BEST PROFITS

A new curve module in SHOP for bidding in mFRR
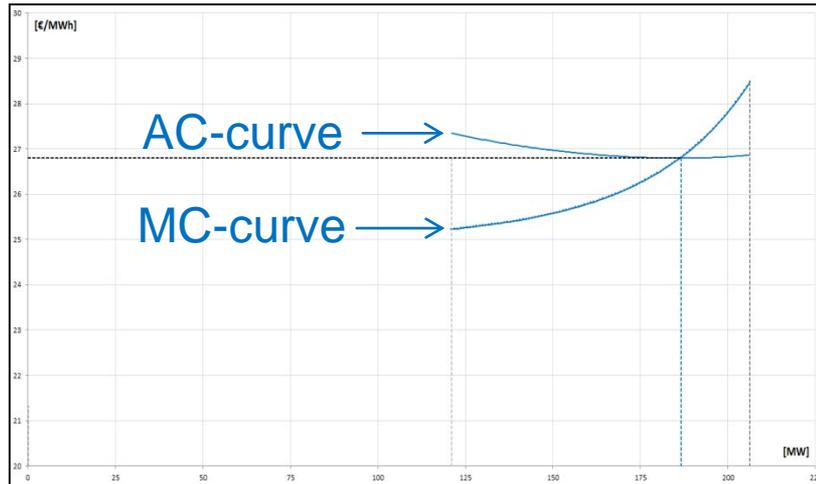
Tellef Juell Larsen

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Theory and terminology

- AC = Average cost = Cost/Prod

- MC = Marginal cost = δCost/δProd

- MC intersects AC in the best operating point, i.e. the watervalue

- Optimum market adaption
  - Max profit
  - Profit >0

- Spot market*

Max Profit	Profit > 0
Max {Price*Prod – Cost} δProfit / δProd = 0 Price – MC = 0 **Price = MC**	Price*Prod - Cost > 0 Price > Cost/Prod **Price > AC**

*for a price taker in a single price spot market ignoring other costs than water consumption

- Both conditions are applicable when bidding in mFRR

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BestProfits?

▸ BestProfit is a curve (BP-curve) that shows
- the <u>plant</u> production
- that gives the best profit
- as a function of the market price
- in a timestep
- considering relevant costs and constraints

▸ The BP-curves are primarily developed for bidding in mFRR (RK)
- Can in principle be used for bidding in other energy markets
- Will focus on mFRR in this presentation

▸ The development was started in Q3 2016
- Will be finished in Q2 2017
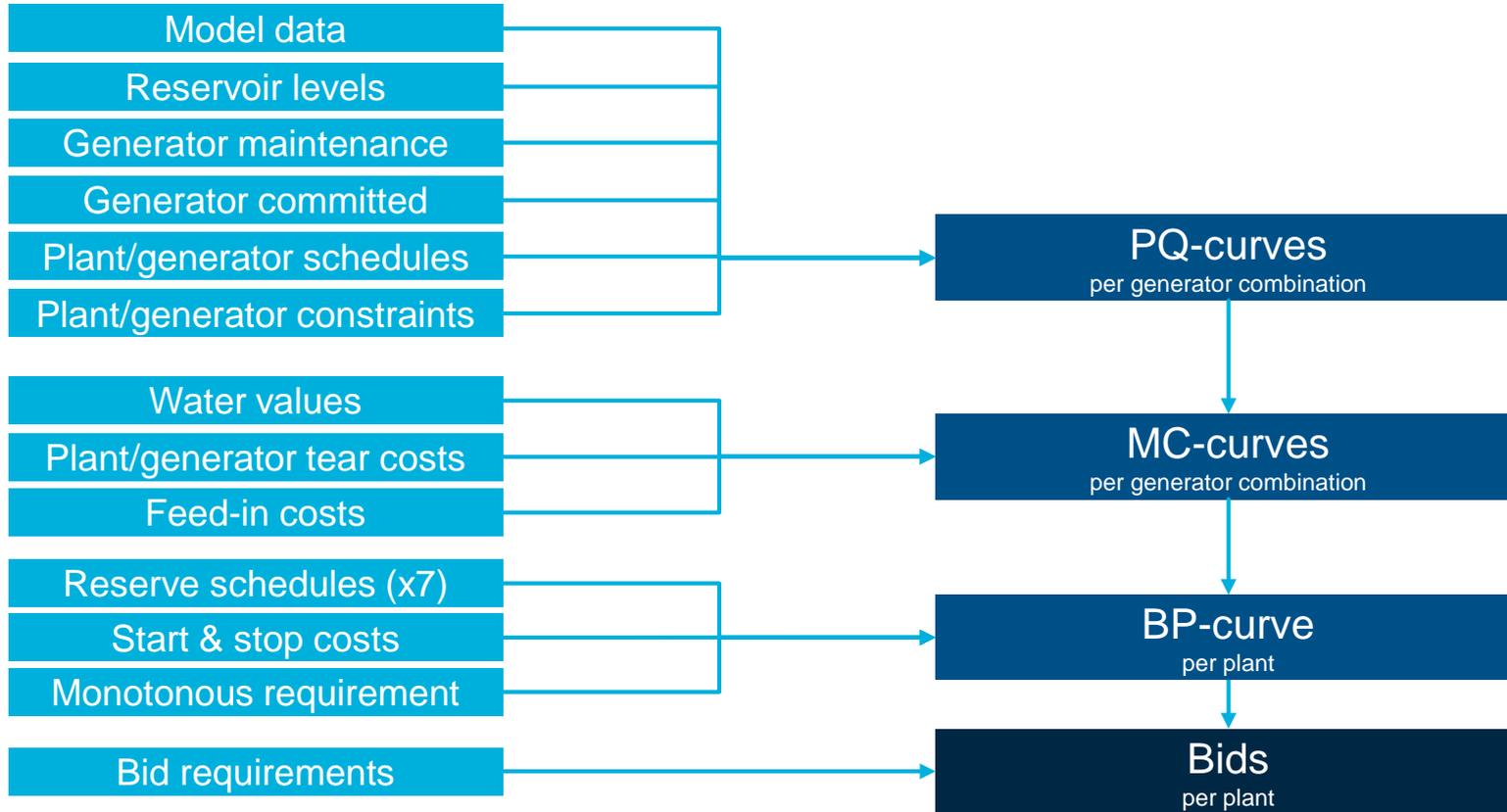- Early version was taken into operative use on Monday

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Why?

▸ MC-module already exists in SHOP
- Calculates PQ-, MC- and AC-curves
- With some errors and weaknesses

▸ We have been using the MC-module since 2010 for mFRR/RK-bidding
- In-house user interface
- Applies the PQ-curves and converts them to bids
- User interface outdated - mainly due to requirements of 15 min bidding

▸ Opportunity to
- Improve and use the AC/MC-calculations in SHOP
- Simplify the handling of Pelton turbines
- Move the calculation of BestProfit-curves into SHOP
- We also thought of using SHOP to calculate bids as well

