Short Term Hydro Power Planning Coordinated with Wind Power in Areas with Congestion Problems

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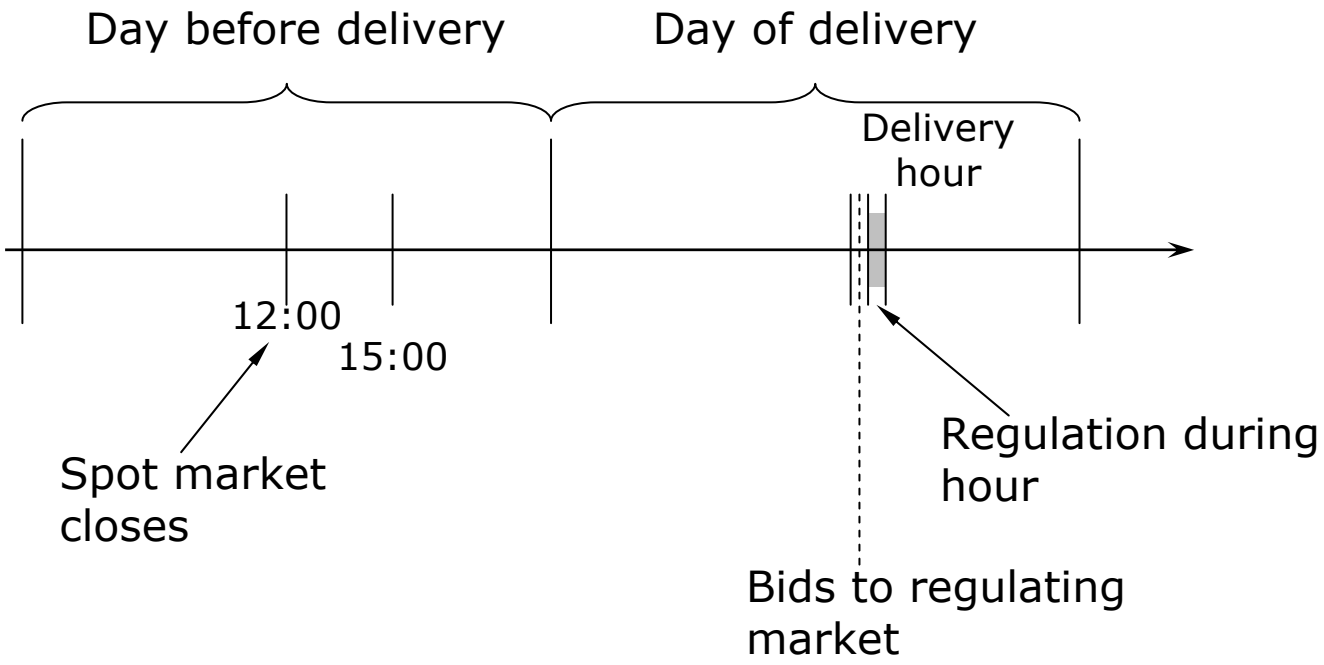
Outline

- Background
- Planning algorithm
- Results from the case study
- Conclusions and future work

