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ASRM – Energy-efficient and power optimized motion profiles

Inspiring change in intralogistics

ASRM – value added topics

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Speed synchronism & Load distribution	Minimizing slippage and …	**… maximizing acceleration**
Oscillation damping	Reduced mechanical stress and …	**… increased throughput**
Safety	Optimization of the plant through …	**… flexible safety concepts at all levels**
Bufferless storage	Through omission of mechanical buffers …	**… more room, reduced costs**
Energy storage	Energy storage at the DC link …	**… reduces size and costs for the electrical periphery**
Optimized motion profiles	Adaption of starting time or dynamic parameters …	**… will help to reduce the required energy and the power peaks.**

Agenda

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Energy-efficient and power optimized motion profiles
Overview

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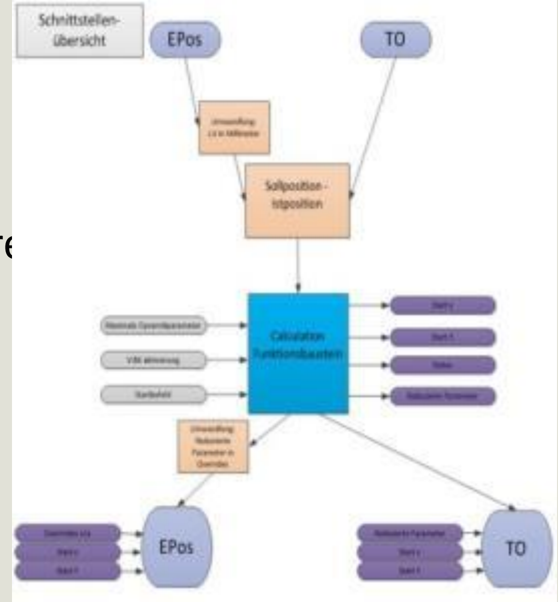
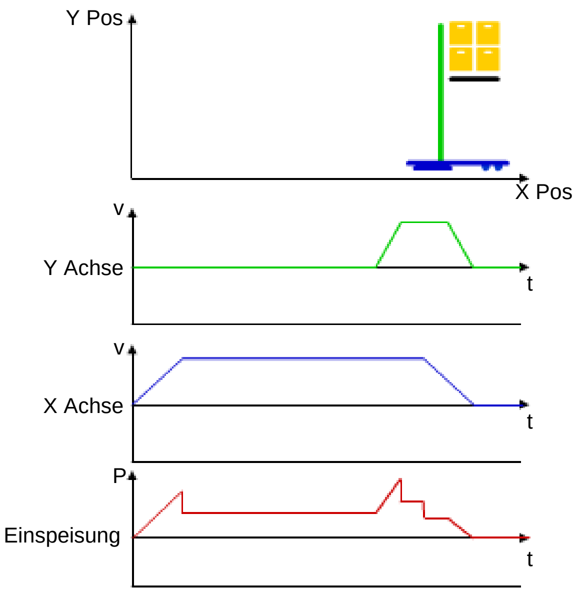
Energy/power saving with optimized moving profiles

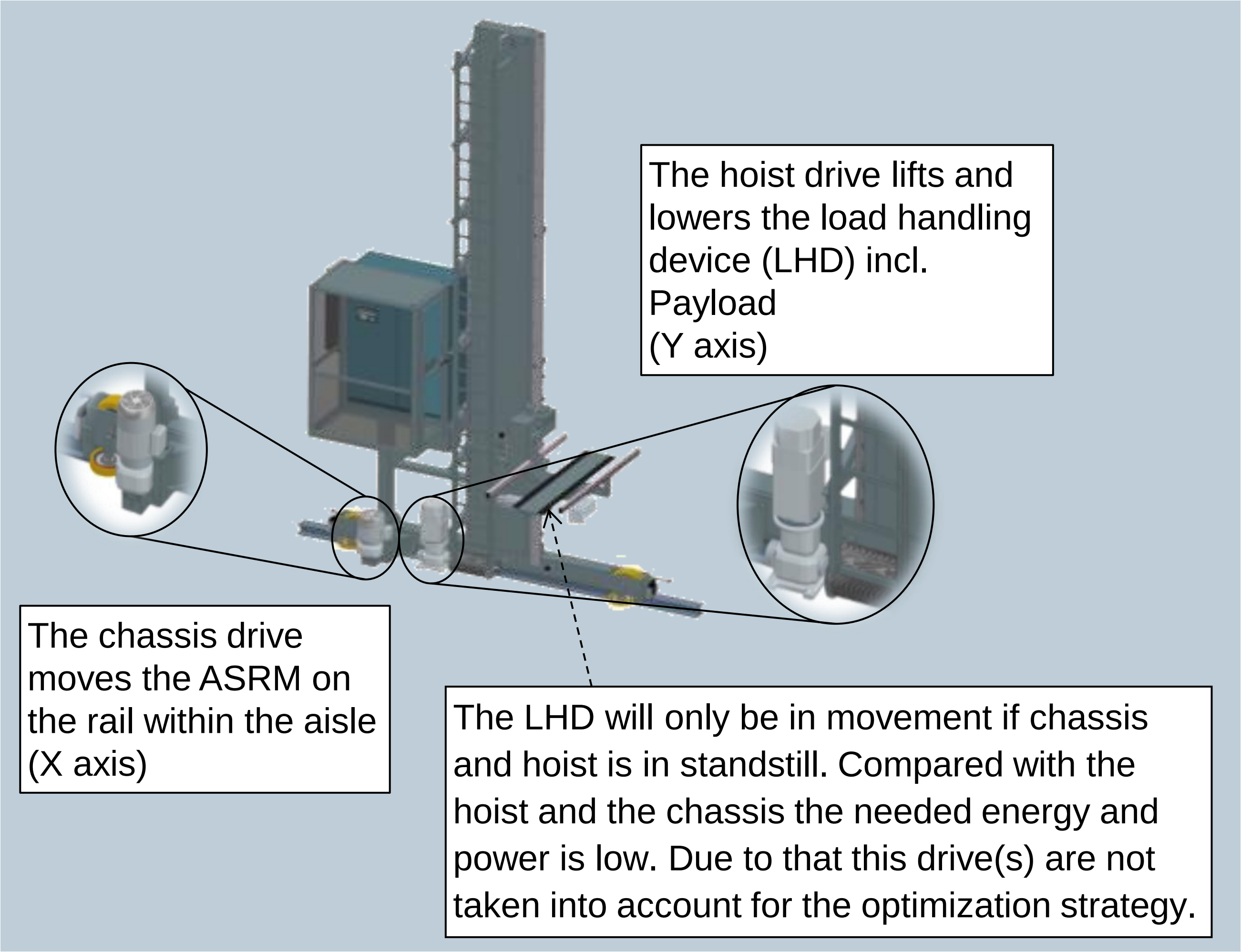
- Analysis of chassis (X) and hoist movement (Y)
- Time-critical movement will not be adapted -> performance is not reduced!
- Adaption of the non critical movement, e.g.:
    - Delayed start of the movement
    - Reduced acceleration and/or deceleration
    - Reduced positioning speed
- Software decides about the most effective measure regarding energy and power consumption
- Power peaks can be reduced up to 20% (depending on the specific machine)
- Additional potential for reduction by reducing the performance only for a small number of positions (e.g. 5%).



