



Methods For Optimal Operation And Market Participation Of District Heating Systems

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CITIES Final Conference, Lyngby, 09/11/2020



Agenda



- 1. Heat Unit Replacement Bidding Method
- 2. Implementation in Sæby & Viborg

Motivation



Setting:

District heating provider with a portfolio of production units including combined heat and power (CHP) plant

Goal:

- Optimize the daily production of heat to cover the heat demand at minimal cost
- Sell the electricity from the CHP, if beneficial for the overall system cost
 - \rightarrow Bidding method



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Novel bidding method



Related bidding methods for CHP units in literature:

[Conejo et al., 2002, Rodriguez and Anders, 2004, Schulz et al., 2016, Dimoulkas and Amelin, 2014, Ravn et al., 2004]

- \rightarrow Take a power producer perspective
- \rightarrow all methods plan bids for the CHP units, if the electricity price forecast indicates its beneficial

Our approach:

Heat Unit Replacement Bidding (HURB) method

- Make use of the fact that we have to produce the heat for the district heating network anyway
- Bidding based on replacing heat unit production by CHP production

Blanco, I., Andersen, A. N., Guericke, D., & Madsen, H. (2019). A novel bidding method for combined heat and power units in district heating systems. Energy Systems. https://doi.org/10.1007/s12667-019-00352-0



HURB – Step 1



Optimize heat production without market participation (using mixed-integer linear programming)



HURB – Step 2



Replace iteratively heat-only units by CHP production (in descending order of operational costs)

1. Iteration: Replacing the gas boiler (GB)



- Bidding amount: Power production amount of the CHPs.
- **Bidding price**: Cost CHP Cost GB = (610.84 404.02) * 1.18 = 244.045

HURB – Step 2



Replace iteratively heat-only units by CHP production (in descending order of operational costs)

2. Iteration: Replacing the wood chip boiler (WCB)



- **Bidding amount:** Power production amount of the CHPs
- Bidding price: Cost CHP Cost WCB = (610.84 211.45) * 1.18 = 471.279



Comparison with 5 bidding methods for CHP units from literature

Conejo, A. J., Nogales, F. J., and Arroyo, J. M. (2002). Price-taker bidding strategy under price uncertainty. IEEE Trans. Power Syst., 17(4):1081–1088.

Dimoulkas, I. and Amelin, M. (2014). Constructing bidding curves for a CHP producer in day-ahead electricity markets. In 2014 IEEE Int. Ener. Conf., pages 487–494.

Ravn, H. V., Riisom, J., Schaumburg-Müller, C., and Straarup, S. N. (2004). Modelling Danish local CHP on market conditions. In Proc. 6th IAEE European Conference: Modelling in Energy Economics and Policy.

Rodriguez, C. P. and Anders, G. J. (2004). Bidding strategy design for different types of electric power market participants. IEEE Trans. Power Syst., 19(2):964–971.

Schulz, K., Hechenrieder, B., and Werners, B. (2016). Optimal operation of a CHP plant for the energy balancing market. In Operat. Res. Proceed. 2014, pages 531–537. Springer.

Rolling horizon length = Number of days considered in one optimization step





Results - Bids



Percentage of hours with bids and won bids in one month averaged over several samples

Method	Receding Horizon	CHP 1		CHP 2		
		Bids	Won	Bids	Won	
HURB Worst	1	98.91	41.95	98.70	41.91	
HURB Avg.	-	99.79	42.19	99.75	42.15	
HURB Best	10	99.89	42.28	99.87	42.26	
Conejo et al.	10	44.92	39.34	44.92	39.31	
Rodriguez & Anders	5	82.52	35.85	82.40	35.82	
Schulz et al.	12	45.02	18.54	45.01	18.53	
Dimoulkas & Amelin	12	75.55	26.56	75.55	26.55	
Ravn et al.	5	44.84	32.58	44.83	32.57	

We can take advantage of the portfolio of heat production units and base the bidding amounts and prices on the heat production.



Having Implemented The Heat Unit Replacement Bidding Method in Sæby & Viborg





energyTRADE planning bidding prices in Day-ahead market and regulating power market in Sæby, using The Heat Unit Replacement Bidding Method







Production and storage capacities at Sæby District Heating

Solar collector	36549m3
Two CHP's	11,8MW-el
Gas boiler	17,5 MW-heat
Electrical boiler	11,8MW-heat
Thermal storage	5400m3
Heat rejection unit	7MW-heat





The hottest part of the exhaust gas from the CHPs is used to run an absorption heat pump, condensating the exhaust gas, making a total efficiency of the CHPs > 100%.







energyTRADE planning bidding prices in Day-ahead market and regulating power market in Sæby, using The Heat Unit Replacement Bidding Method







Data providers makes energyTRADE communicate with trader, prognosis and SCADA-data













A summer operation in Sæby







energyTRADE planning bidding prices in Day-ahead market and regulating power market in Viborg District Heating, using The Heat Unit Replacement Bidding Method











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Day ahead calculation Regulating market calculation







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Further research needed for optimizing biddings at Thisted District Heating





A energyTRADE 4.7 - Thisted energyTRADE 29-10-2020 (Calculated)

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Time series: Ønsket slutlager Bid type: Turbinen_kondensatoren Price indeper v Gasmotor Nord 1 Price indeper v Gasmotor Nord 2 Price indeper v

Day ahead calculation Regulating market calculation







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Thanks for the attention!