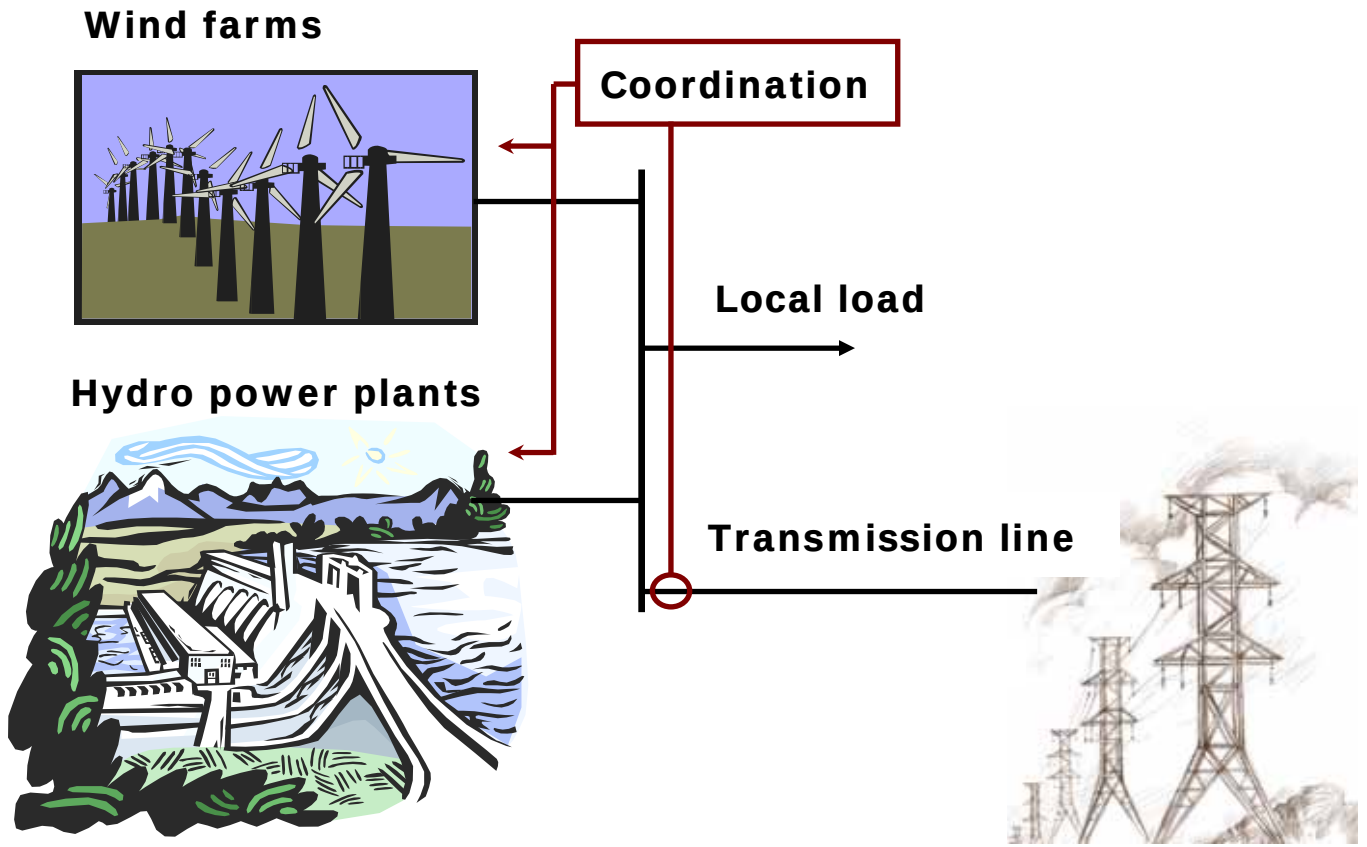
Background

- The best conditions for wind power are in remote areas far from the load centres;
- The transmission system is not dimensioned for additional large scale wind power plants;
- The transmission capacity might be reserved for existing power plants;
- The full load hours of the wind farm 2000-4000 h/year;
- Transmission peaks and wind power production peaks do not always coincide;
- Possible to store wind energy;
- Battery storage or new pumped hydro storage for large scale wind power is expensive;
- Existing conventional power plants with fast production control and sufficient storage capacity may be used;

Market structure



Coordination of Wind and Hydro



Overview of the considered case

HPP Planning Coordinated with Wind Power

- The objective: to maximise the income of hydro power utility;
- Wind farm pays hydro power utility for coordination;

$$\text{Price for coordination} < \frac{\text{WF loses due to curtailments}}{\text{Total curtailed energy}}$$

On the other hand the income of the hydro power utility should be at least as high as in the uncoordinated case. This provides the lower limit for the price.

HPP Planning Coordinated with Wind Power (cont.)

It is important to keep track of the exact amount of hydro production reduction because of wind power and transmission congestions. Thus, the planning is devided in two parts:

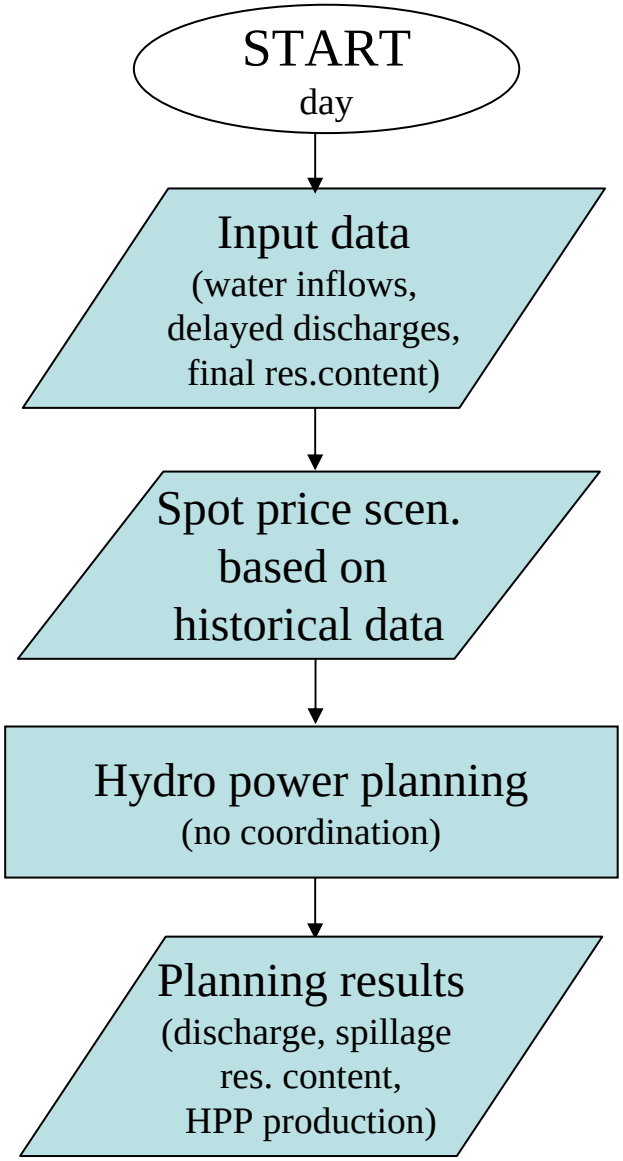
1. Base case hydro power planning for the spot market (stochastic spot prices), without consideration of wind power;

2. Re-planning of hydro power production for the spot and regulating market (stochastic spot and regulating market prices), considering wind power forecast and its uncertainty;

Assumptions

- Hydro power utility is a price-taker;
- Planning for the comming day is conducted before the closure of the spot market, i.e. 12:00 the day before;
- Besides the planing day the rest of the ongoing week is included in the planning, to account for wind power that might be produced during the followind days;
- Cooperative (fair) behaviour of the hydro power utility;

