

Minimizing Regulation Costs in Multi-Area Systems with Uncertain Wind Power Forecasts



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Outline of presentation



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- Background
- Optimization model
 - Multi-area model
 - Optimization model
- Case study
- Results
- Conclusions

Aim of PhD project



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- A method to simulate the balance regulation within an hour to use reserves in an optimal way
- Determine costs for reserve power when there are large amounts of wind power
- Determine at which integration level the wind power has to take part in the balance regulation

The Nordic system

- Nordic system
 - 4 countries
 - 4 TSOs
 - hourly market
 - all TSOs can select bids in all countries
- Frequency control
 - primary control
 - secondary control
 - no AGC



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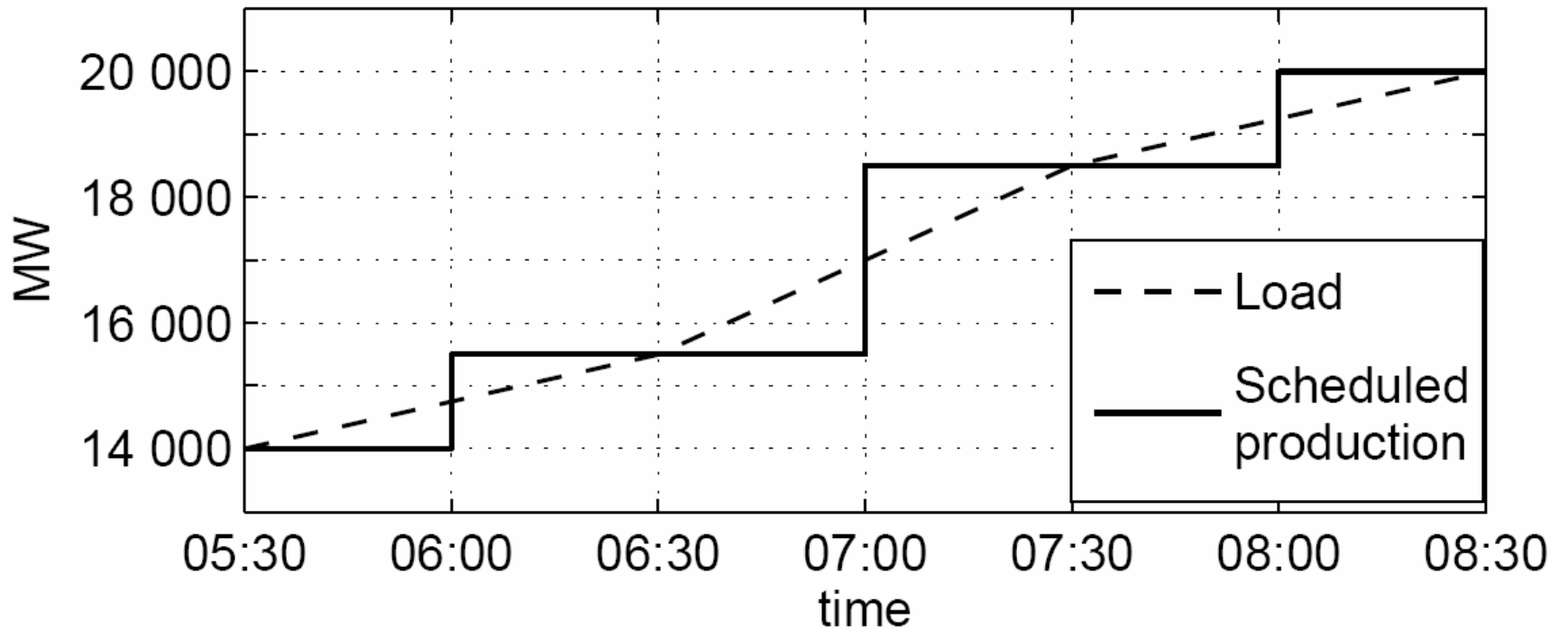
Frequency control