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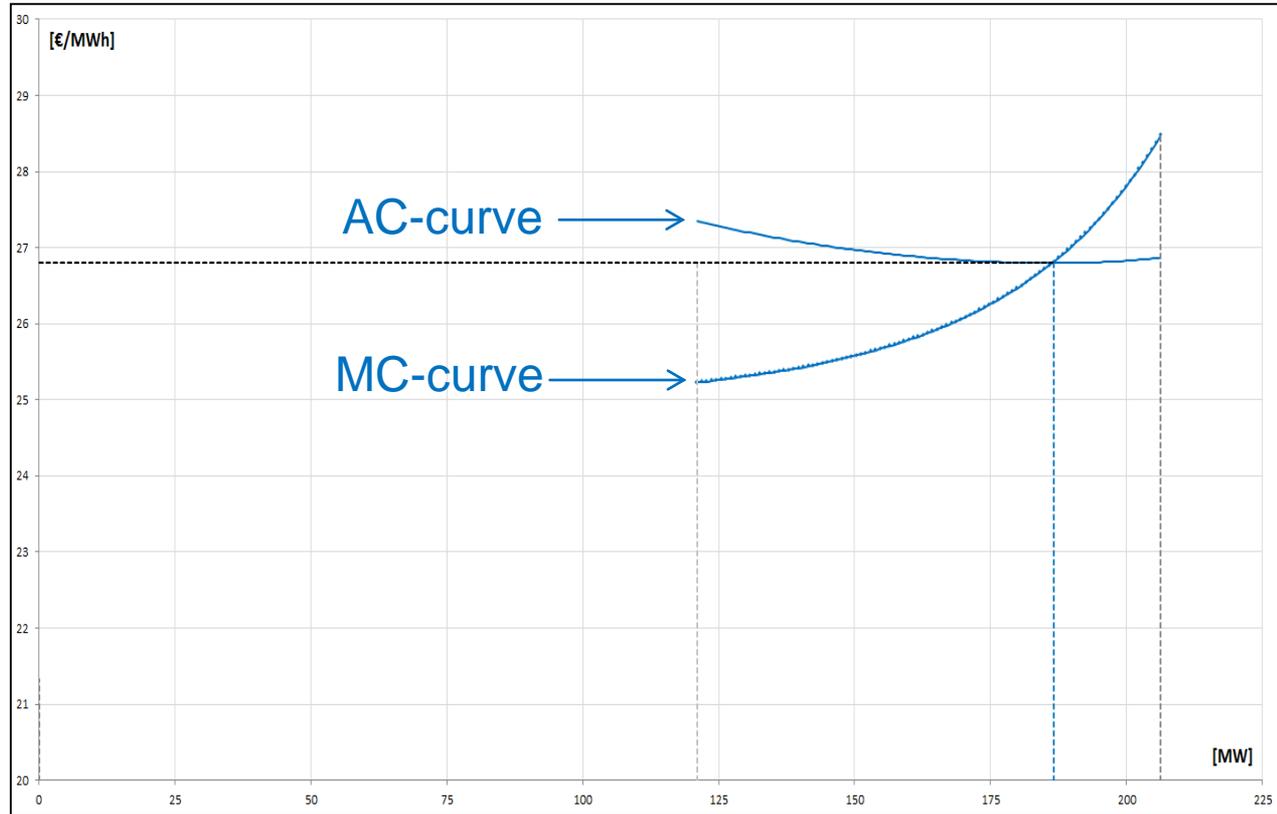
How?

Model data
Reservoir levels
Generator maintenance
Generator committed
Plant/generator schedules
Plant/generator constraints

→ **PQ-curves**
per generator combination

Water values
Plant/generator tear costs
Feed-in costs

→ **MC-curves**
per generator combination

Reserve schedules (x7)
Start & stop costs
Monotonous requirement

→ **BP-curve**
per plant

Bid requirements

→ **Bids**
per plant

EXAMPLES

One generator

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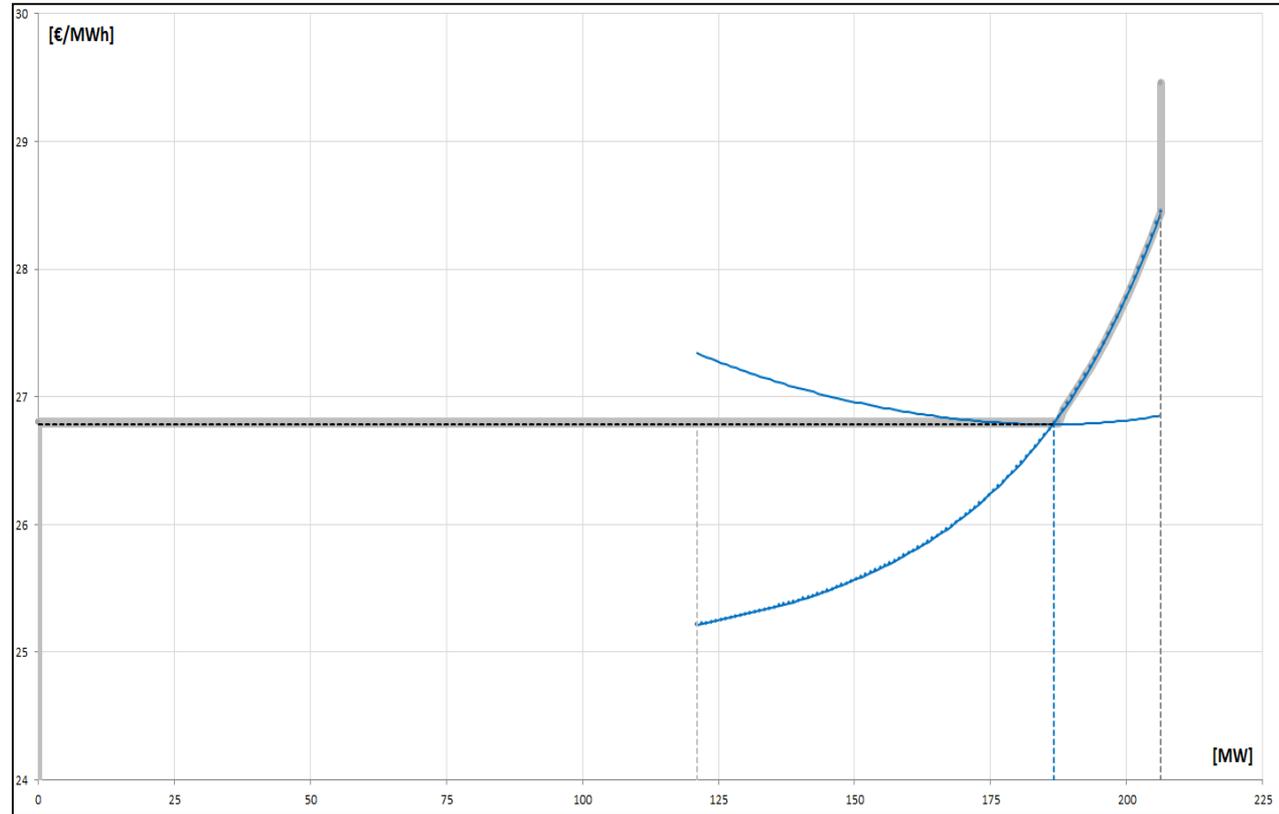
Examples: One generator