https://support.industry.siemens.com/cs/ww/en/view/101167223



Energy-efficient and power optimized motion profiles
Concept

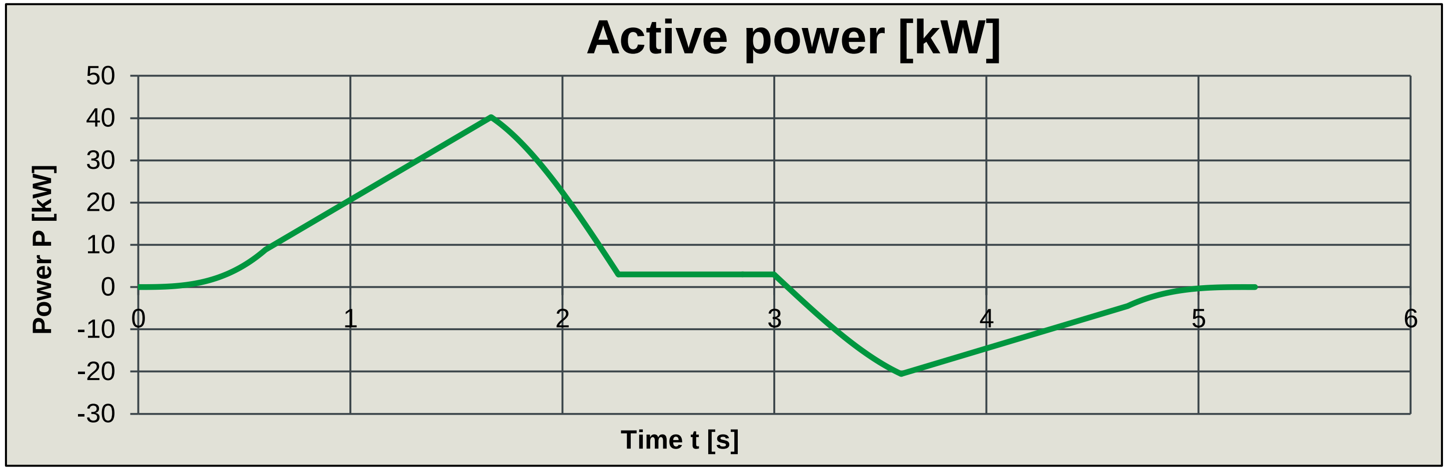


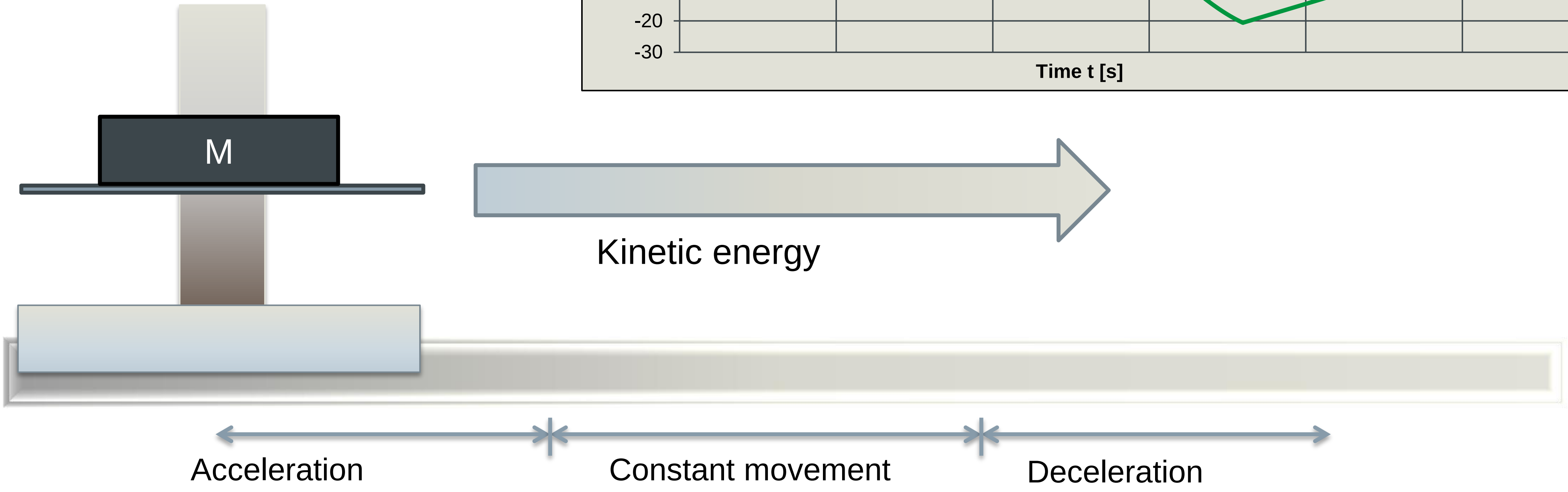
Methods to reduce the power peaks and to increase the energy efficiency:

1. Energy-efficient and power optimized motion profiles
2. Limitation of maximum electrical connection power
3. Brake management for hoist drive
4. Energy saving mode
5. Asymmetrical acceleration/ deceleration

Chassis unit
Kinetic energy and active power

Example: Traveling distance = 15m





Hoisting unit - Lifting
Kinetic energy and active power

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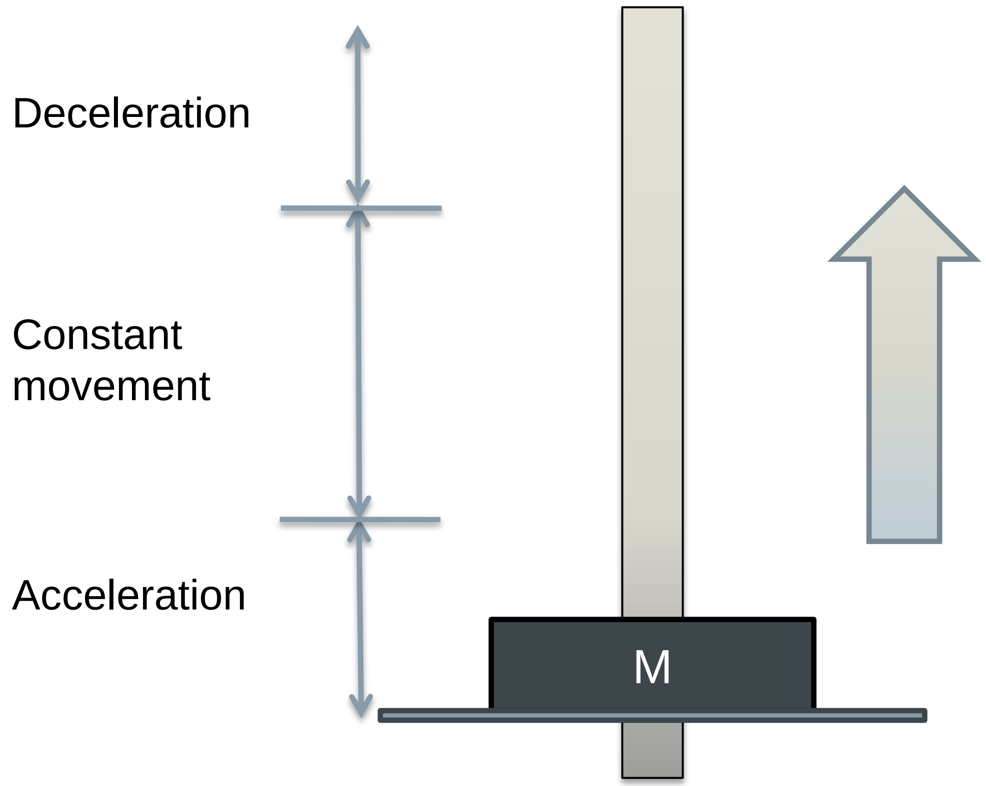
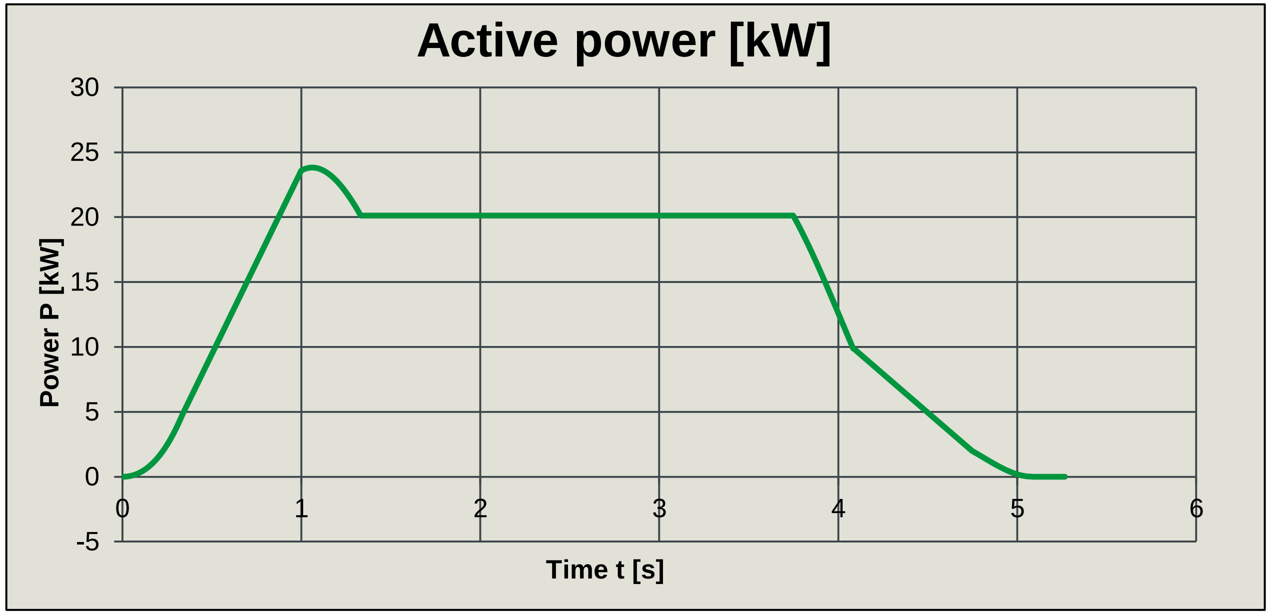
Example: Height =15m