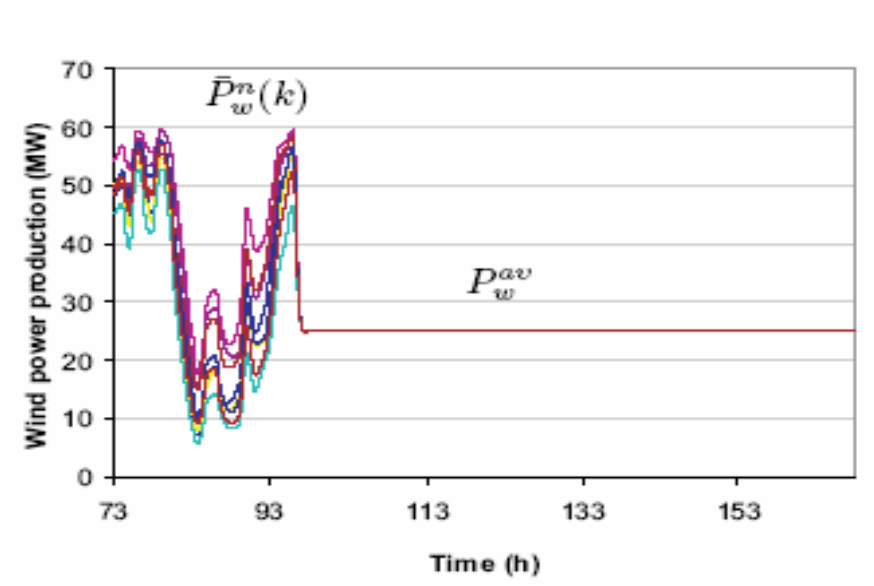
Planning algorithm, base case

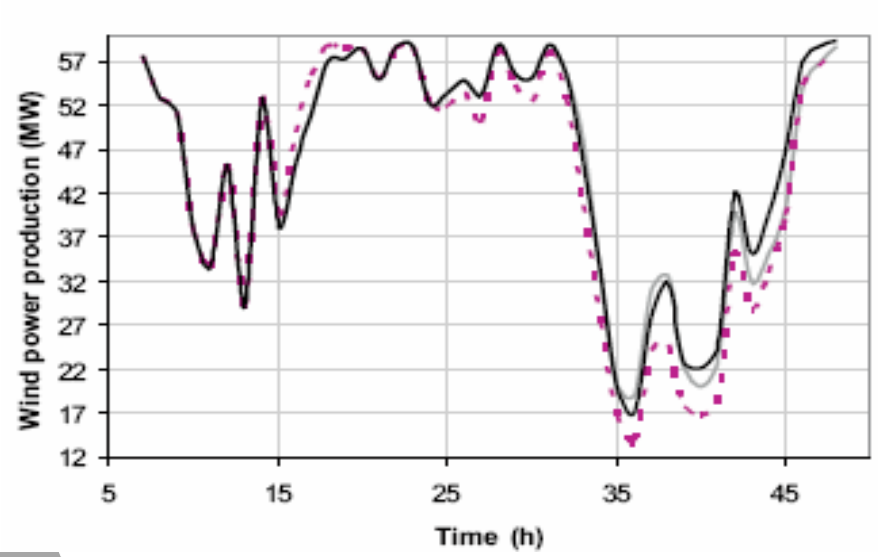


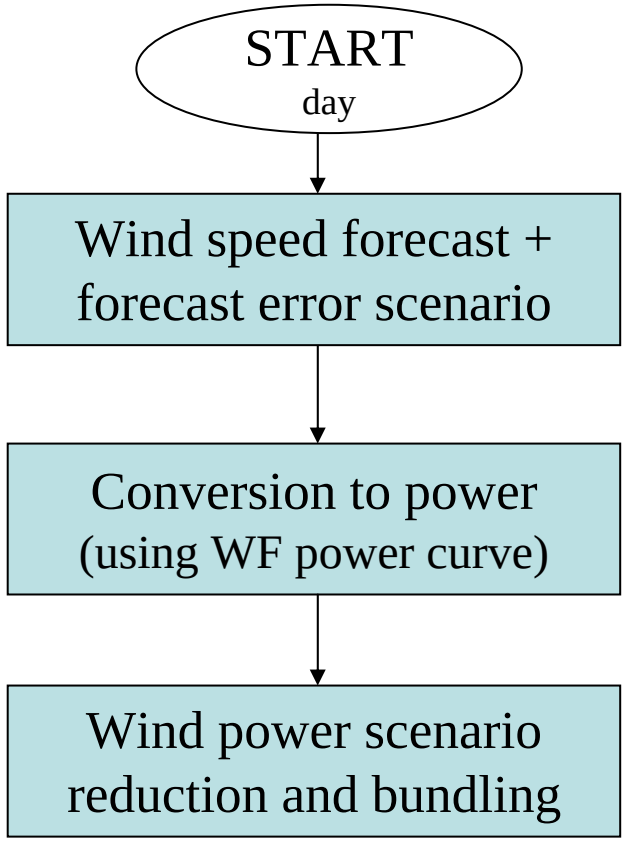
Linear stochastic optimisation

Hydrological constraints,
Transmission constraint,
Tech. and environ. limitations