A. AC- and MC-curves

B. BP if decommitted & zero start/stop-costs

C. BP if decommitted & start/stop-costs >0

D. BP if committed

E. BP if must run

F. BP if reserves

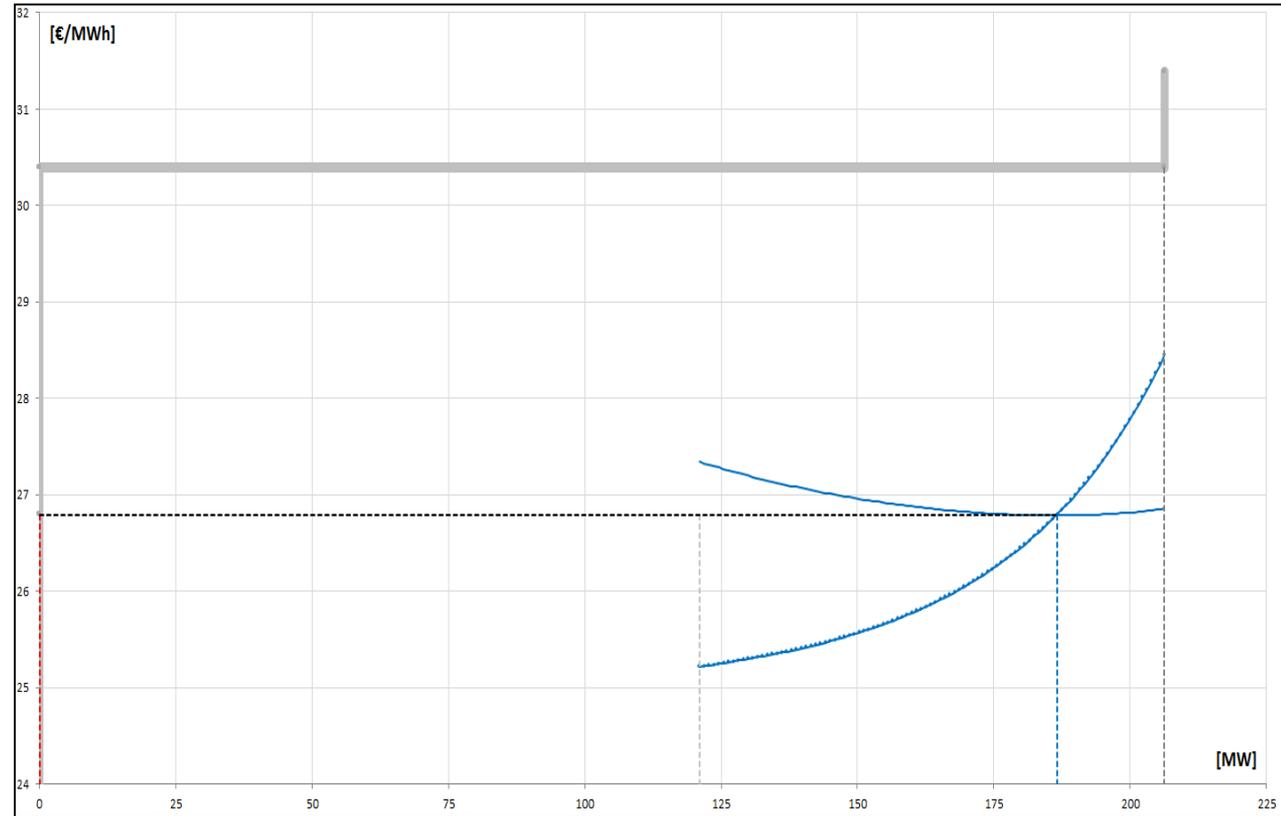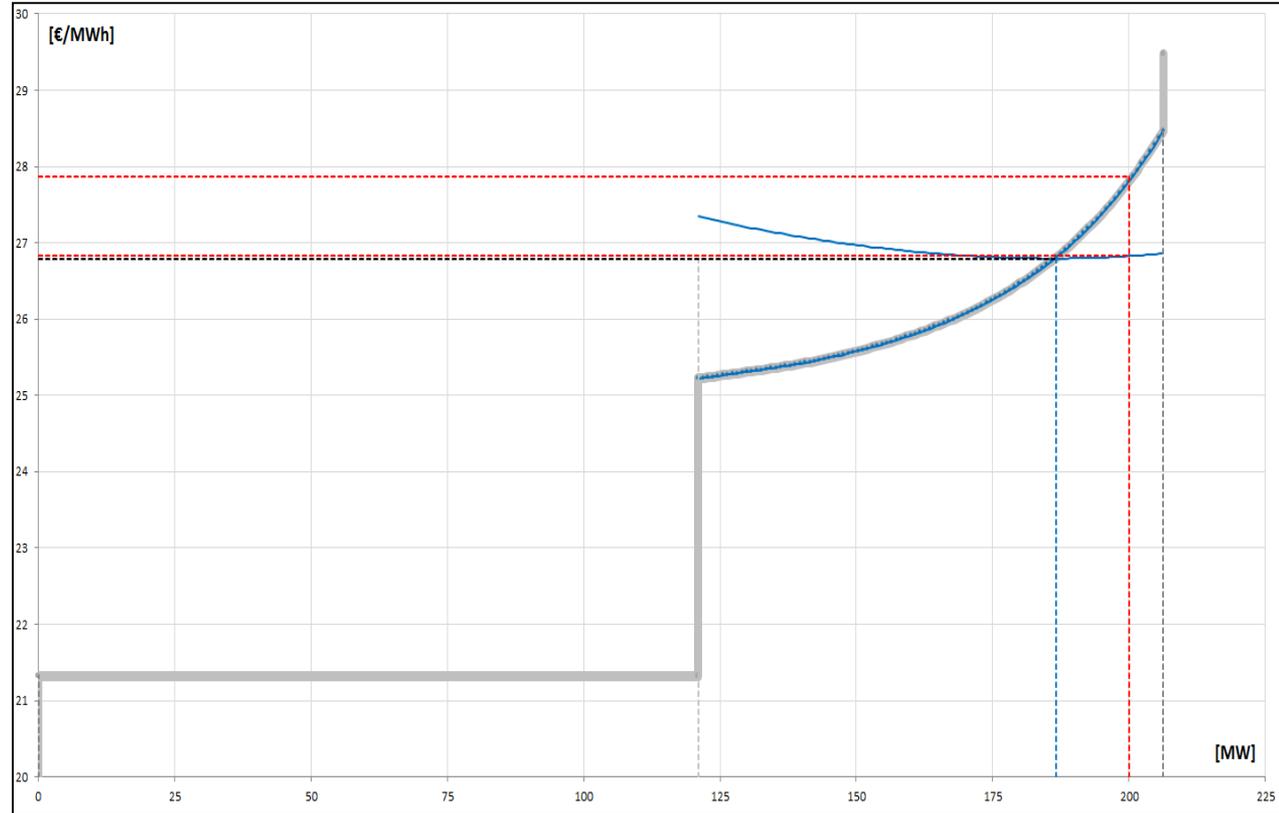# Examples: One generator