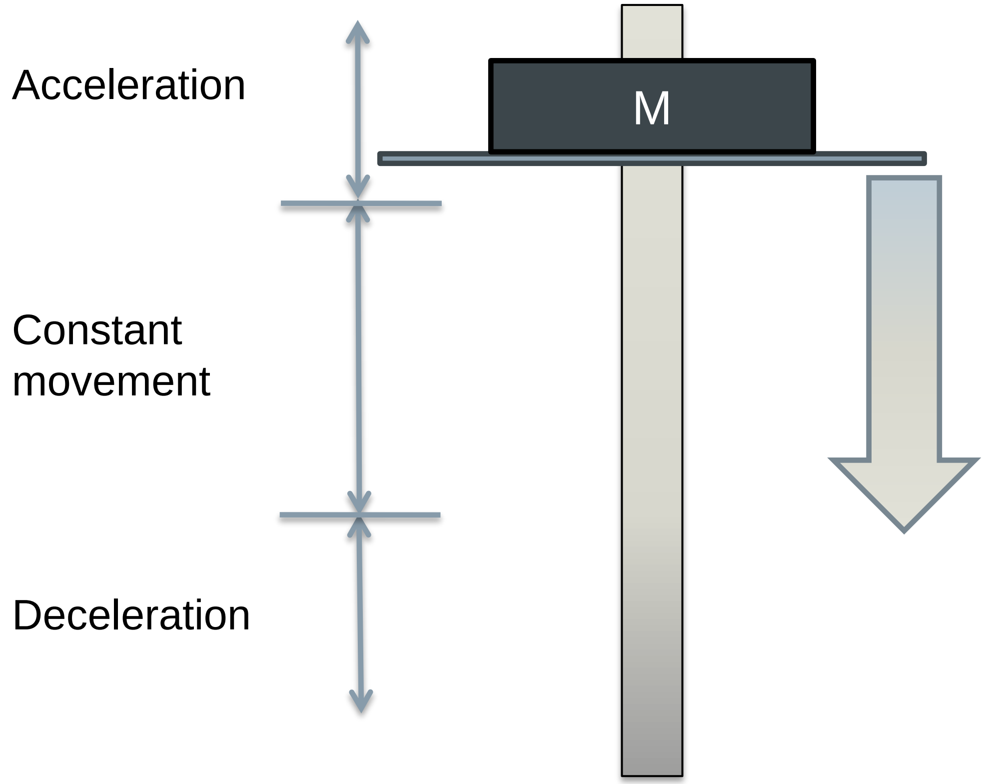
Lifting process – share of energy:

- Potential energy (depending on the height)
- Kinetic energy (during movement)



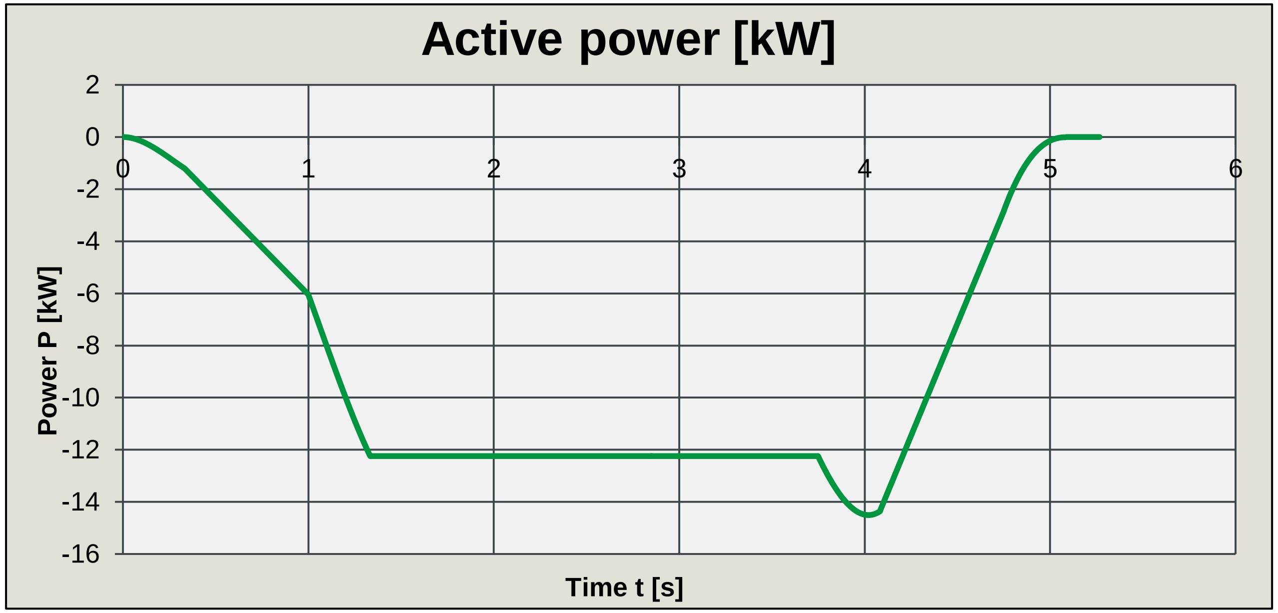
Hoisting unit - Lowering
Kinetic energy and active power

Example: Height =15m

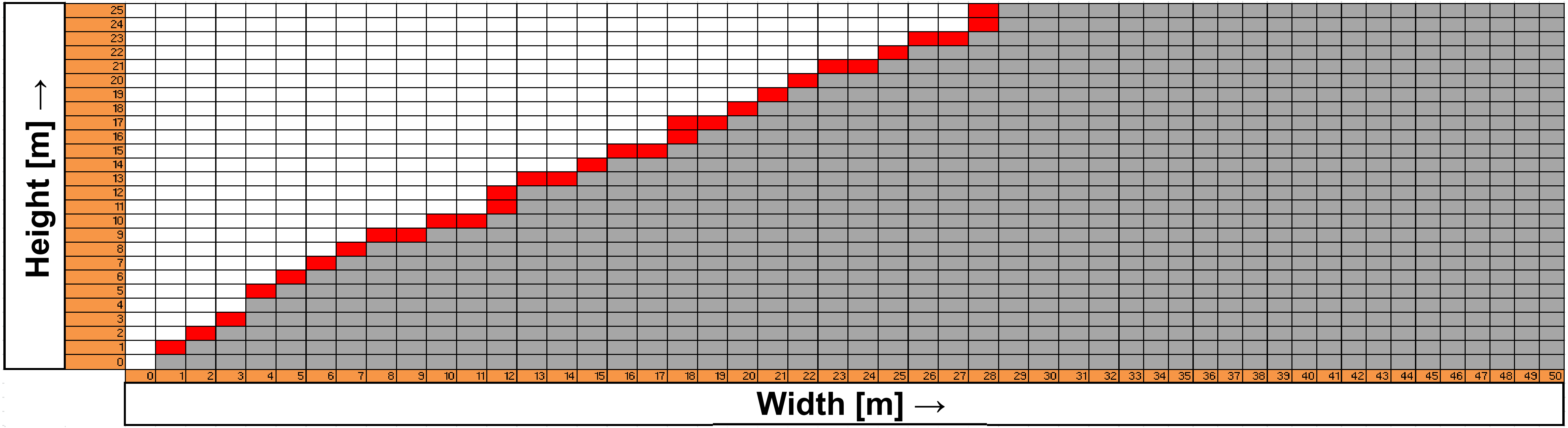


Lowering process – share of energy:

- Potential energy (depending on the height)
- Kinetic energy (during movement)



Shelf geometry
What movement is typically time-critical?



	white	red	grey
Share of stockyard (inside the shelf)	30%	5%	65%
Time-critical axis (movement of this axis defines total positioning time)	Hoisting unit	Hoist and chassis	Chassis
Non-critical axis: (movement of this axis takes less time)	Chassis	-	Hoisting unit