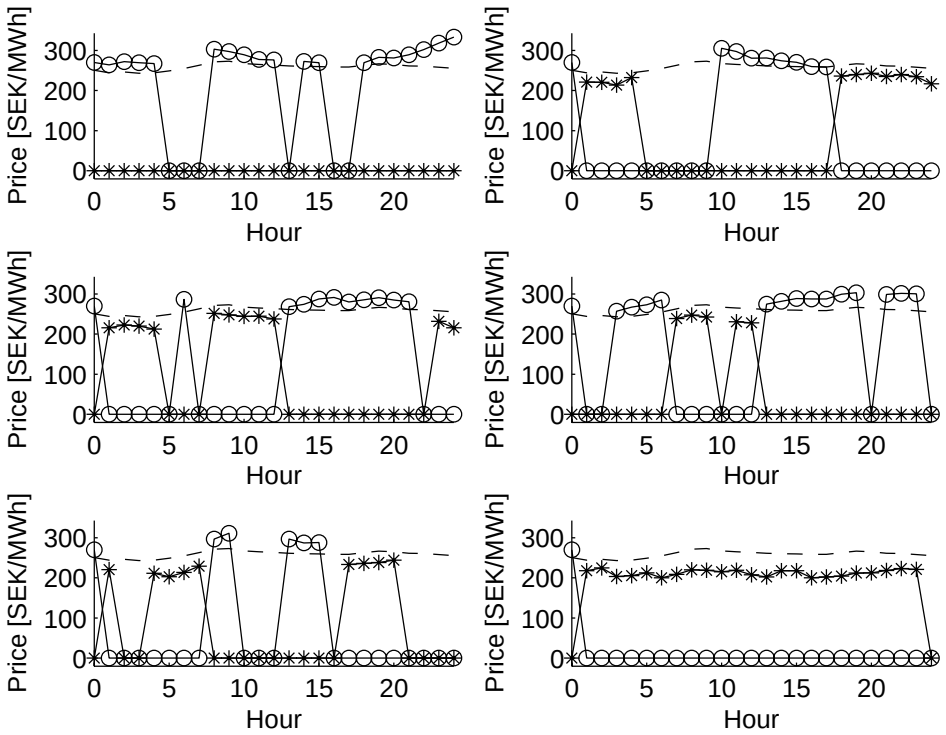
Planning algorithm, wind scenarios

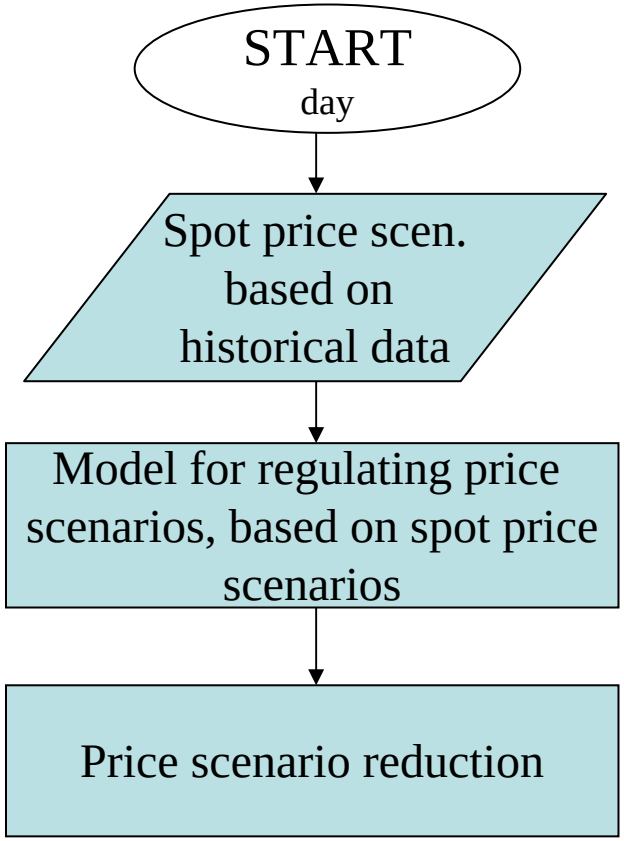




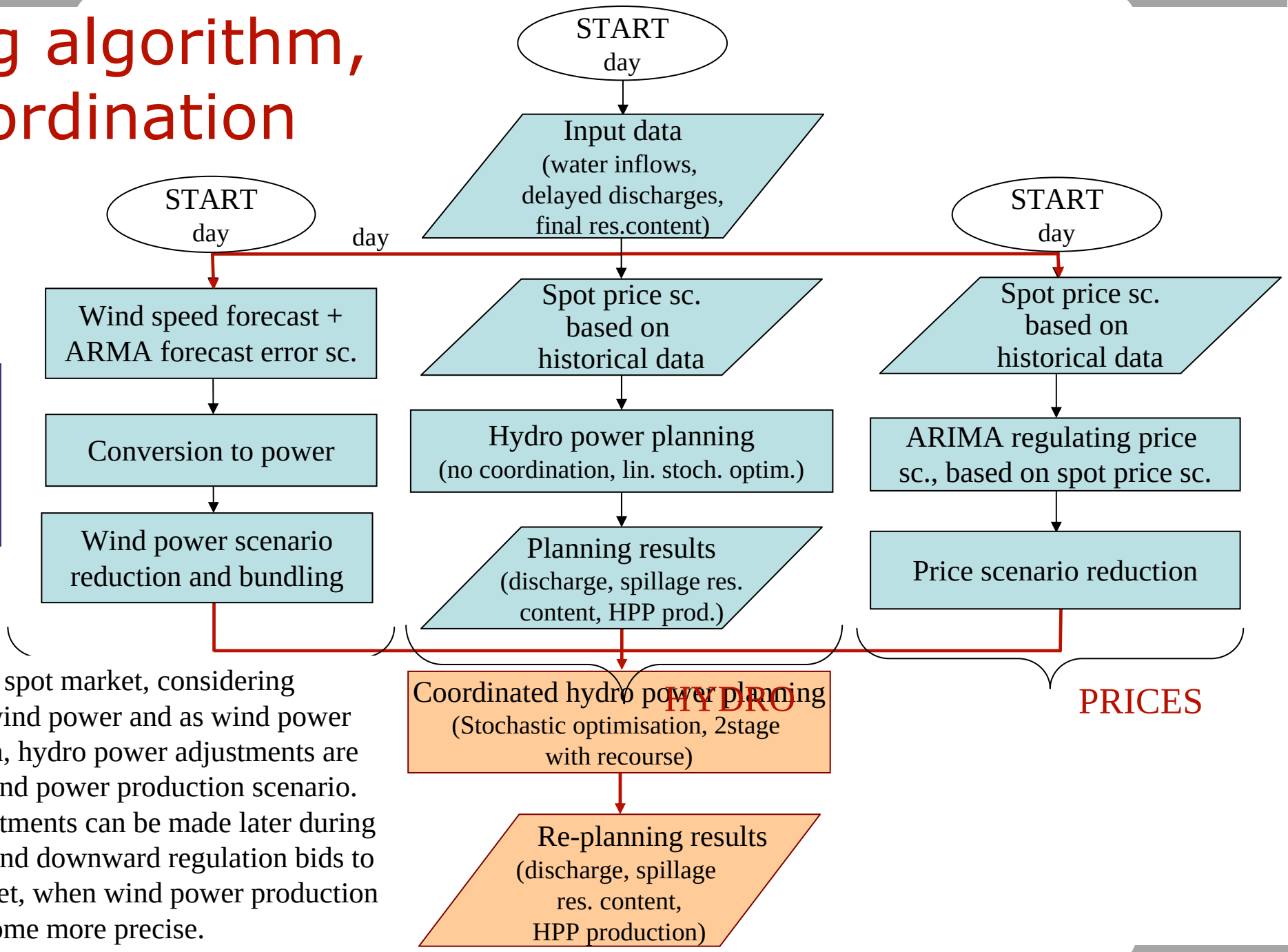


Planning algorith, market price scenarios



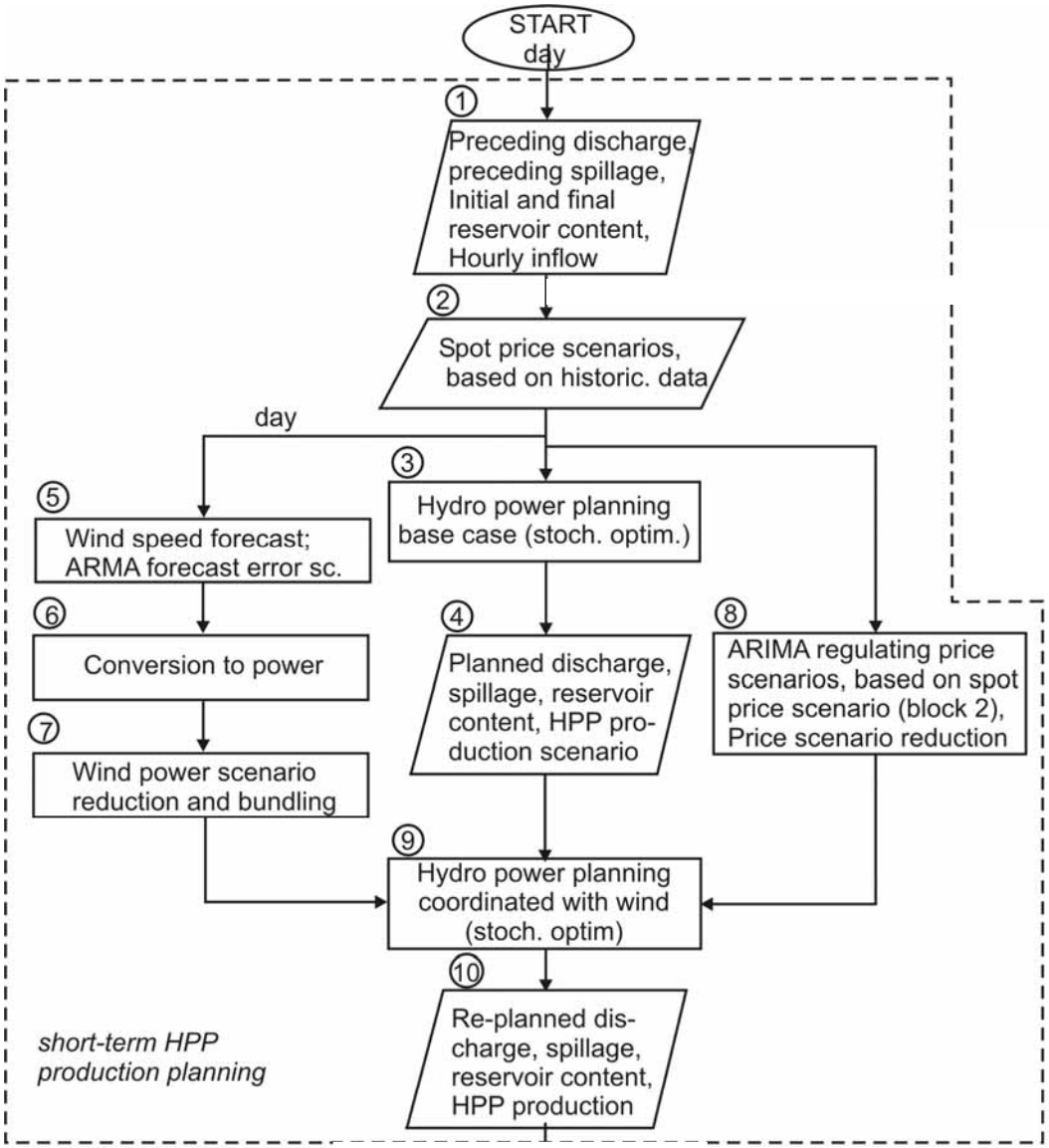


Planning algorithm, with coordination



Re-planning for the spot market, considering coordination with wind power and as wind power forecast is uncertain, hydro power adjustments are planned for each wind power production scenario. Bids for these adjustments can be made later during the day as upward and downward regulation bids to the regulating market, when wind power production forecast would become more precise.