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Examples: One generator

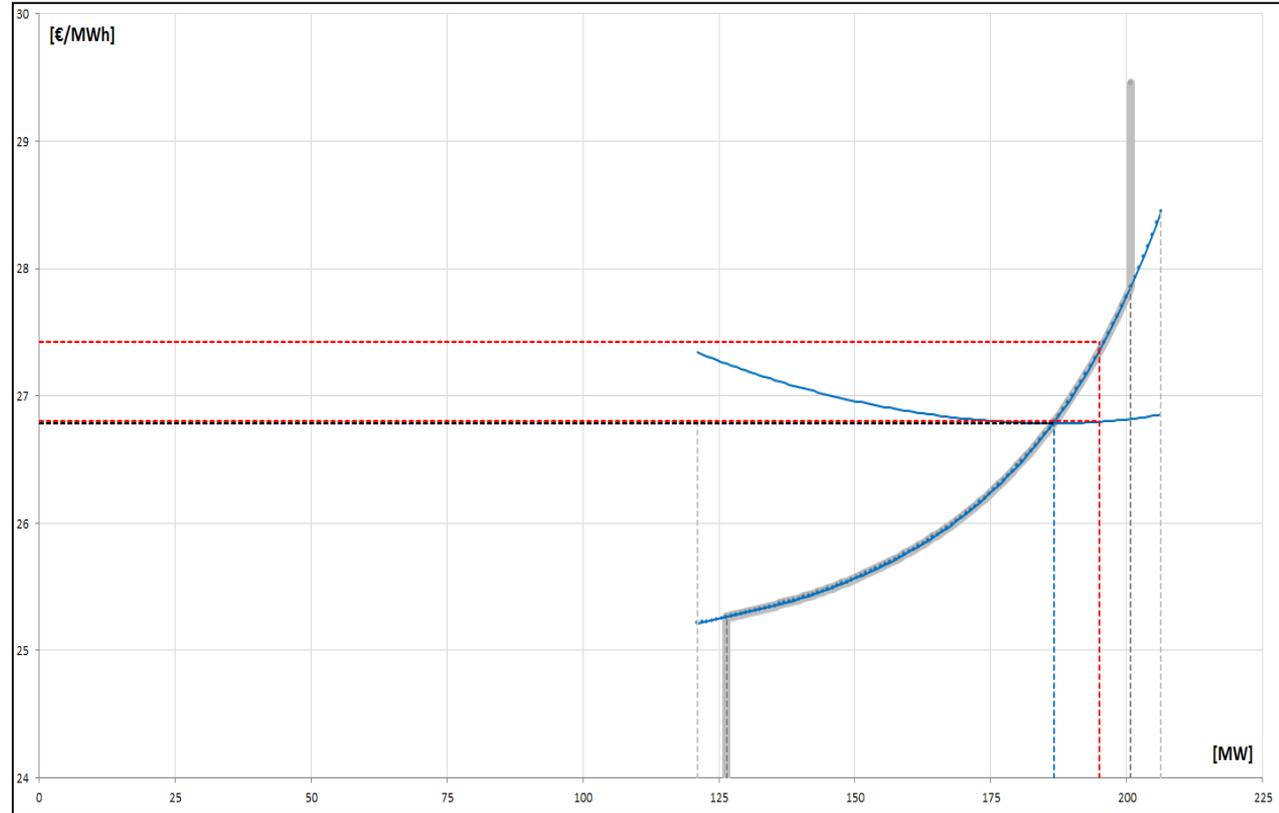A. MC- and AC-curves

B. BP if decommitted & zero start/stop-costs

C. **BP if decommitted & start/stop-costs >0**

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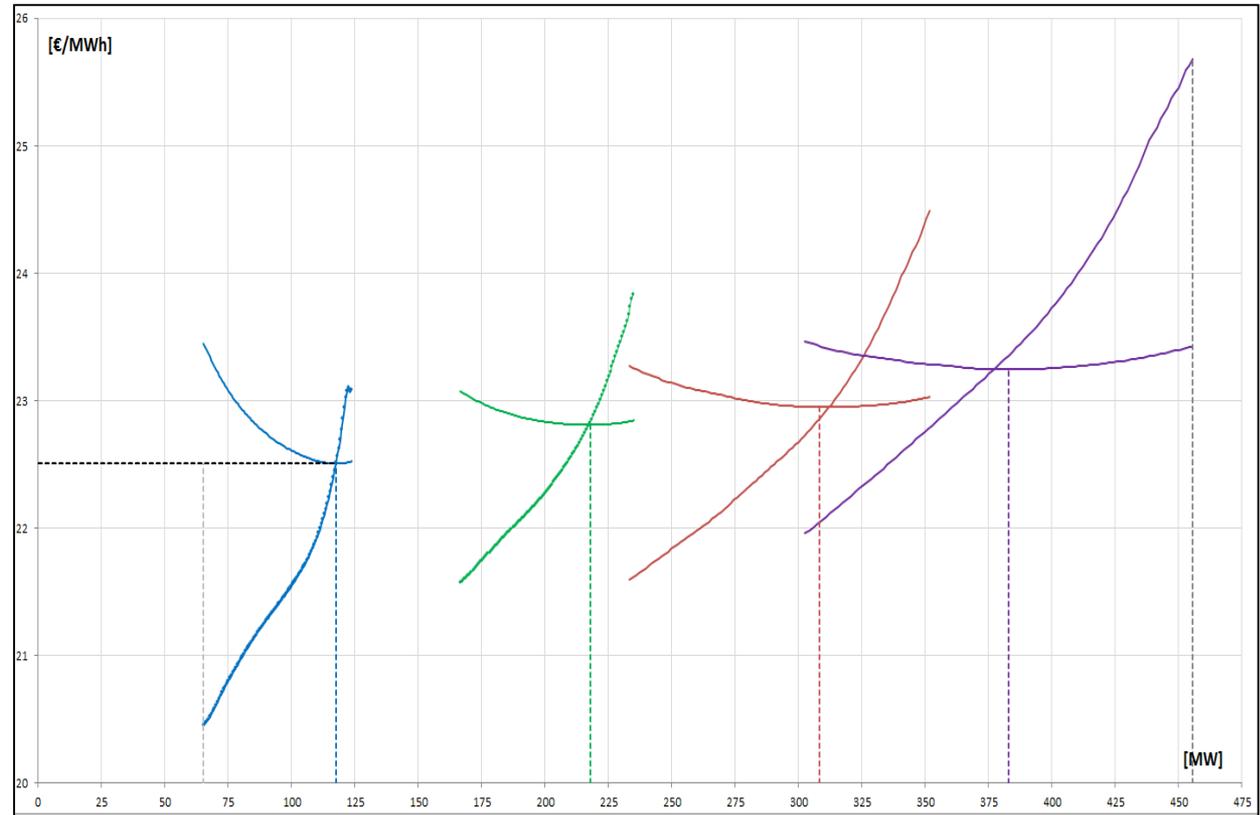# Examples: One generator

A. MC- and AC-curves

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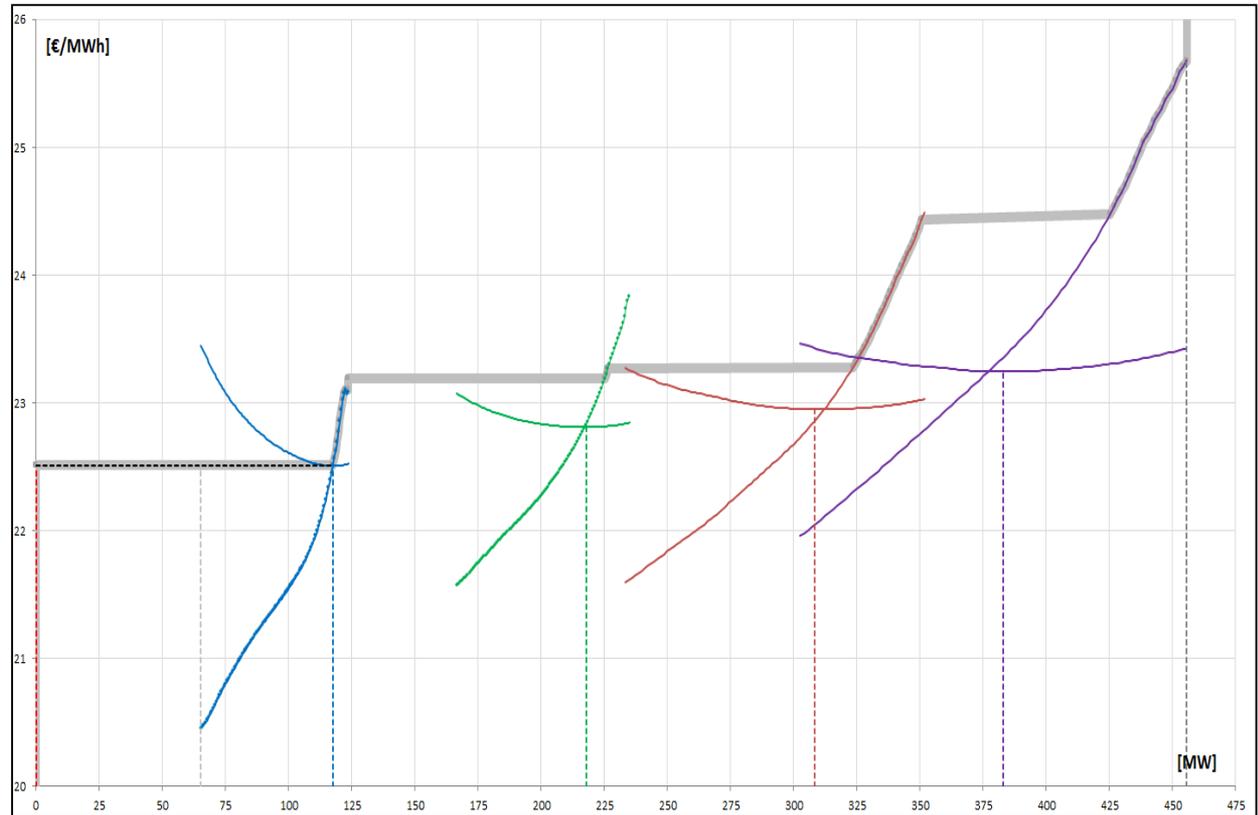E. BP if must run