Goals and optimization strategies

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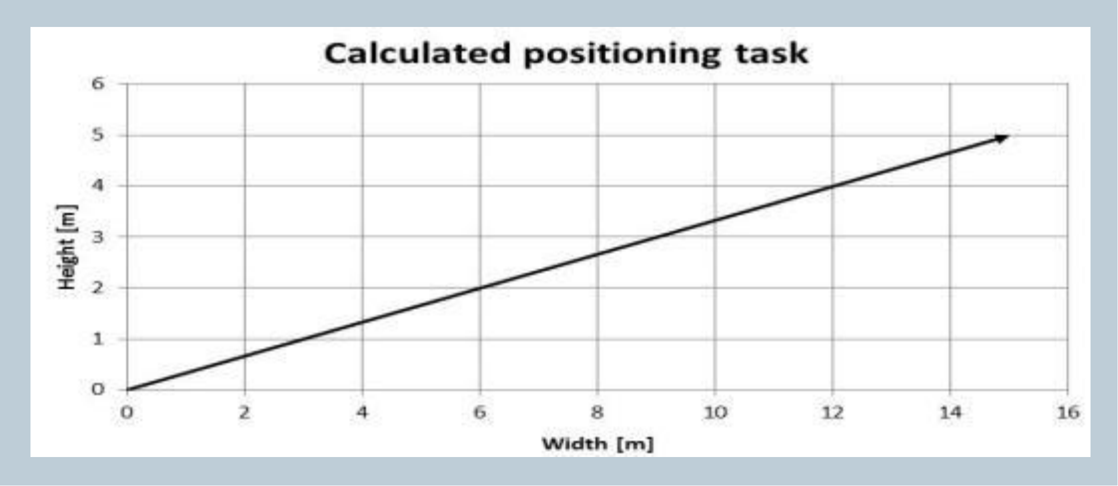
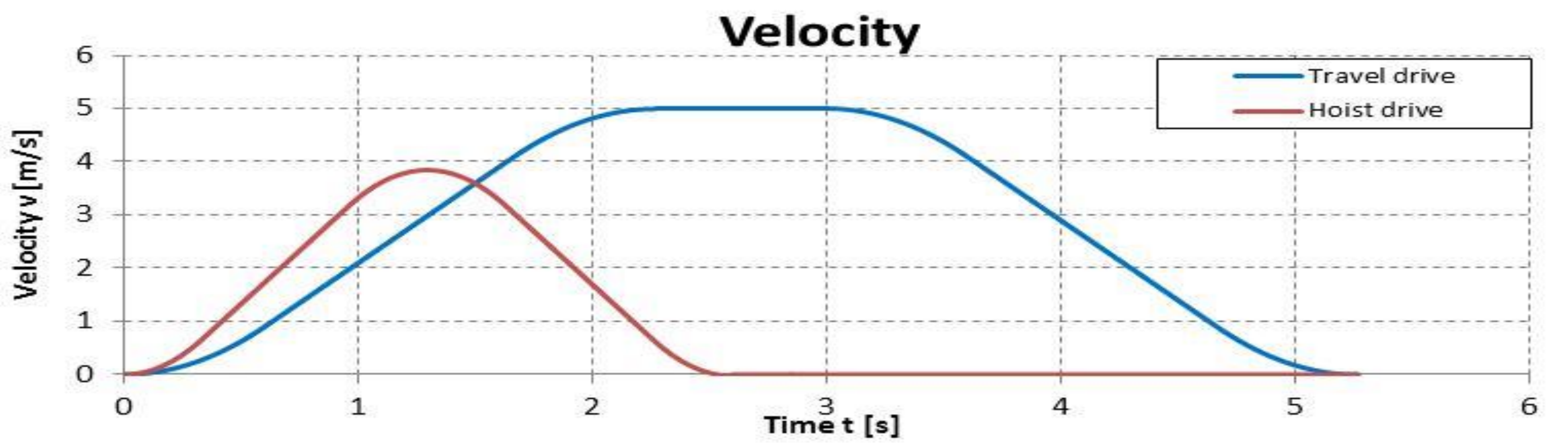
1. **Avoid peak power**
   - Higher losses in areas with maximum active power
   - More costs for higher infeed power
2. **Use regenerative energy**
   - system is not always able to infeed regenerative energy back to the grid (for example: basic line module)
   - Improvement of the energy effectivity for the complete warehouse
3. **Prevent mechanics from damage**
   - Reduce wear and tear

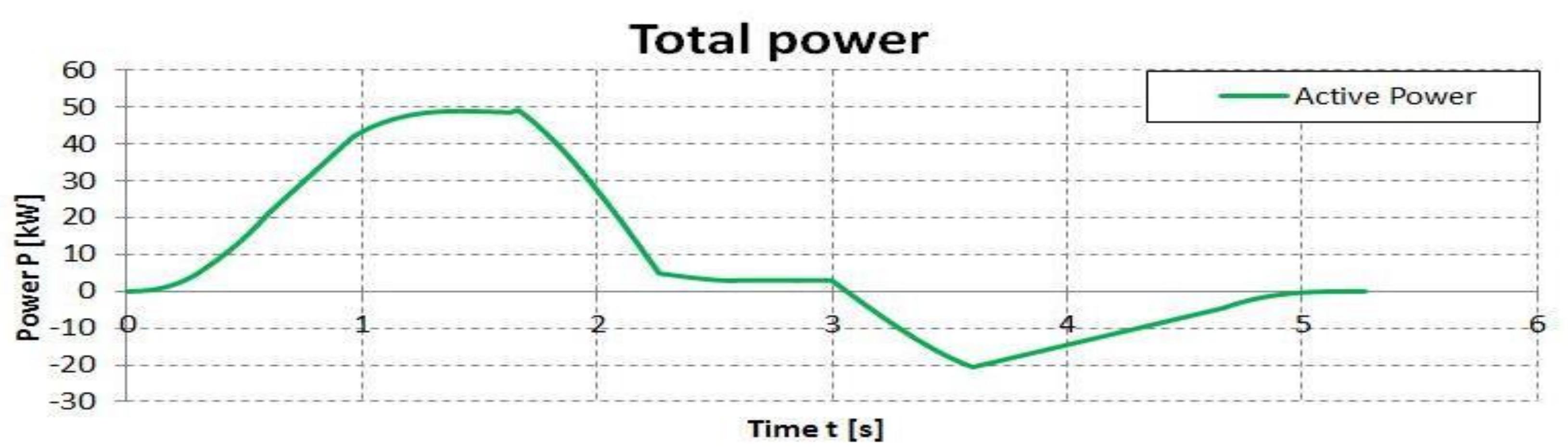
Comparison of two different optimization strategies with the shown positioning task.

Chosen positioning task is 15 meters in X direction and 5 meters in Y direction



Initial state (before optimization)
Velocity and power

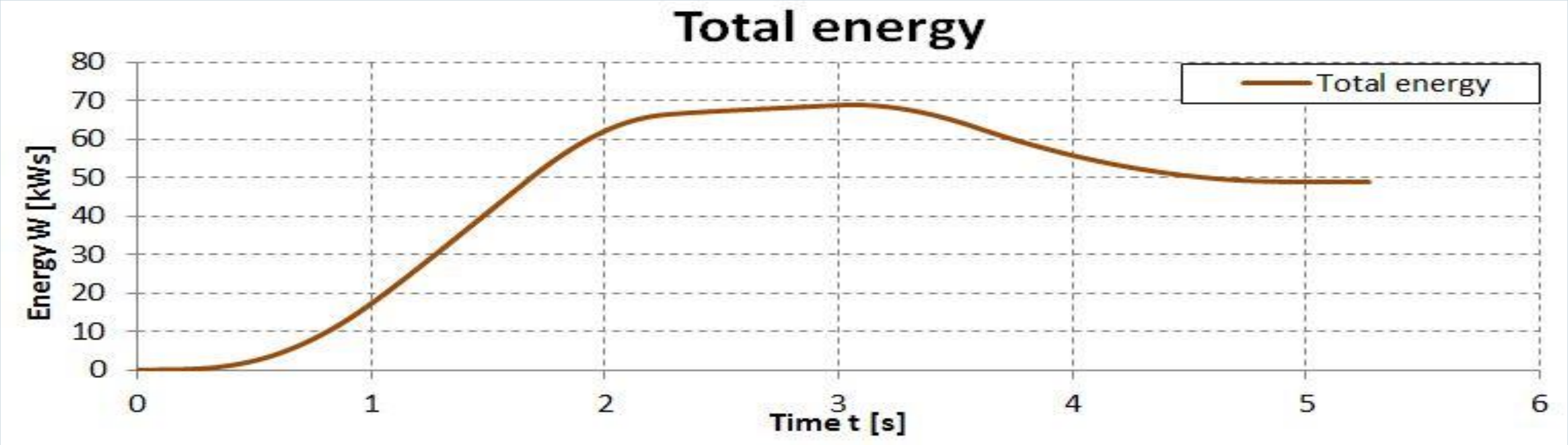


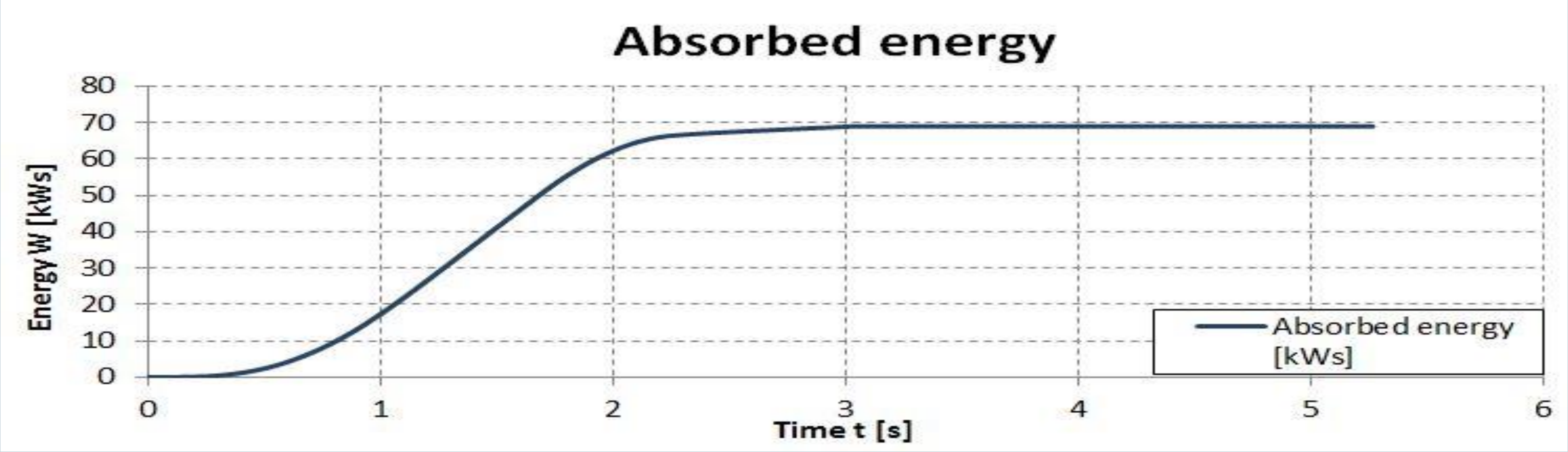


Simulation of mechanical power with no optimization.