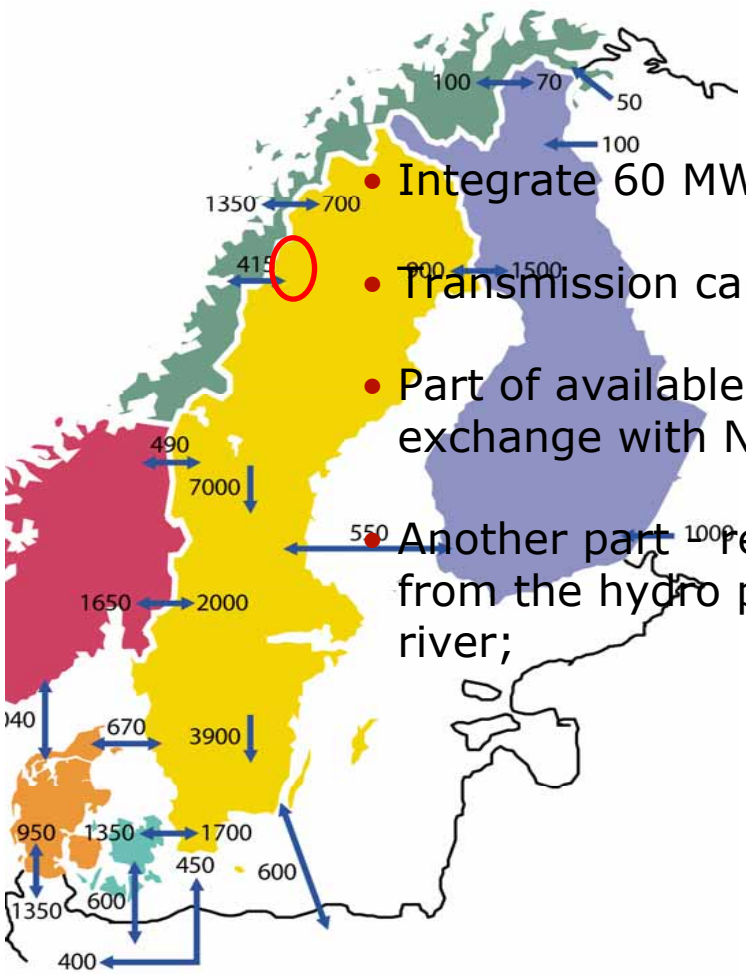
Planning algorithm, overview



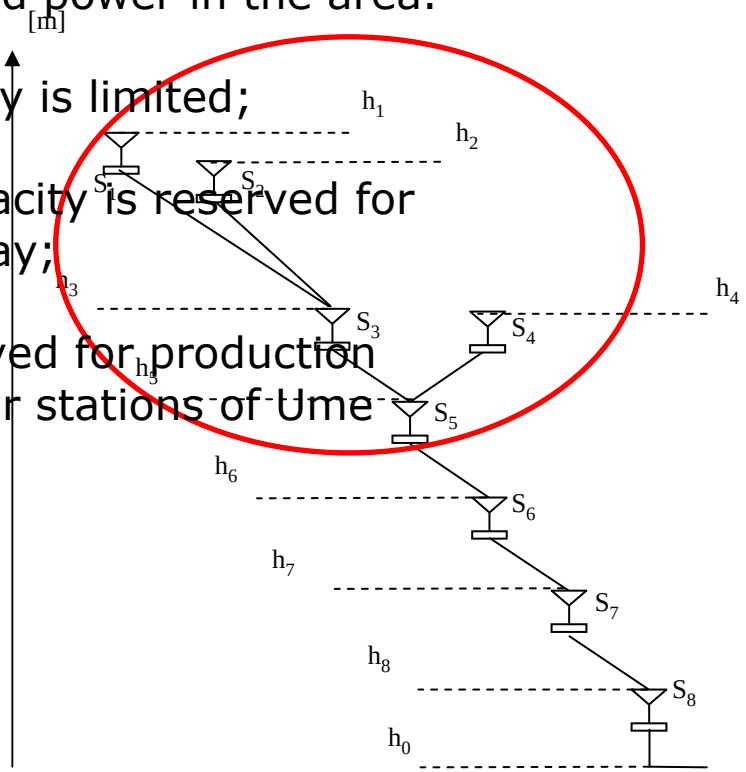
To evaluate the planning algorithm, it is repeated for each day succesively for one week

The results are compared to the uncoordinated planning for one week.