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- Primary control automatically balances small variations
- Secondary control handled by accepting regulating bids from bid list, containing
 - price
 - volume
 - location

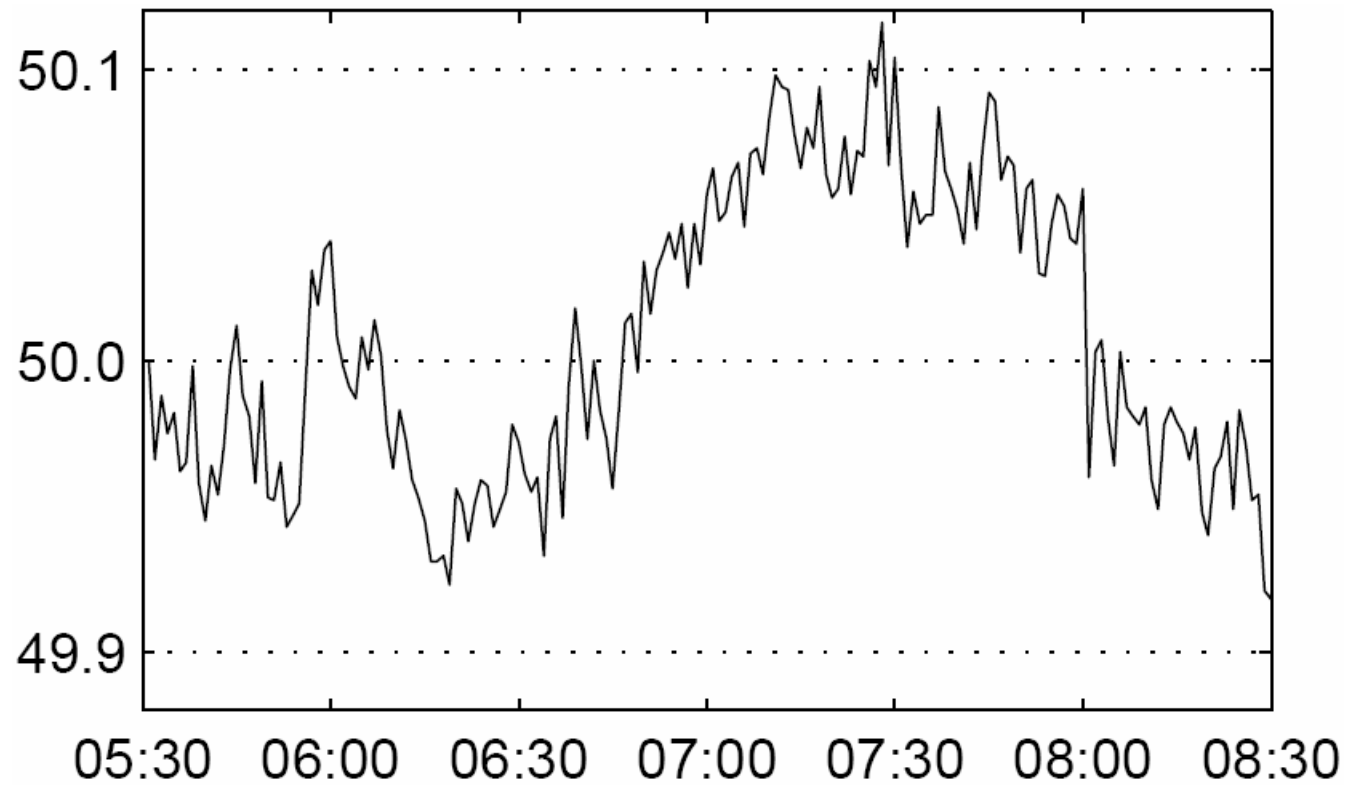
Typical morning



Measured frequency



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Solution: re-scheduling

- Instead of using bids from the regulating market around change of hour, the producers are paid to re-schedule planned production changes (at least in Sweden)



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Transmission limits



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- If transmission limits are reached, it is necessary to balance load variations in the same area as the consumers are located
- In Sweden, this can sometimes be a problem, since most of the consumption is located in the south, and most of the production/regulating power is located in the north