- Axis start synchronous with their maximum dynamic parameters.
- Motoric power peaks overlay due to the acceleration of both axis.

Initial state (before optimization)
Electrical energy





Energy

$$W = \int_{t_0}^{t_1} P(t) \cdot dt$$

Total electrical energy:

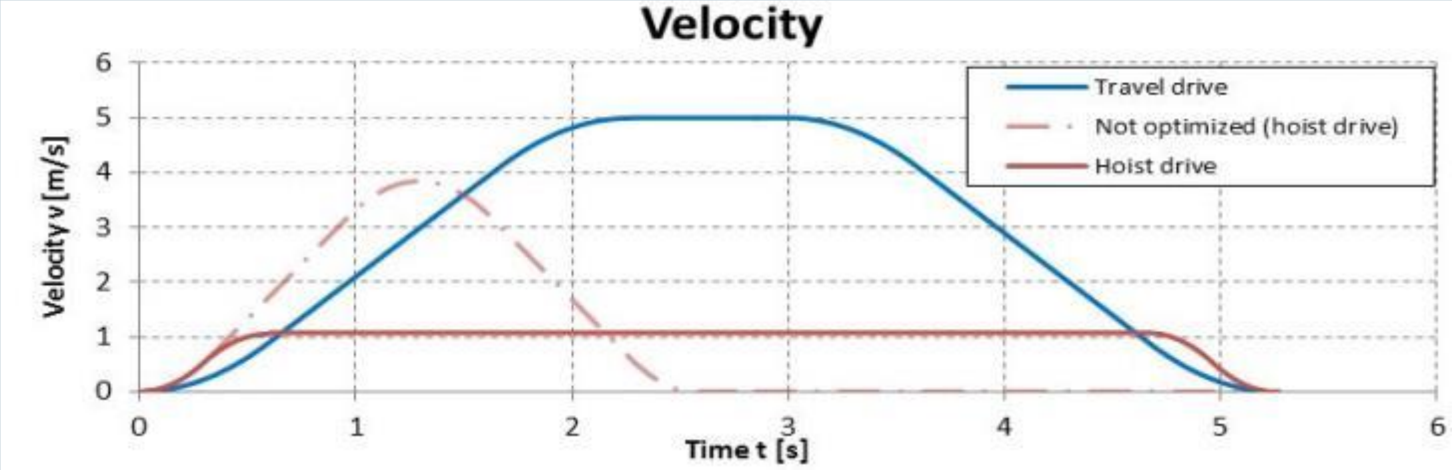
Diagram of total electrical energy including regenerative feedback

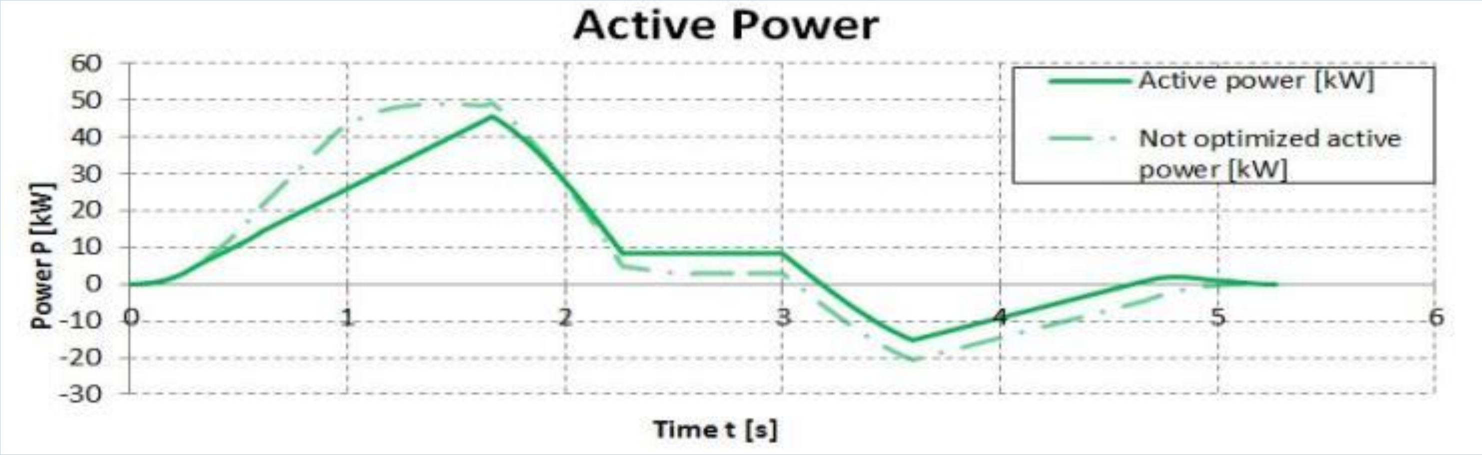
Absorbed energy:

Energy that is taken from the grid without regenerative feedback

Feedback to the grid is typically not paid by the energy provider

Optimization strategy 1 – Adapting dynamic parameters
Velocity and active power





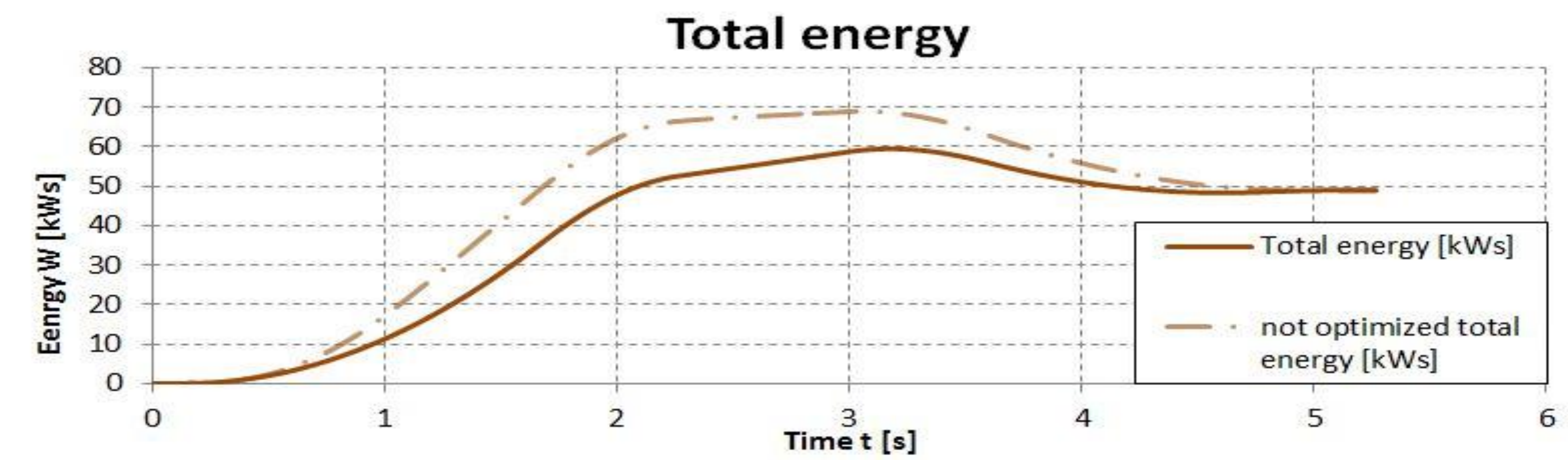
Adapting the dynamic parameters:

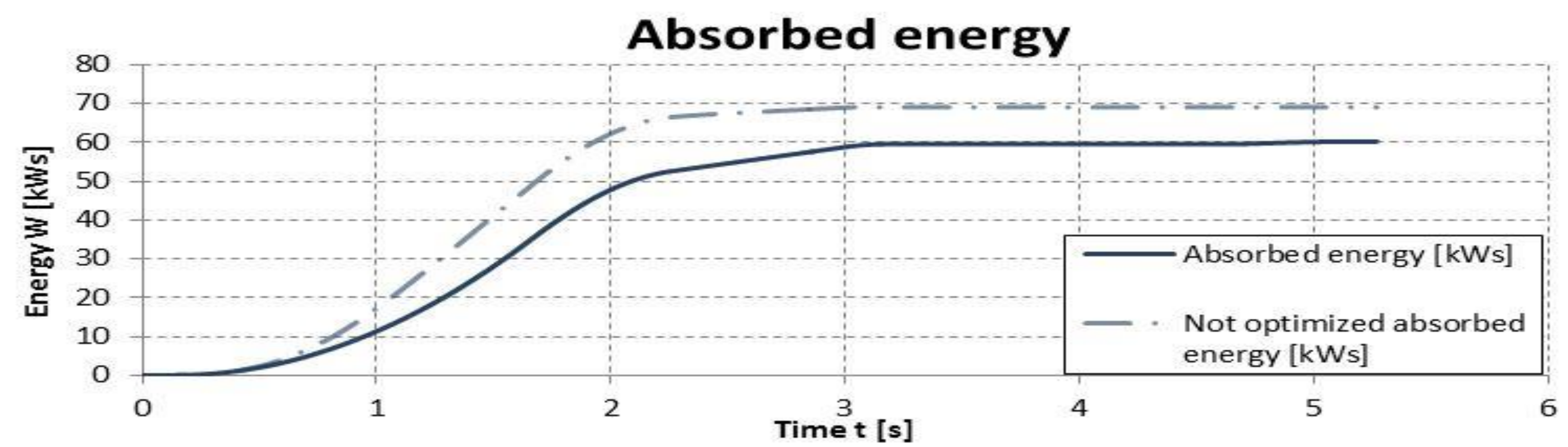
- Speed or acceleration / deceleration of non time critical axis are reduced. Both axis reach the target position at the same time.
- Hoist: Reduction of the speed (see example)
- Chassis: Decrement of acceleration and deceleration

Compared with initial state the power peak is reduced by approx. 10% due to optimization.