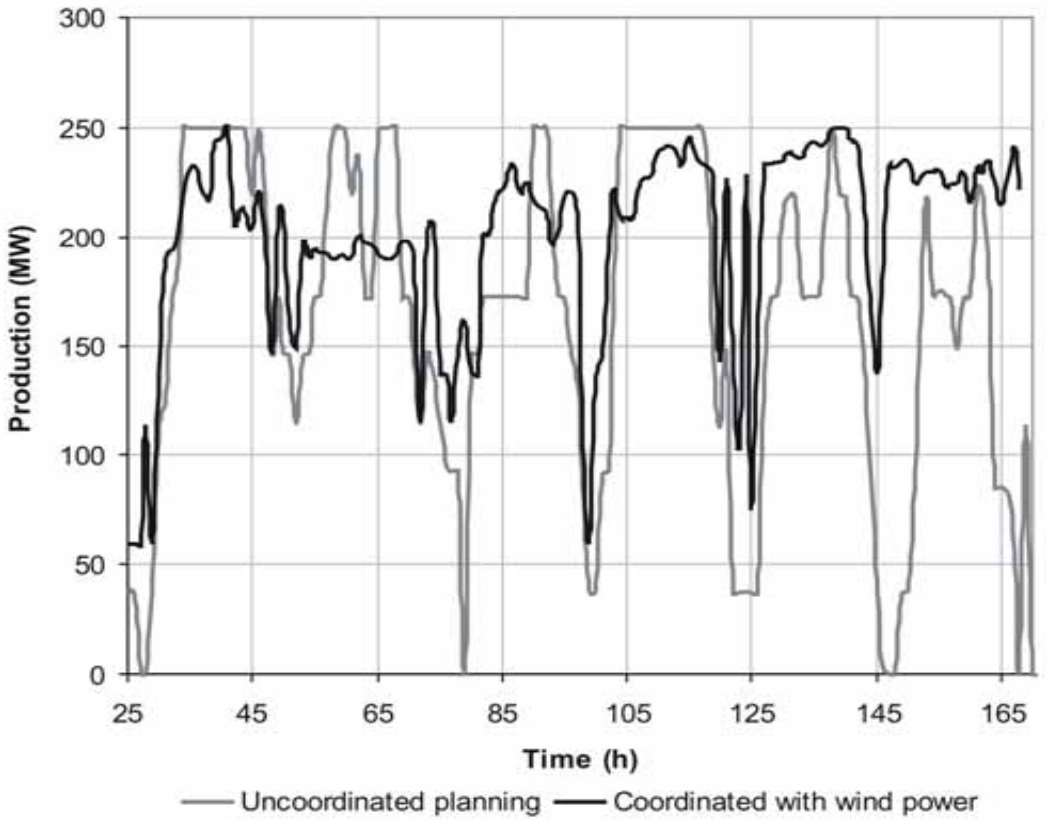
Case study



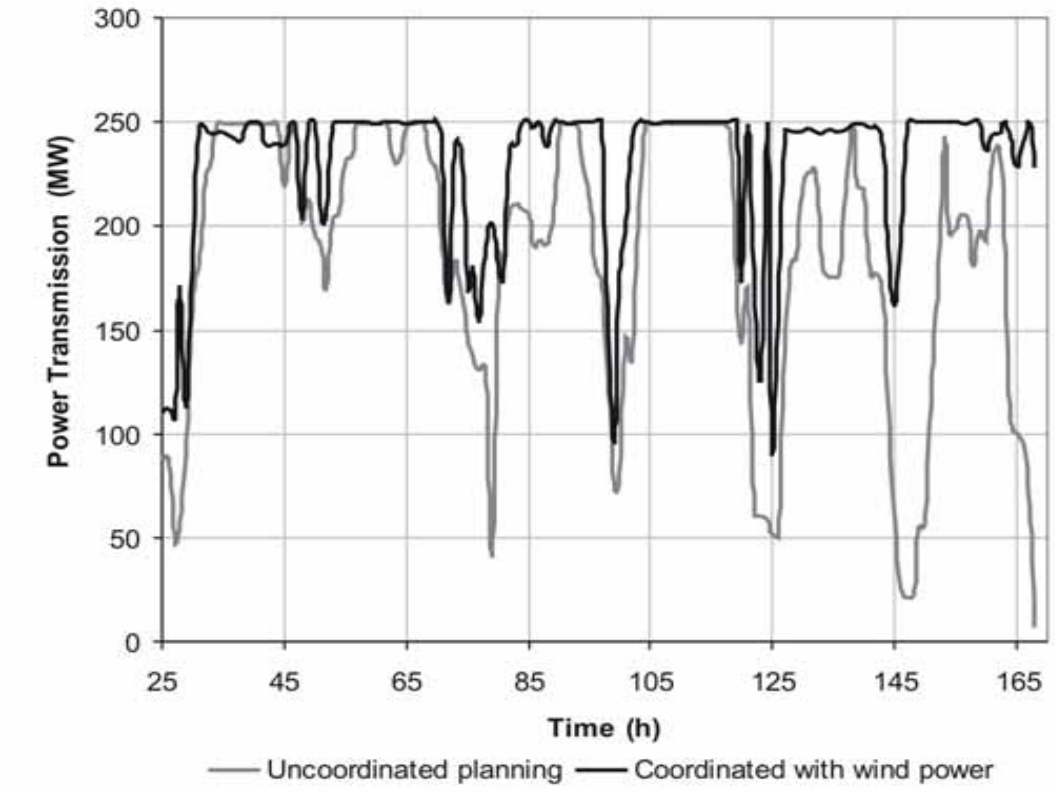
- Integrate 60 MW wind power in the area.
- Transmission capacity is limited;
- Part of available capacity is reserved for exchange with Norway;
- Another part reserved for production from the hydro power stations of Ume river;



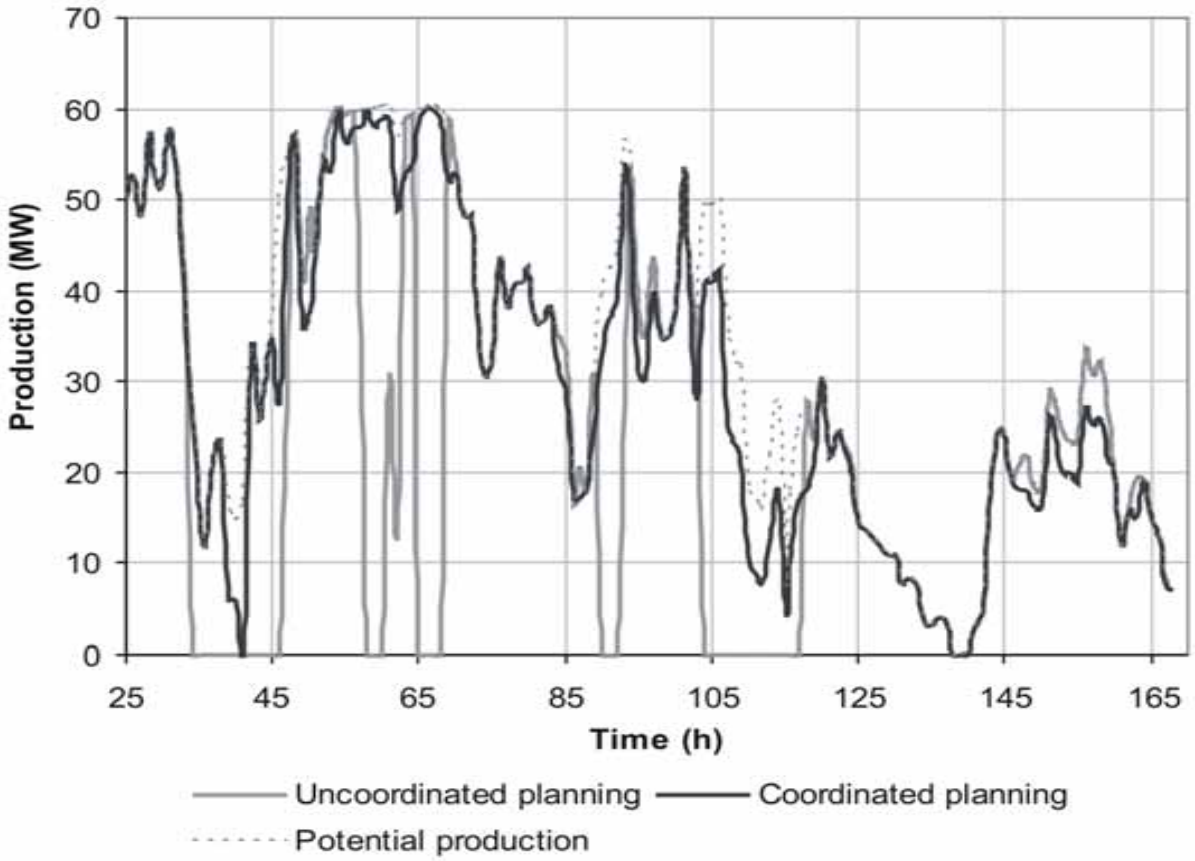
Coordinated planning results, 1 week, HPP production of 5st.