Wind power impact



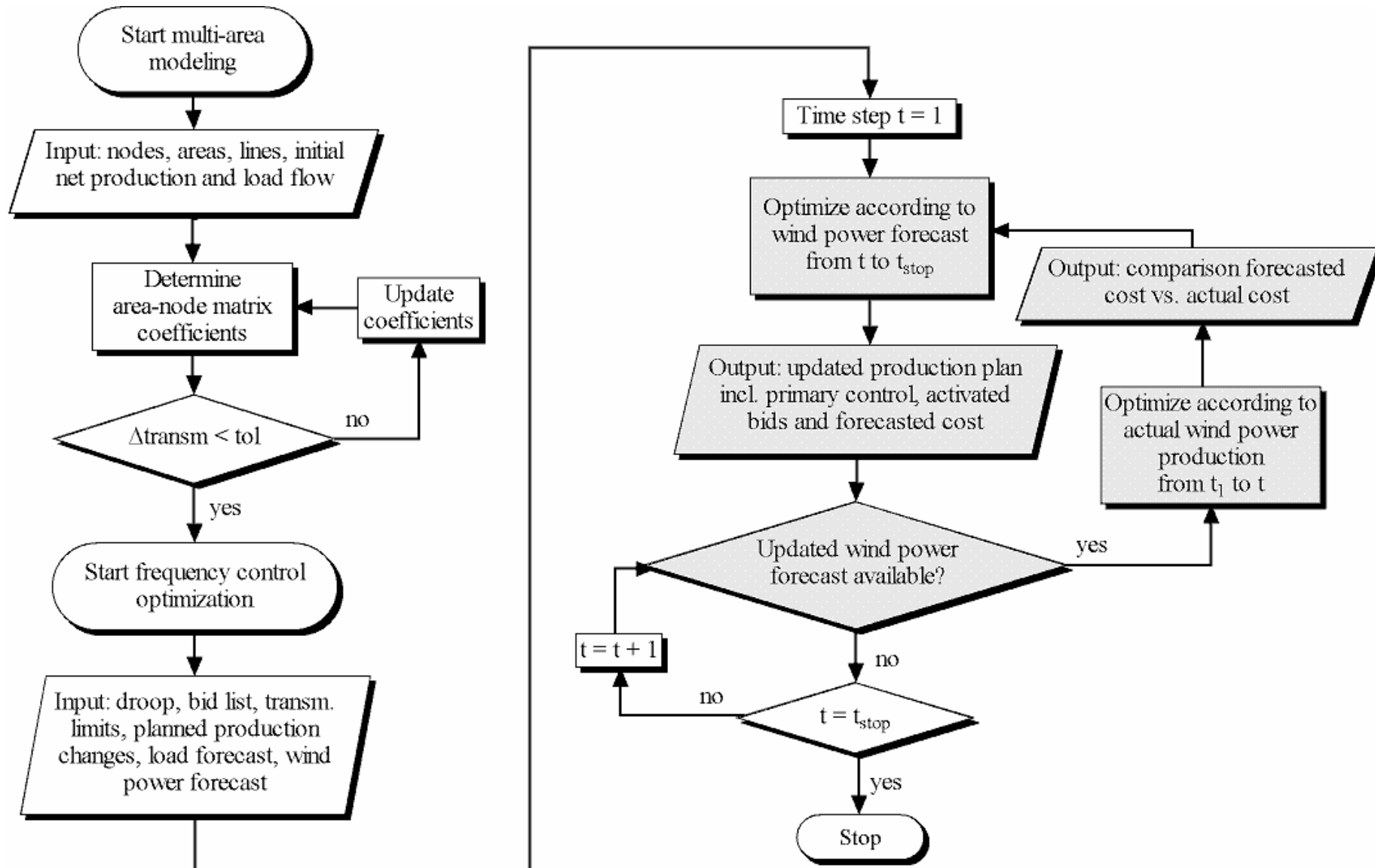
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- Wind power varies as wind speed varies, and variations can be large within an hour
- Both variations of wind power production and load must be balanced, instead of only balancing the load variations
- Wind power plants are normally used at the maximum possible level, not keeping reserves