45kW instead of 50kW
at the same performance

Optimization strategy 1 – Adapting dynamic parameters
Electrical energy





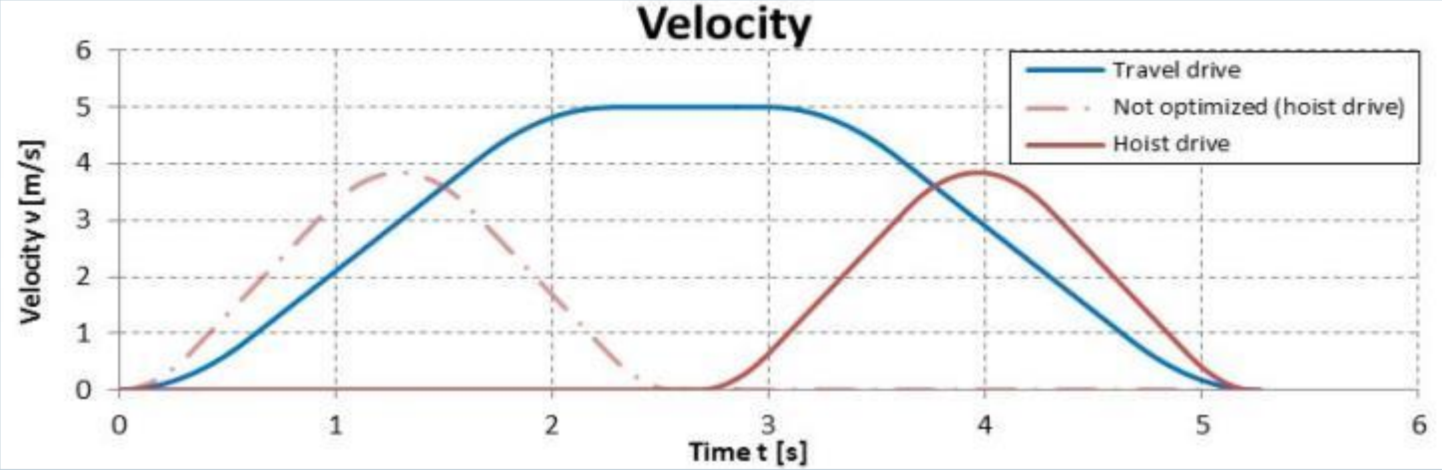
Energy

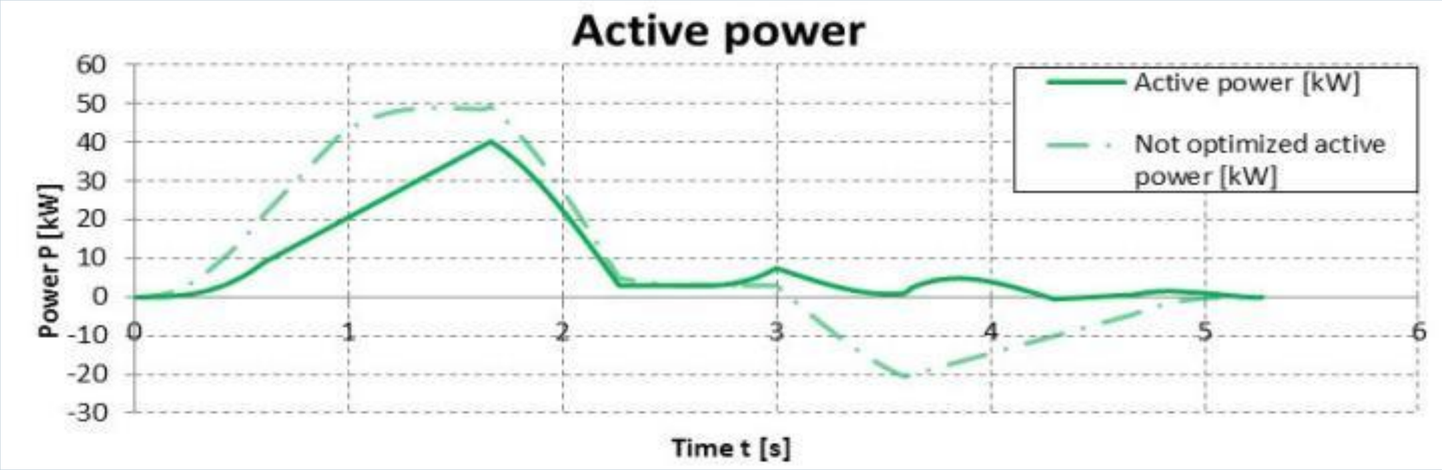
$$W = \int_{t_0}^{t_1} P(t) \cdot dt$$

Compared with the initial state the absorbed energy from the grid is reduced by approx. 14%.

60kWs instead of 70kWs
at the same performance

Optimization strategy 2 – Adapting starting time
Velocity and active power





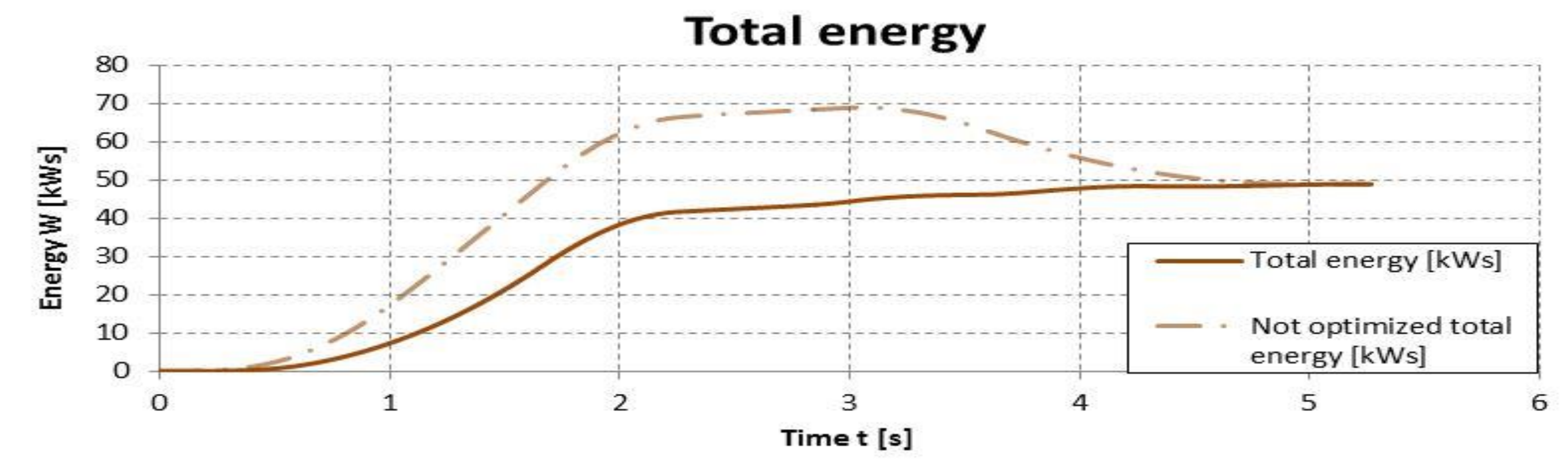
Adaption of starting time:

