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Energy-SmartOps Integrated Control and Operation of Process, Rotating Machinery and Electrical Equipment

Steel Plant Scheduling with Electricity Contracts Optimization

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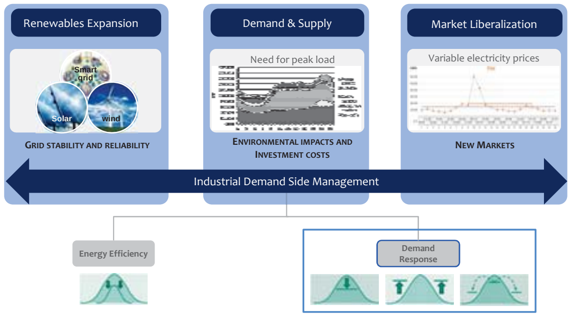
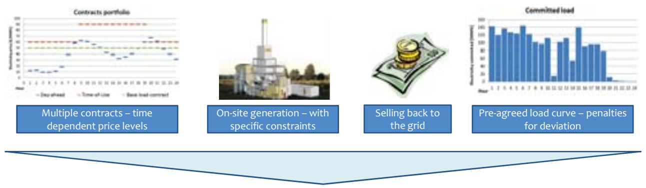
Motivation and background

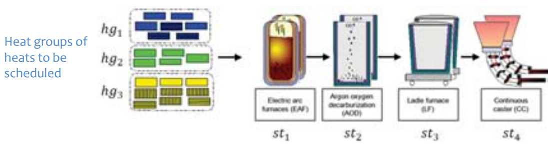


Goal and problem statement

Electricity contracts management



Steel production process



Scheduling model adapted from Harjunkoski and Grossmann (2001)

- Batch process with semi-continuous stage st_4 (CC)
- Equipment specific setup t_m^{setup} and transportation times $t_{m,m'}^{min}$
- Parallel, non-identical equipment m
- Max hold-up times $t_{p,st}^{max}$ between stages
- Min transportation times $t_{m,m'}^{min}$
- Machine specific setup times t_m^{setup}
- Maintenance tasks on st_1(EAFs) and st_2 (AODs)

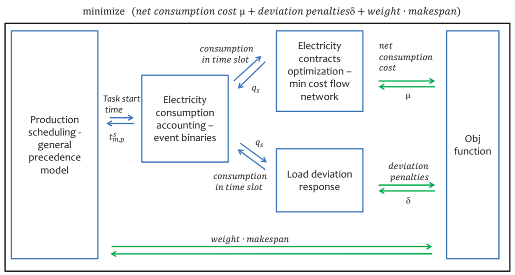
Optimized production schedule

Research methodology and solution approach

Mixed Integer Linear Programming monolithic model (Hadera & Harjunkoski 2013, Hadera et al. 2014) implemented in GAMS/CPLEX

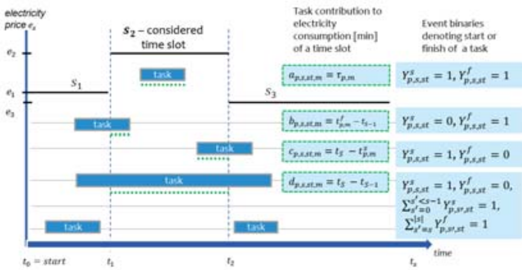
- Monolithic model structure

minimize (*net consumption cost* μ + *deviation penalties* δ + *weight* · *makespan*)

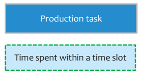


Monolithic model integrating the scheduling problem with electricity management aspects

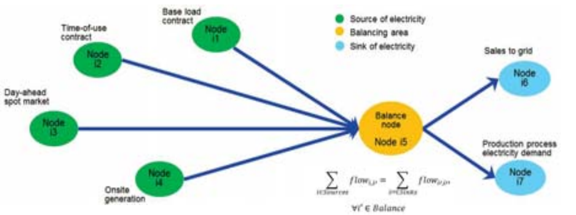
- Electricity consumption accounting – discrete time grid with task-time slot relations via event binaries



Event binaries defined using big M formulation



- Electricity contracts optimization – minimum cost flow network



Each arc is defined for each time slot by parameters and flow level variable

- *Time Slot*
- *Min Flow*
- *Max Flow*
- *Cost*
- *Flow*

Results and discussion

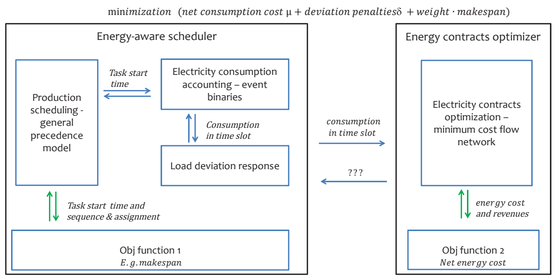
- Case study for 20 products and 24h scheduling horizon with fixed sequence and assignment variables

Assumptions	Computation		Economic assessment					
Purchase structure	CPUs	CPUs 2% Gap	Net cost [k€]	Purchase cost [k€]	Deviation penalties [€]	Day-ahead market [MWh]	TOU market [MWh]	Onsite generation [MWh]
Base case (all contracts)	228	12	109	128	26	0	10	952
Low volatility of spot	3 081	10	76,8	166,6	13	1275	0	952
No base load	570	13	143	96,4	24	190	1 097	952
No onsite gen	300	41	107,5	144,7	27	22	229	-
Sale as spot	771	4	-1642	1623	24	0	19 734	952
No penalties	2	2	109,1	128,5	-	0	16	952
No spot-fixed penalties	70	10	109	128	24	-	10	952
Flow-minimal schedule	1	1	242,2	170	11 0292	287	84	0

Further work

- Energy contracts optimizer as black-box due to complexity
- Iterative framework "composition" structure with functionally separated models

minimization (*net consumption cost* μ + *deviation penalties* δ + *weight* · *makespan*)



References

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