Simulation method



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Multi-area model



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- Simplified model with all nodes aggregated into a few areas
- Limited transmission capacity between areas, no losses
- Transmission calculated from DC load flow

Optimization model

Determine

- when to accept bids of regulating power, and which bids, to minimize regulation costs
- costs of regulating power



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Objective

- Minimize costs for secondary control (bids)

Constraints on power & frequency



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- Power from primary reserves is determined in proportion to droop
- Scheduled production changes can be re-scheduled up to 15 minutes earlier or later
- Frequency is determined from changes in net production, droop and previous frequency
- Frequency should stay within 50 ± 0.1 Hz
- Time deviation less than 30 sec

Constraints on bids

- Any volume of a bid can be used up to the maximum available volume
- A bid is stopped at change of hour or earlier
- A bid can only be used the hour it is available



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Constraints on transmission

- Transmission should stay within limits

Successive deterministic optimization



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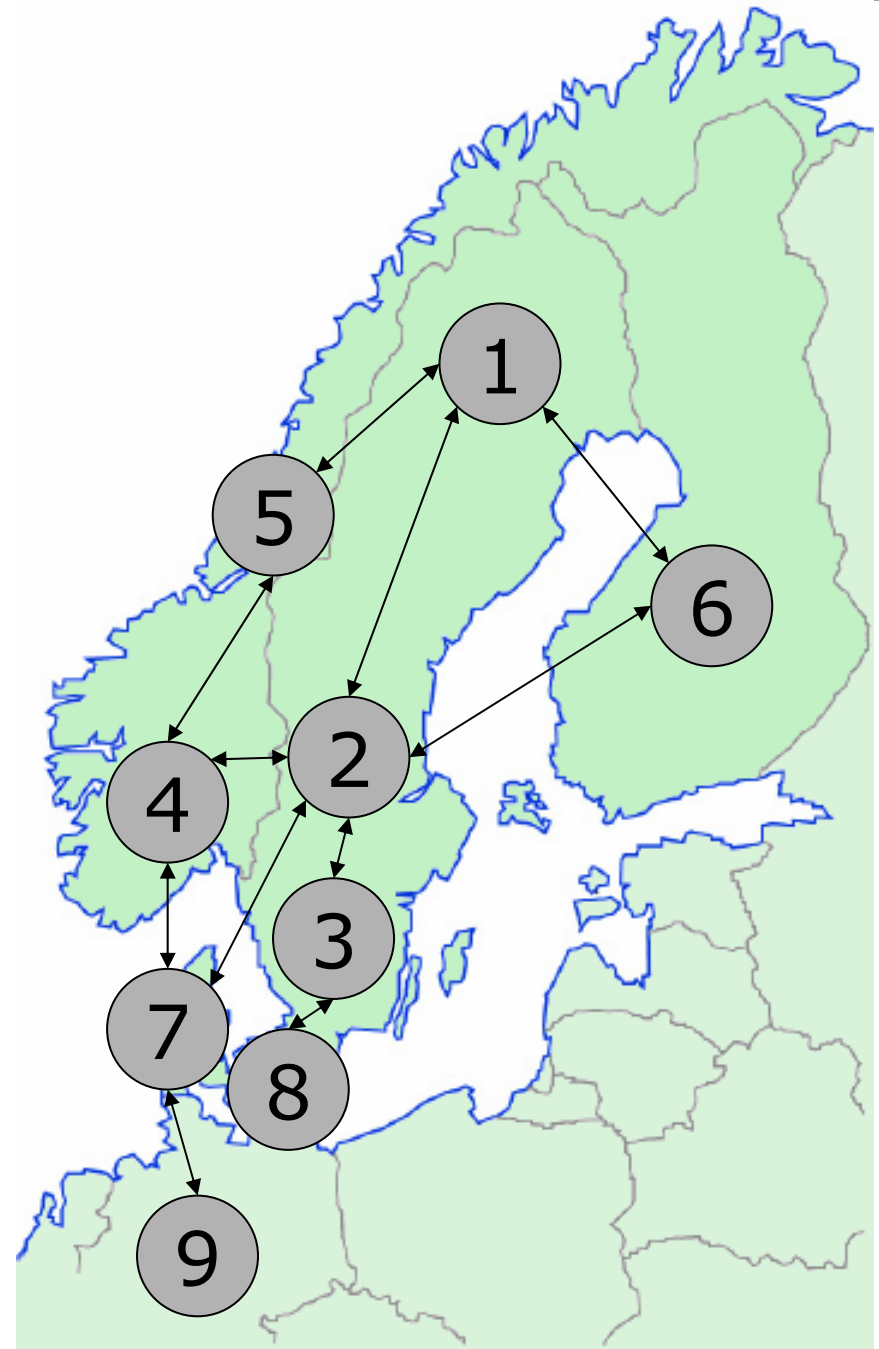
- If an updated wind power forecast is available, the problem is re-optimized
- Calculation is made in time steps of 5 min
- Deterministic data
 - Available bids: prices, volumes, locations
 - Scheduled production changes
 - Loads
 - Speed-droop characteristics [MW/Hz]
 - Transmission limits
 - Wind power production