F. BP if reserves

EXAMPLES

Four generators

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Examples: Four generators

A. MC- and AC-curves

B. BP if decommitted & zero start/stop-costs

C. BP if decommitted & start/stop-costs >0

D. BP if 2 committed and1 must run

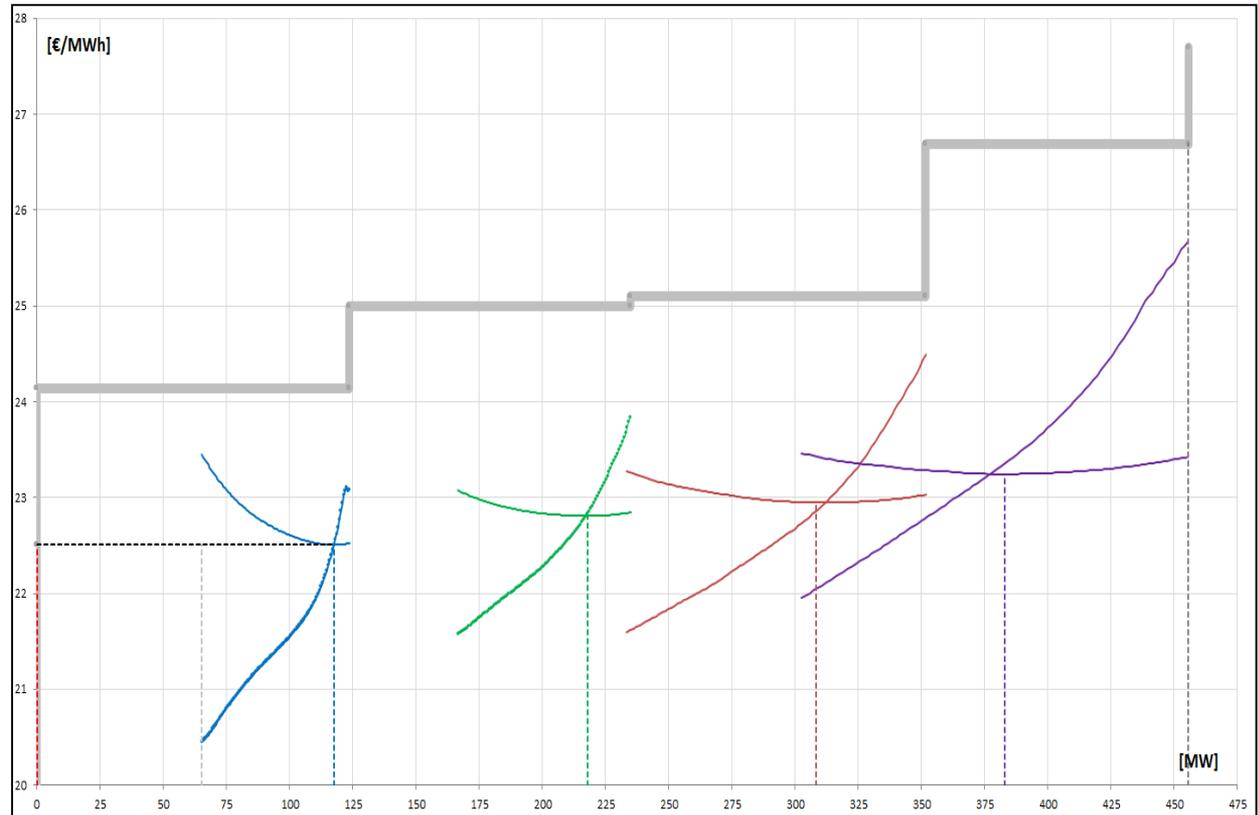E. BP if 4 committed and 2 with reserves

F. BP if all with reserves

Examples: Four generators

A. MC- and AC-curves

B. BP if decommitted & zero start/stop-costs

C. BP if decommitted & start/stop-costs >0

D. BP if 2 committed and1 must run

E. BP if 4 committed and 2 with reserves

F. BP if all with reserves

Examples: Four generators

A. MC- and AC-curves

B. BP if decommitted & zero start/stop-costs

C. BP if decommitted & start/stop-costs >0

D. BP if 2 committed and 1 must run

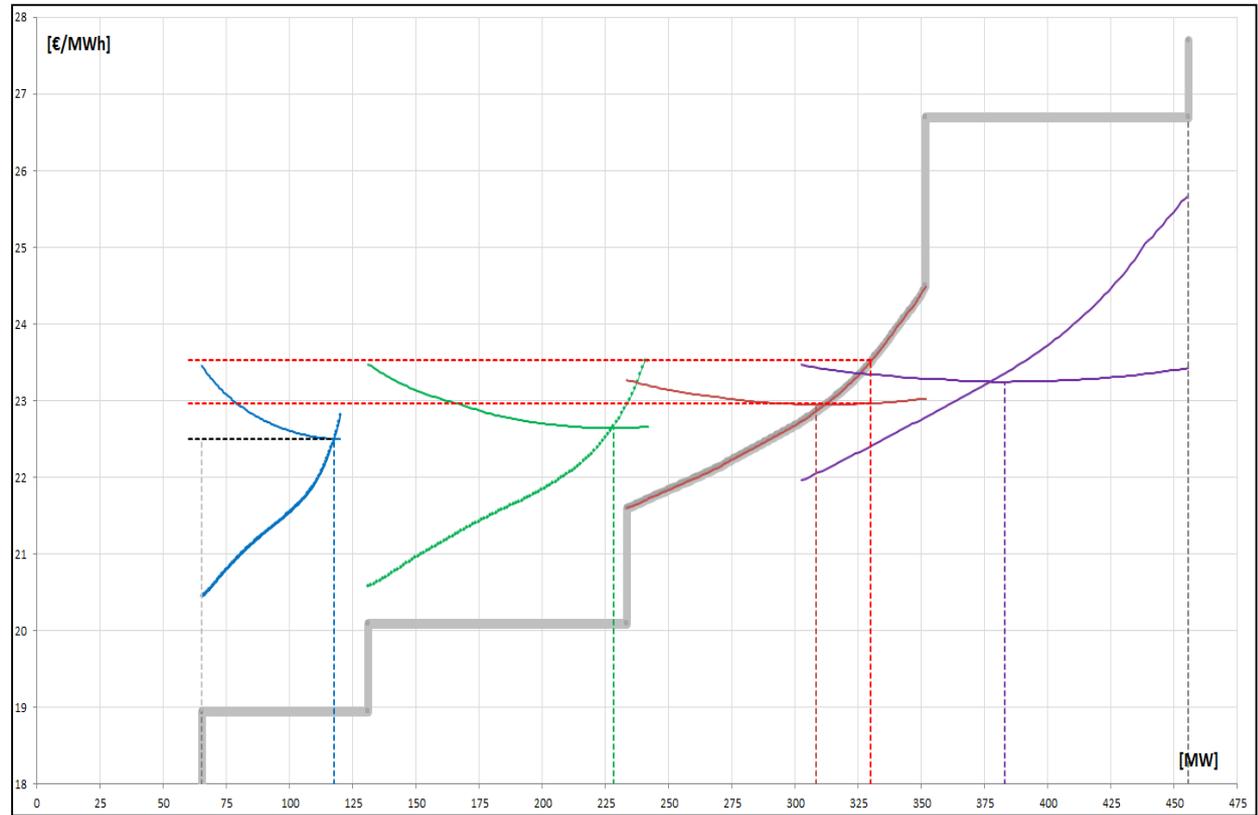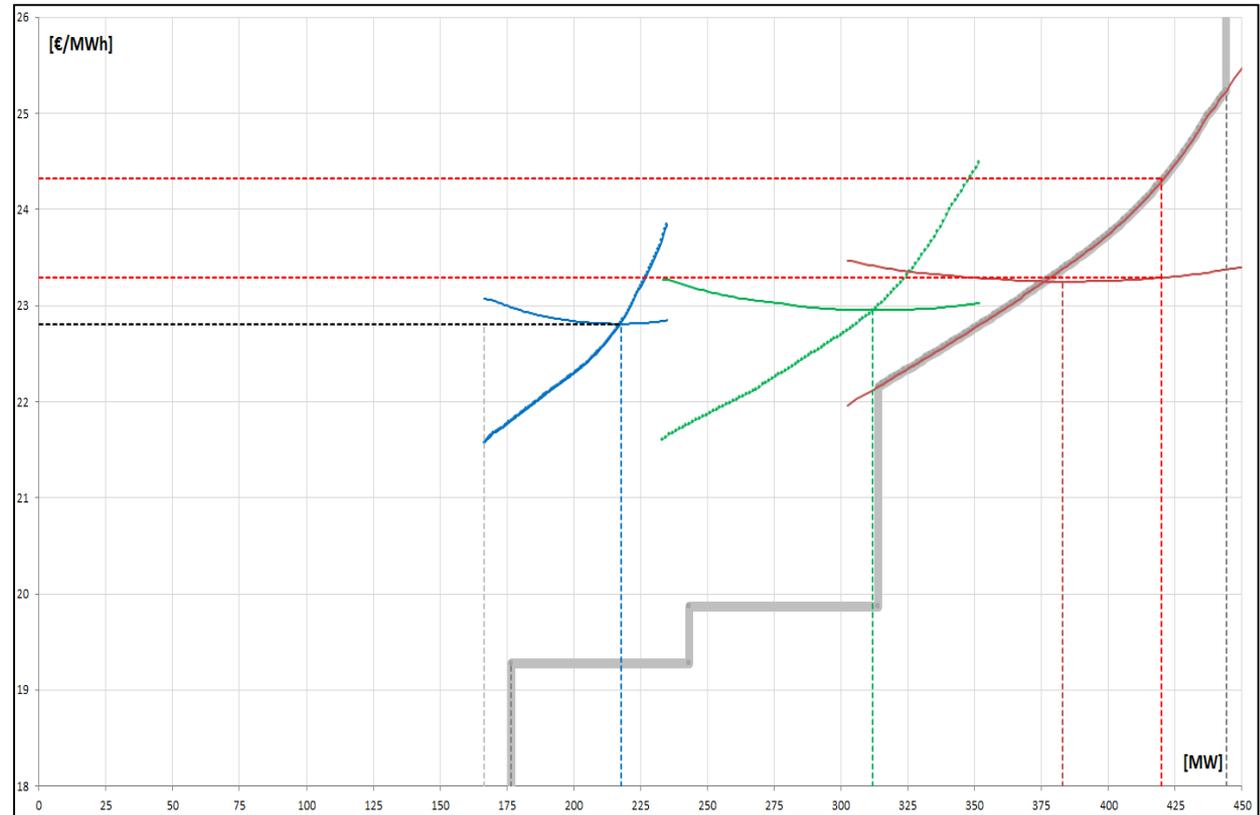E. BP if 4 committed and 2 with reserves

F. BP if all with reserves