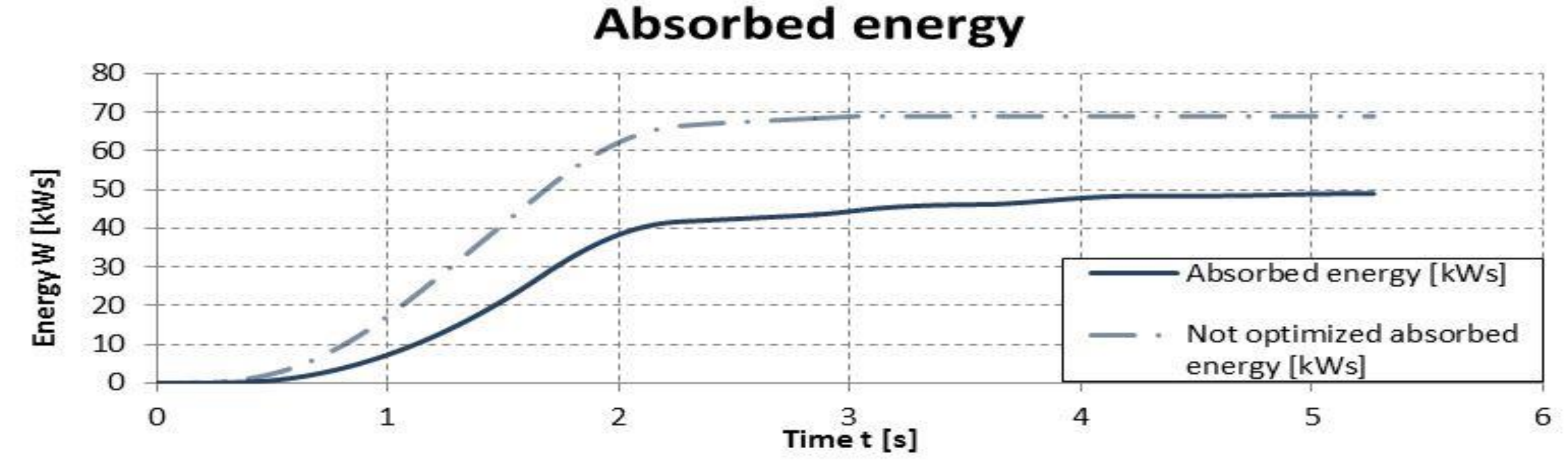
- Chassis is time critical:
  - A delay time before or after hoist movement avoids an overlap of the power peaks.
  - The chassis braking energy can be used for lifting
- Hoist is time critical -> Strategy 1 is used

Compared with the initial state the power peak is reduced by approx. 20%.

40kW instead of 50kW
at the same performance

Optimization strategy 2 – Adapting starting time
Electrical energy





Energy

$$W = \int_{t_0}^{t_1} P(t) \cdot dt$$

Compared with the initial state the absorbed energy from the grid is reduced by approx. 30%.

50kWs instead of 70kWs
at the same performance

Comparison of strategies 1 and 2

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	Initial state	Strategy 1 – Adapting dynamic parameters	Strategy 2 – Adapting starting time
Motoric peak power [kW]	50	45	40
Savings in %	-	10 %	20 %
Energy absorbed [kWs]	70	60	50
Savings in %	-	14 %	30 %

Calculated power peaks for the entire shelf
Initial state

Height [m] \ Width [m]	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0	25,0	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0	37,0	38,0	39,0	40,0	41,0	42,0	43,0	44,0	45,0	46,0	47,0	48,0	49,0	50,0
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green	< 49[kW]
light yellow	49[kW] … 55[kW]
orange	55[kW] … 59[kW]
red	> 59[kW]

Calculated power peaks for the entire shelf
Optimization strategy 1 – Adapting dynamic parameters

Height [m] => / Width [m] =>

Height [m]	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0	25,0
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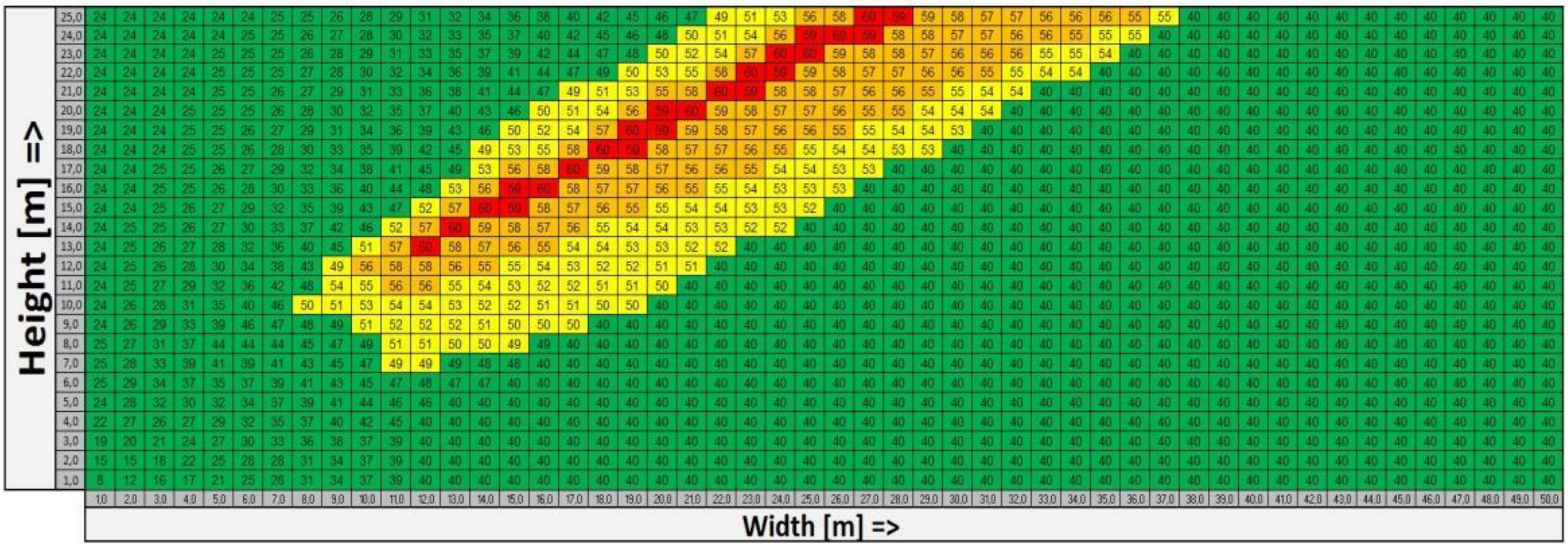
5,0	24	28	32	30	32	34	37	39	41	44	46	46	46	46	46	45	45	45	45	45	44	44	44	44	44
4,0	22	27	26	27	29	32	35	37	40	42	45	45	45	45	44	44	44	44	44	44	44	44	43	43	43
3,0	19	20	21	24	27	30	33	36	38	41	43	44	44	43	43	43	43	43	43	43	43	43	43	42	42
2,0	15	15	18	22	25	28	31	34	37	39	42	43	43	42	42	42	42	42	42	42	42	42	42	42	42
1,0	8	12	16	19	23	26	30	33	35	38	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41

Height [m]	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0	37,0	38,0	39,0	40,0	41,0	42,0	43,0	44,0	45,0	46,0	47,0	48,0	49,0	50,0
25,0	58	60	59	59	58	57	57	56	56	56	55	55	54	54	54	53	53	53	52	52	52	52	52	51	51
24,0	60	59	58	58	57	57	56	56	55	55	55	54	54	54	53	53	53	52	52	52	52	51	51	51	51
23,0	59	58	58	57	56	56	56	55	55	54	54	53	53	53	53	52	52	52	51	51	51	51	51	50	50
22,0	58	57	57	56	56	55	55	54	54	53	53	53	53	52	52	52	51	51	51	51	51	50	50	50	50
21,0	57	56	56	55	55	54	54	54	53	53	53	52	52	52	51	51	51	51	50	50	50	50	50	50	49
20,0	56	55	55	54	54	54	53	53	53	52	52	52	51	51	51	51	50	50	50	50	50	49	49	49	49
19,0	55	55	54	54	53	53	53	52	52	52	51	51	51	51	50	50	50	50	49	49	49	49	49	49	48
18,0	54	54	53	53	53	52	52	51	51	51	51	50	50	50	50	50	49	49	49	49	49	48	48	48	48
17,0	53	53	53	52	52	51	51	51	51	50	50	50	50	49	49	49	49	49	48	48	48	48	48	48	47
16,0	53	52	52	51	51	51	51	50	50	50	50	49	49	49	49	48	48	48	48	48	48	48	47	47	47
15,0	52	51	51	51	50	50	50	49	49	49	49	49	48	48	48	48	48	48	47	47	47	47	47	47	47
14,0	51	50	50	50	50	49	49	49	49	48	48	48	48	48	48	47	47	47	47	47	47	47	46	46	46
13,0	50	50	50	49	49	49	49	48	48	48	48	47	47	47	47	47	47	47	46	46	46	46	46	46	46
12,0	49	49	49	48	48	48	48	48	47	47	47	47	47	47	46	46	46	46	46	46	45	46	46	45	45
11,0	49	48	48	48	48	47	47	47	47	47	47	46	46	46	46	46	46	46	45	45	45	45	45	45	45
10,0	48	47	47	47	47	47	47	46	46	46	46	46	46	46	45	45	45	45	45	45	45	45	45	44	44
9,0	47	47	47	46	46	46	46	46	45	45	45	45	45	45	45	45	45	45	44	44	44	44	44	44	44
8,0	46	46	46	46	45	45	45	45	45	45	45	45	45	44	44	44	44	44	44	44	44	44	44	44	43
7,0	45	45	45	45	45	45	45	44	44	44	44	44	44	44	44	44	44	44	43	43	43	43	43	43	43
6,0	45	44	44	44	44	44	44	44	44	44	44	43	43	43	43	43	43	43	43	43	43	43	43	43	43
5,0	44	44	44	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	42	42	42	42	42	42	42
4,0	43	43	43	43	43	43	43	43	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
3,0	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	41	42	42	42	41	41	41
2,0	42	42	42	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
1,0	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	40