Coordinated planning results, transmission over the line



Coordinated planning results, wind power production



Coordinated planning results, 1 week, general results

- Wind energy curtailments are decreased by 75%, compared to the uncoordinated case;
- Income of the hydro power utility is increased by 3 MSEK, could be increased even more if e.g. weekly average wind power production would be used instead of monthly value;
- Income of wind farm owner is increase by 30 000 SEK. The difference is not high because maximum coordination price was assumed in the case study.

$$\text{Price for coordination} = \frac{\text{WF loses due to curtailments}}{\text{Total curtailed energy}}$$

Conclusions

- Coordination of wind power and hydropower can be mutually beneficial for both utilities;
- Coordination leads to substantial decrease of wind energy curtailments;
- Better utilization of the existing transmission capacity;

Future Work

- Investigate the importance of water inflow uncertainty and include it in the model if necessary.
- Market price and wind power production models could also be improved
- A longer case study would need to be conducted in the future.
- The impact of the coordination on start-ups and efficiency of the hydro power plants should be investigated.
- Analyse the results of the case study and try to extract “common guidelines” for similar cases

„Common guidlines“

A=MW of hydro power connected to a transmission line;

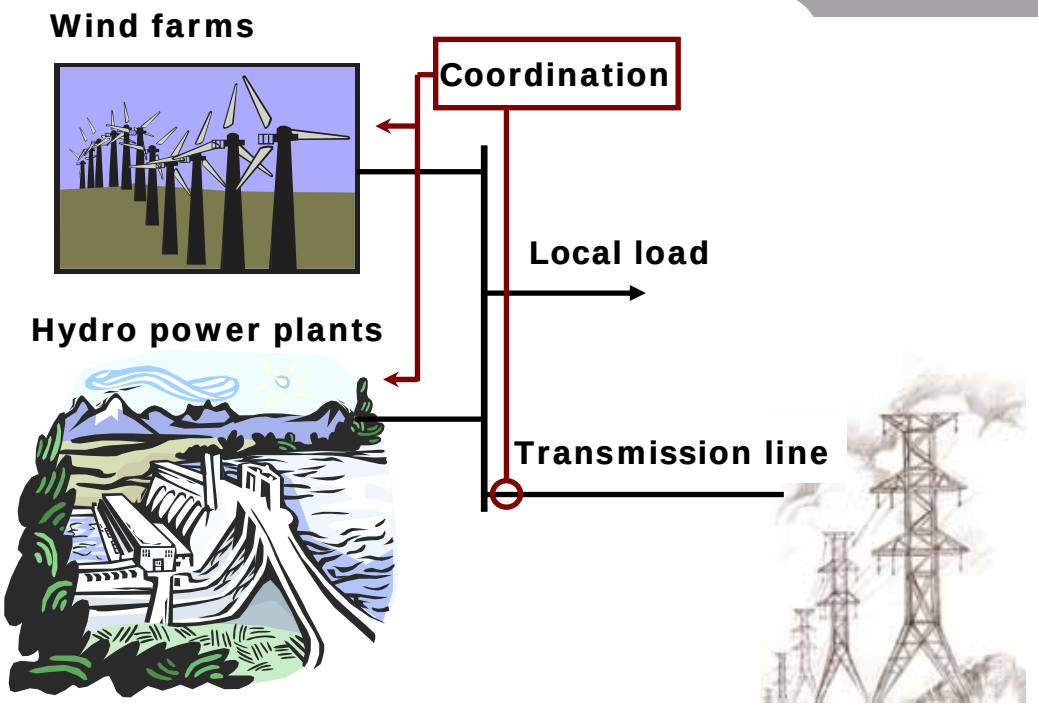
B=MW of wind power planned to be connected to that line;

C=MW transmission capacity of the line;

1. if C-A<B≤**F(A,B,C)** then coordination is an interesting option, which needs to be investigated;
2. if B>**F(A,B,C)** then wind energy curtailments would be too high (even with coordination) and economical solution would be to increase transmission capacity;

where **F(A,B,C)** is a function of A,B,C obtained from analysis of the case study results.

In order to obtain reliable approximation of **F(A,B,C)** several case studies for different cases should be conducted and analysed.



Thank you!

Questions?