Examples: Four generators

A. MC- and AC-curves

B. BP if decommitted & zero start/stop-costs

C. BP if decommitted & start/stop-costs >0

D. **BP if 3 committed and1 must run**

E. BP if 4 committed and 2 with reserves

F. BP if all with reserves

Examples: Four generators

A. MC- and AC-curves

B. BP if decommitted & zero start/stop-costs

C. BP if decommitted & start/stop-costs >0

D. BP if 2 committed and1 must run

E. BP if 4 committed and 2 with reserves

F. BP if all with reserves

Examples: Four generators

A. MC- and AC-curves

B. BP if decommitted & zero start/stop-costs

C. BP if decommitted & start/stop-costs >0

D. BP if 2 committed and1 must run

E. BP if 4 committed and 2 with reserves

F. **BP if all with reserves**

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NON-MONOTONOUS MC-CURVES

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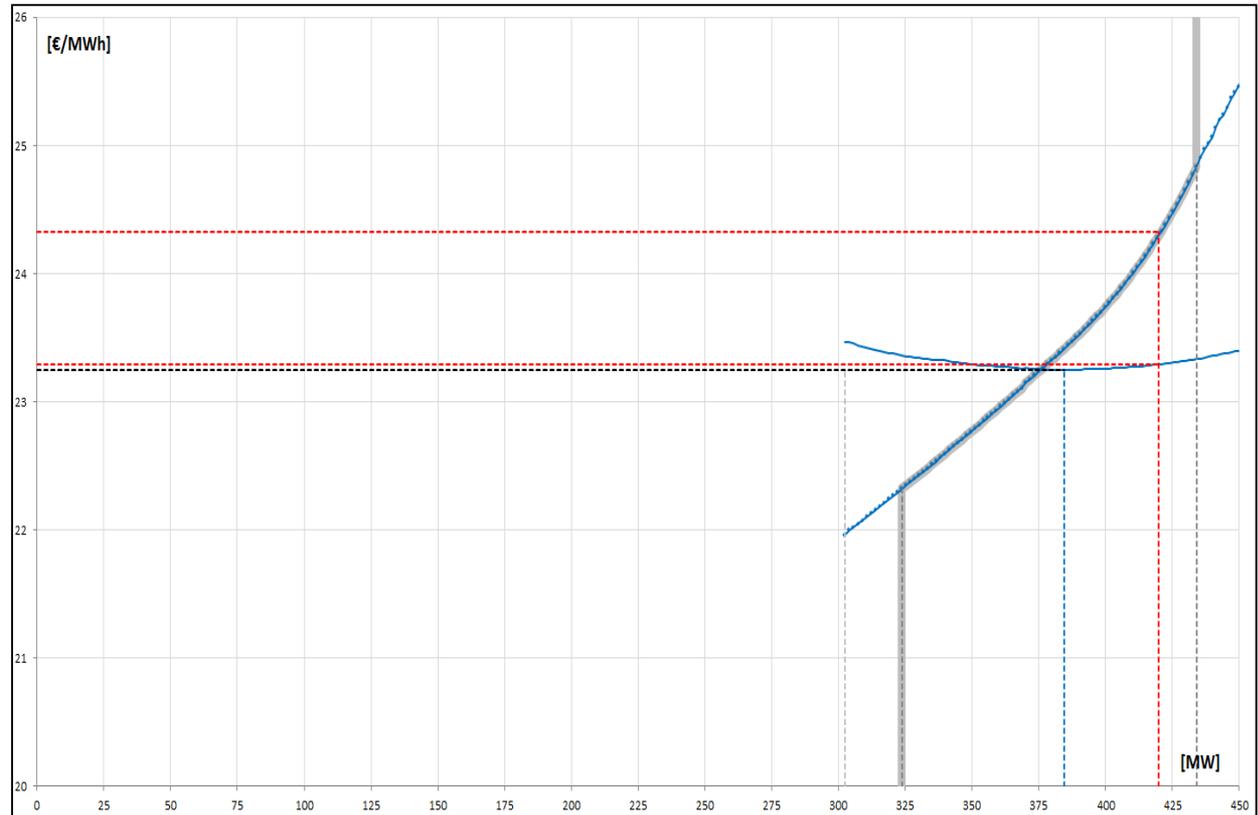
Non-monotonous MC