Case study

- The Nordic system divided into 9 areas
 - 1,2,3 Sweden
 - 4,5 Norway
 - 6 Finland
 - 7,8 Denmark
 - 9 Germany



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3 cases

- Case 1: Planning with persistence forecast
- Case 2: Planning with perfect forecast
- Case 3: Without wind power



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Resulting costs



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	Case 1	Case 2	Case 3
Cost for bids	68 200	39 200	32 700
Cost for re-scheduling	891 300	430 200	438 000
Total cost	959 500	469 400	470 700

Comments



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- The difference between forecasted and actual wind power production is small compared to changes in load and scheduled production
- Up-regulation is used almost all the time, except around change of hour, when down-regulation instead is necessary to compensate for the large step increase in production
- About half of the scheduled production is moved to an earlier time step

Comments



- More down-regulation is used in Case 2 than in Case 1, when wind power production is higher than forecasted
- Less down-regulation is used in Case 3 than in Case 1
- Transmission limits also have impact on costs, when additional bids must be accepted to avoid overload

Conclusions



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- If wind power production is higher than forecasted when there is a power deficit, as in Case 2 at the end of the first hour, then this can lower the cost of TSO
- In a similar way, cost increases in Case 3, when there is less wind power than forecasted
- The model is deterministic, fast and easy to implement
- The model can be extended to include stochastic optimization to more accurately describe the TSO situation in a system with large amounts of wind power

Publications

- E. Lindgren, L. Söder, *Power System Modeling for Multi-Area Regulating Market Simulation*, in Proceedings of PowerTech'2005, June 27-30, 2005, St.Petersburg, Russia.
- E. Lindgren, L. Söder, *Minimizing Regulation Costs in Multi-Area Markets*, in Proceedings of 15th Power Systems Computation Conference PSCC'05, August 22-26, 2005 Liège, Belgium.
- E. Lindgren, L. Söder, *Wind Power Impact on Costs for Regulating Power in Multi-Area Markets*, in Proceedings of Fifth International Workshop on Large-Scale Integration of Wind Power and Transmission Networks for Offshore Wind Farms, April 7-8 2005, Glasgow, Scotland.
- E. Lindgren, L. Söder, *Minimizing Regulation Costs in Multi-Area Systems with Uncertain Wind Power Forecasts*, in Proceedings of Nordic Wind Power Conference NWPC '2006, May 22-23 2006, Espoo, Finland.

Accepted for publication

- E. Lindgren, L. Söder, *Minimizing Regulation Costs in Multi-Area Systems with Uncertain Wind Power Forecasts*, in Wind Energy Journal

Thank you



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