying the impact of wind power on spot prices, In: 16. Proc. Power Systems Computation Conf., Scotland, 2008.
11. German Advisory Council on the Environment, Climate-friendly, reliable, affordable: 100% renewable electricity supply by 2050, 2010
12. Bökenkamp G. The Role of Norwegian Hydro Storage in Future Renewable Electricity Supply Systems in Germany: Analysis with a Simulation Model. PhD Thesis Universität Flensburg. 2014.

The 8 paper most relevant papers for the research questions

1. Korpås M, et.al. Balancing of Wind Power Variations using Norwegian Hydro Power. Wind Engineering 37(1), 2013
2. Aigner T, et. al, The Effect of Large-Scale Wind Power on System Balancing in Northern Europe, IEEE Transaction on Sustainable Energy 3(4), 2012
3. Farahmand H, et.al, Nordic hydropower flexibility and transmission expansion to support integration of North European wind power, Wind Energy (2014),
4. Harby, A, et.al . Pumped Storage Hydropower. Transition to Renewable Energy Systems, 2013
5. Jaehnert S, et.al. Transmission expansion planning in Northern Europe in 2030 – Methodology and analyses Energy Policy 61 (2013)
6. Aigner T. System Impacts from Large Scale Wind Power. PhD Thesis NTNU. 2014
7. German Advisory Council on the Environment, Climate-friendly, reliable, affordable: 100% renewable electricity supply by 2050, 2010
8. Bökenkamp G. The Role of Norwegian Hydro Storage in Future Renewable Electricity Supply Systems in Germany: Analysis with a Simulation Model. PhD Thesis Universität Flensburg. 2014.

Information structured – example (I:II)

Title	Main research question	Q1	Q2	Q3	Q4
……	……	…..			
System Impacts from Large Scale Wind power	Wind power variation and measures for efficient and secure integration (inter area and cross-border cost-optimal grid expansions, integration of intra-hour and regulating power markets)	X	X	X	
….	…				

Q1 - The need for balancing and storage in the future system
Q2 – How can the Nordic power system be further developed to cover a larger share of the need for balancing and storage?
Q3 – Consequences of different market solutions
Q4 – Changes in operation patterns of the Nordic hydropower system

Information structured - example (II:II)

Title/Year of publishing	Time perspective/ geographical area	Main input data	Analytic models	Main findings
…..	……			
System Impacts from Large Scale Wind power /2013	2010- 2030, Northern Europe	COSMO EU data for onshore and offshore wind resources, 4Coffshore for offshore wind power capacities, www.thewindpower.net for onshore wind power capacities, UCTE, ENTSO-E and NORDEL data	EMPS, PSST	Despite distribution of WPP in 2030, the WPP varies between 2 and 62% of installed capacity.
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The research gap

1. The need for balancing and storage in the future power system
   - Either too limited volumes of WPP and SPP, too limited geographical area, too low temporal resolution of data, too low spatial resolution of data
2. How can the Nordic power system be further developed to cover a larger share of the need for balancing and storage
3. Consequences of different market solutions
4. Changes in operation patterns of the Nordic hydro power system
   - 2, 3 and 4 dependent on 1.

Conclusion: knowledge about the need for balancing and storage in the future power system in Northern Europe can still be improved by developing betters data models for wind and solar resources. Other research questions should be investigated based on these models.