▶ An important criteria when bidding is that the price-volume relationship is monotonously increasing

- This requires that the BP curve is monotonous

▶ However, many plants have MC-curves that are non-monotonous

- Typically Pelton and smaller units
- 1/3 of our Norwegian plants are non-monotonous

▶ Such curves cannot be used directly to create BP-curves

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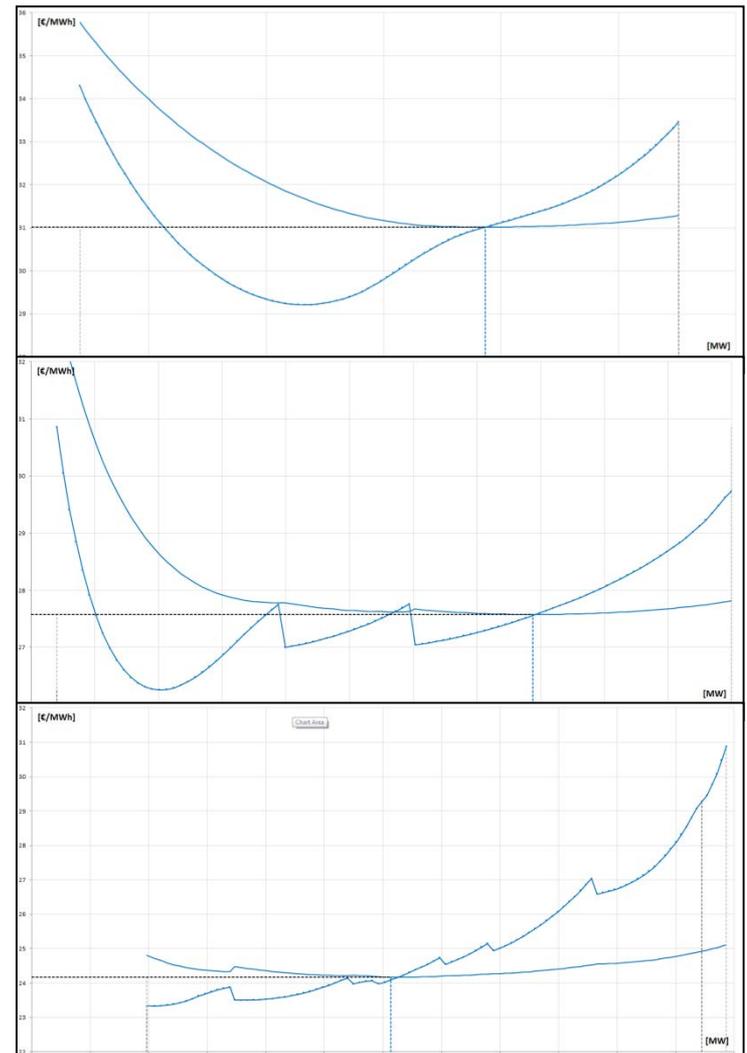
# How to deal with non-monotonous MC-curves?
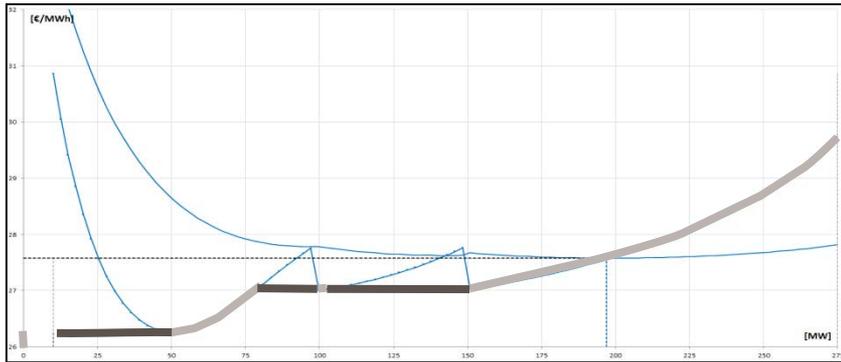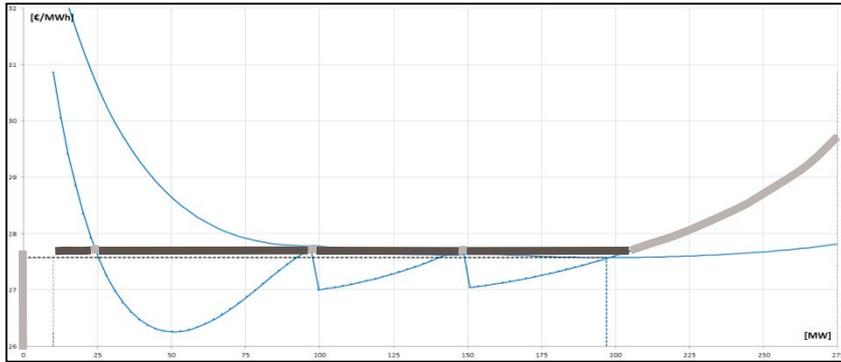
1. REMOVE points from the MC-curve
   - Jump when equally profitable
   - Will loose many potential operating points

2. MOVE points on the MC-curve
   - Make points monotonous <u>and</u> profitable
   - Will keep all potential operating points

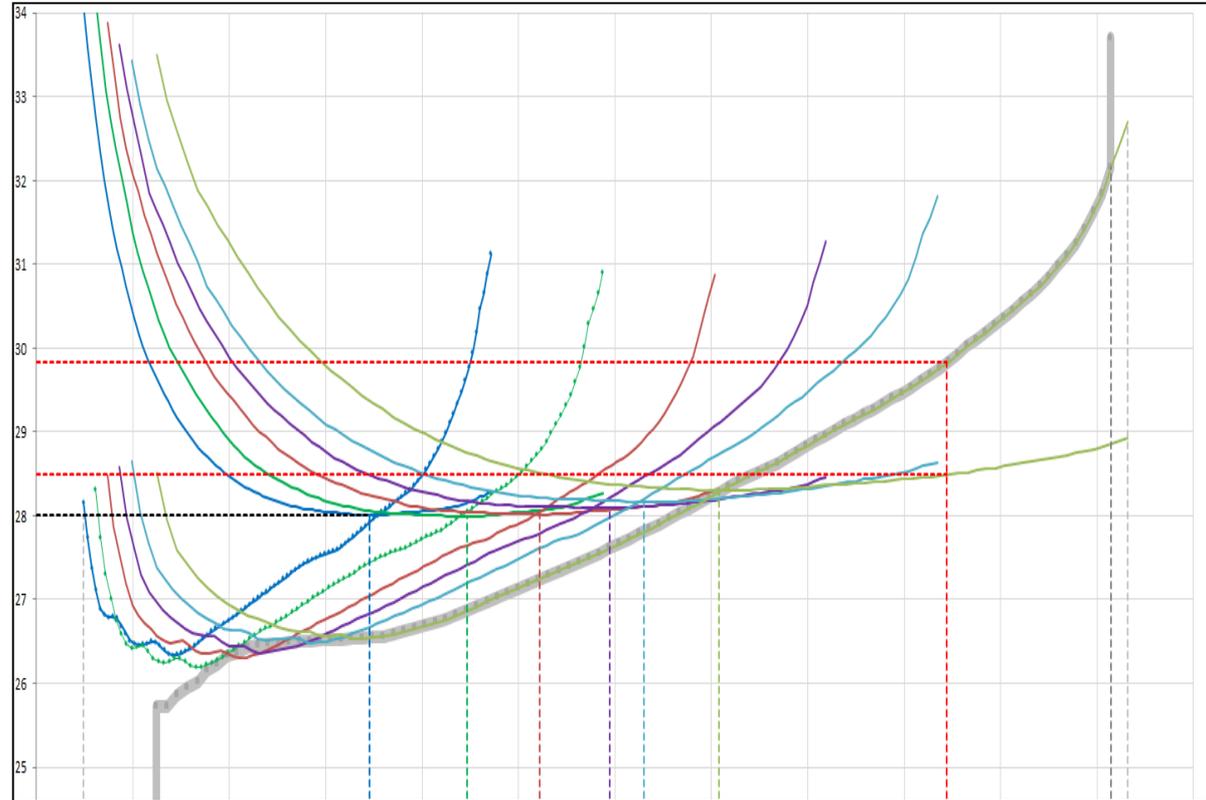=> Two different bidding strategies are implemented

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Examples: Non-monotonuous MC-curves

A. BP for mFRR with forced monotonity
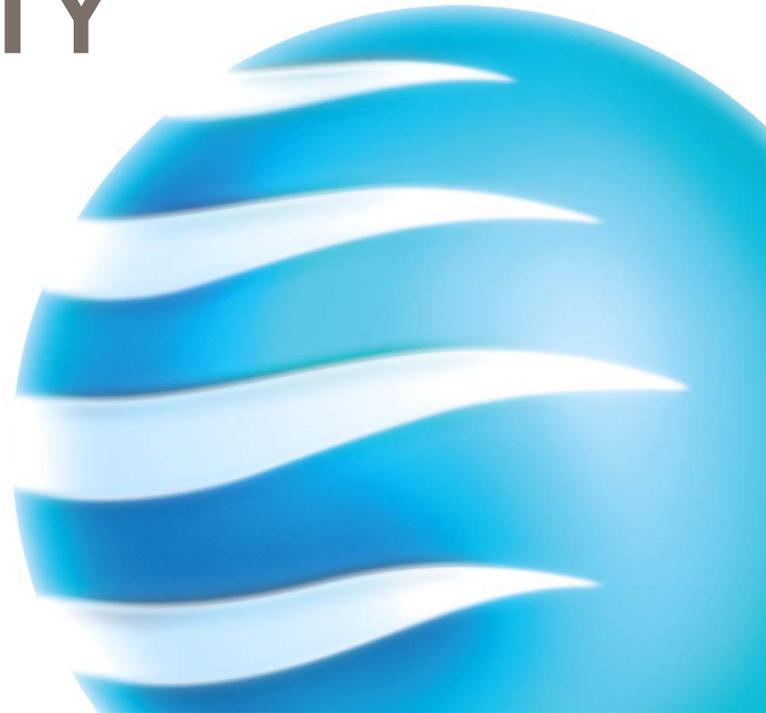
B. BP for mFRR with forced monotonity and positive profit
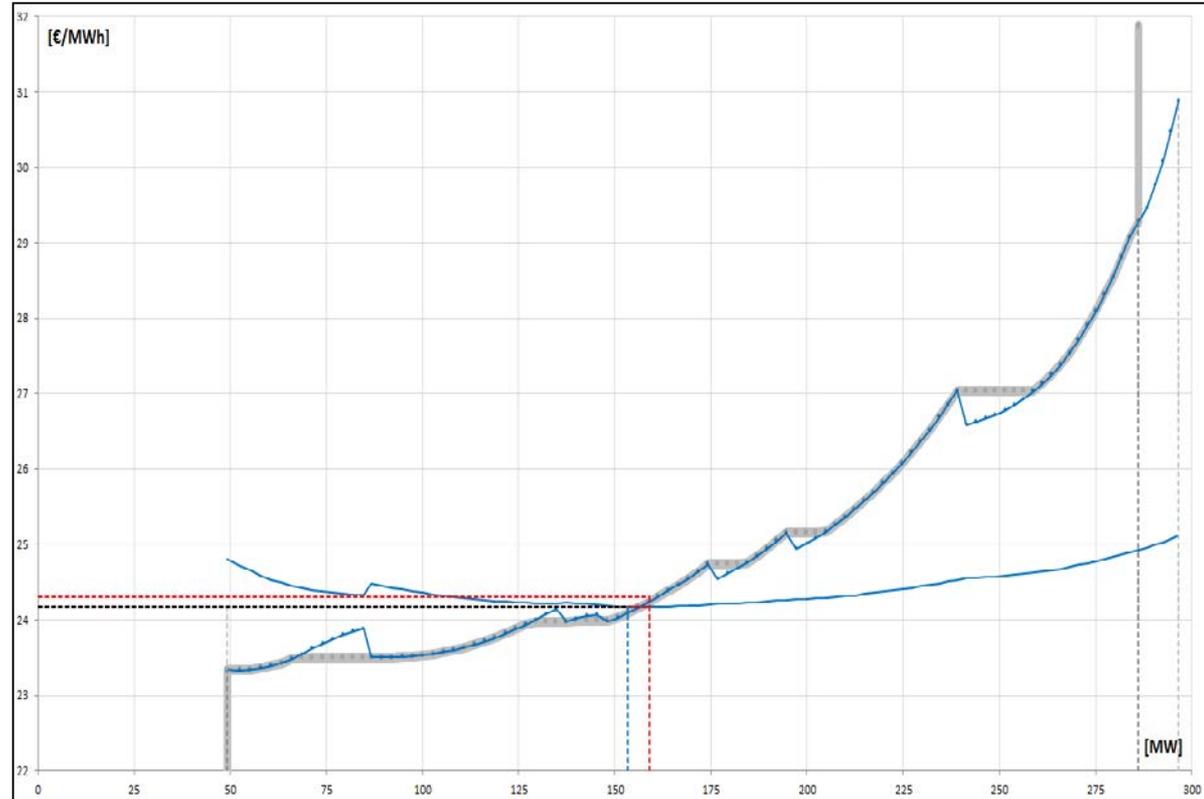
Examples: Non-monotonuous MC-curves

A. BP for mFRR with forced monotonity

B. BP for mFRR with forced monotonity and positive profit

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SHOP FUNCTIONALITY

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Running SHOP

▸ New command after optimization

- print bp_curves 0 23   Prints MC- and BP-curves for hour 0 to 23
  /operation   will REMOVE non-monotonous points

▸ It is possible to reduce the optimization time,
  running only one incremental iteration

- GENERATOR ref_production   Gives SHOP an initial plan

- set prod_from_ref_prod   Tells SHOP to use ref_production
- start sim 1   Runs one incremental iteration
- print bp_curves 0 23   Prints the curves for hour 0 to 23

Result files

▸ Two files are generated for each plant:

1. mc_<plantname>   Data for each generator combination, for all timesteps
   - P   Production
   - Q   Discharge
   - MC   Marginal cost ($\delta C / \delta P$)
   - AC   Average cost (C/P)
   - Eeq   Energy equivalent
   - Eff   Efficiency

   Same data as in the MC-module

2. bp_<plantname>   Data for the whole plant, for all timesteps
   - p   Price to bid
   - P   Optimum production for the plant
   - Pgen   Optimum dispatch on each generator

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SUMMARY

Improvements compared with the MC-module

▸ Improved calculations of MC/AC-curves
- Gives smooth and more correct curves

▸ Improved calculation of needle combinations for Pelton turbines
- Handled implicit in the curves

▸ Tear costs and feed-in costs are included in the MC/AC-curve

▸ Calculation of BP-curves are added

▸ Reserve schedules on generators are handled
(FCR up/down, FDR up, aFRR up/down, mFRR up/down)

▸ The BP-curve also prints the optimum generator combination
- To be applied directly when a bid is activated

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Summary

Results

▸ Improved calculation of PQ/AC/MC-curves

▸ Added printout of BestProfit-curves

Benefits

▸ Better curves that are easier to use in bidding mFRR

▸ Increased understanding of energy management

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