Green	< 49[kW]
Light yellow	49[kW] ... 55[kW]
Orange	55[kW] ... 59[kW]
Red	> 59[kW]

Calculated power peaks for the entire shelf
Optimization strategy 2 – Adapting starting time



Height [m] =>																																																		
25,0	24	24	24	24	24	24	25	25	26	28	29	31	32	34	36	38	40	42	45	46	47	49	51	53	56	58	60	59	59	58	57	57	56	56	56	55	55	40	40	40	40	40	40	40	40	40	40	40	40	40
24,0	24	24	24	24	24	25	25	26	27	28	30	32	33	35	37	40	42	45	46	48	50	51	54	56	59	60	59	58	58	57	57	56	56	55	55	55	40	40	40	40	40	40	40	40	40	40	40	40	40	40
23,0	24	24	24	24	25	25	25	26	28	29	31	33	35	37	39	42	44	47	48	50	52	54	57	60	60	59	58	58	57	56	56	56	55	55	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
22,0	24	24	24	24	25	25	25	27	28	30	32	34	36	39	41	44	47	49	50	53	55	58	60	59	59	58	57	57	56	56	55	55	54	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
21,0	24	24	24	24	25	25	26	27	29	31	33	36	38	41	44	47	49	51	53	55	58	60	59	58	58	57	56	56	55	55	54	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
20,0	24	24	24	25	25	25	26	28	30	32	35	37	40	43	46	50	51	54	56	59	60	59	58	57	57	56	55	55	54	54	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
19,0	24	24	24	25	25	26	27	29	31	34	36	39	43	46	50	52	54	57	60	59	59	58	57	56	56	55	55	54	54	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
18,0	24	24	24	25	25	26	28	30	33	35	39	42	45	49	53	55	58	60	59	58	57	57	56	55	55	54	54	53	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
17,0	24	24	25	25	26	27	29	32	34	38	41	45	49	53	56	58	60	59	58	57	56	56	55	54	54	53	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
16,0	24	24	25	25	26	28	30	33	36	40	44	48	53	56	59	60	58	57	57	56	55	55	54	53	53	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
15,0	24	24	25	26	27	29	32	35	39	43	47	52	57	60	59	58	57	56	55	55	54	54	53	53	52	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
14,0	24	25	25	26	27	30	33	37	42	46	52	57	60	59	58	57	56	55	54	54	53	53	52	52	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
13,0	24	25	26	27	28	32	36	40	45	51	57	60	58	57	56	55	54	54	53	53	52	52	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
12,0	24	25	26	28	30	34	38	43	49	56	58	58	56	55	55	54	53	52	52	51	51	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
11,0	24	25	27	29	32	36	42	48	54	55	56	56	55	54	53	52	52	51	51	50	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
10,0	24	26	28	31	35	40	46	50	51	53	54	54	53	52	52	51	51	50	50	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
9,0	24	26	29	33	39	46	47	48	49	51	52	52	52	51	50	50	50	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
8,0	25	27	31	37	44	44	44	45	47	49	51	51	50	50	49	49	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
7,0	25	28	33	39	41	39	41	43	45	47	49	49	49	48	48	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
6,0	25	29	34	37	35	37	39	41	43	45	47	48	47	47	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
5,0	24	28	32	30	32	34	37	39	41	44	46	46	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
4,0	22	27	26	27	29	32	35	37	40	42	45	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
3,0	19	20	21	24	27	30	33	36	38	37	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
2,0	15	15	18	22	25	28	28	31	34	37	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
1,0	8	12	16	17	21	25	28	31	34	37	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0	25,0	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0	37,0	38,0	39,0	40,0	41,0	42,0	43,0	44,0	45,0	46,0	47,0	48,0	49,0	50,0

Width [m] =>

(green)	< 49[kW]
(light yellow)	49[kW] ... 55[kW]
(orange)	55[kW] ... 59[kW]
(red)	> 59[kW]

Calculated absorbed energy for the entire shelf
Initial state

SIEMENS
Ingenuity for life

Height [m] \ Width [m] =>	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0	25,0
25,0	127	129	130	132	134	136	138	140	143	145	147	148	148	149	149	150	151	151	152	152	153	154	154	155	155
24,0	122	123	125	127	129	131	133	135	138	140	142	143	143	144	145	145	146	146	147	148	148	149	149	150	151
23,0	117	118	120	122	124	126	128	130	132	134	137	138	138	139	139	140	141	141	142	142	143	144	144	145	147
22,0	112	114	115	117	119	121	123	125	127	130	132	133	133	134	135	135	136	136	137	138	138	139	140	143	147
21,0	107	109	110	112	114	116	118	120	122	125	127	128	128	129	129	130	131	131	132	132	133	135	138	142	146
20,0	102	103	105	107	109	111	113	115	117	119	122	123	123	124	125	125	126	126	127	128	129	134	138	142	145
19,0	97	98	100	102	104	106	108	110	112	114	117	118	118	119	119	120	121	121	122	124	129	133	137	140	142
18,0	92	93	95	97	99	101	103	105	107	109	112	113	113	114	114	115	116	116	120	124	128	132	135	137	139
17,0	87	88	90	92	94	96	98	100	102	104	107	108	108	109	109	110	111	115	119	123	127	129	132	133	135
16,0	82	83	85	87	89	91	93	95	97	99	102	103	103	104	104	106	110	115	119	122	124	126	128	129	130
15,0	77	78	80	82	84	86	88	90	92	94	96	97	98	99	101	106	110	113	117	119	121	123	124	125	125
14,0	72	73	75	77	79	81	83	85	87	89	92	93	93	96	101	105	109	111	114	115	117	118	119	120	120
13,0	67	68	70	72	74	76	78	80	82	84	86	88	92	96	100	104	106	108	110	112	113	114	114	115	115
12,0	62	63	65	67	69	71	73	75	77	79	83	87	92	95	98	101	103	105	106	107	108	109	109	110	110
11,0	57	58	60	62	64	66	68	70	72	77	82	87	90	93	96	98	99	101	102	102	103	104	104	105	105
10,0	52	53	55	57	59	61	63	66	71	76	82	85	88	90	92	94	95	96	97	97	98	99	99	100	100
9,0	47	48	50	52	54	56	59	64	69	75	80	83	85	87	89	90	90	91	92	92	93	94	94	94	95
8,0	41	43	45	47	49	52	57	62	67	72	77	80	82	83	84	85	85	86	87	87	88	89	89	90	90
7,0	36	38	40	42	45	50	55	60	64	69	74	76	78	78	79	80	80	81	82	82	83	84	84	85	85
6,0	31	33	35	38	42	47	52	56	61	65	70	72	73	73	74	75	75	76	77	77	78	78	79	79	80
5,0	26	28	30	34	39	43	48	52	57	61	65	67	68	68	69	70	70	71	72	72	73	73	74	74	75
4,0	21	23	26	31	35	39	44	48	52	56	61	62	63	63	64	65	65	66	66	67	68	68	69	69	70
3,0	16	19	22	27	31	35	39	43	47	51	56	57	58	58	59	60	60	61	61	62	63	63	64	64	65
2,0	11	15	18	22	26	30	34	38	42	46	50	52	53	53	54	55	55	56	56	57	58	58	59	59	60
1,0	7	10	14	17	21	25	29	33	37	41	45	47	48	48	49	50	50	51	51	52	53	53	54	54	55

Height [m] \ Width [m] =>	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0	37,0	38,0	39,0	40,0	41,0	42,0	43,0	44,0	45,0	46,0	47,0	48,0	49,0	50,0
25,0	156	157	161	165	170	173	176	178	179	181	182	183	183	184	185	185	186	187	187	187	188	189	189	190	190
24,0	152	156	161	165	168	170	172	174	175	176	177	178	178	179	180	180	181	182	182	182	183	184	184	185	185
23,0	152	156	160	163	165	167	169	170	171	171	172	173	173	174	175	175	175	176	177	177	178	179	179	180	180
22,0	151	155	158	160	162	163	165	165	166	166	167	168	168	169	169	170	171	171	172	172	173	174	174	175	175
21,0	150	152	155	156	158	159	160	160	161	161	162	163	163	164	164	165	166	166	167	167	168	169	169	170	170
20,0	147	149	151	152	153	154	155	155	156	156	157	158	158	159	160	160	160	161	162	162	163	164	164	165	165
19,0	144	145	147	148	148	149	150	150	151	151	152	153	153	154	155	155	155	156	157	157	158	158	159	160	160
18,0	140	141	142	143	143	144	145	145	146	146	147	148	148	149	149	150	151	151	152	152	153	154	154	155	155
17,0	136	136	137	138	138	139	140	140	141	141	142	142	143	144	144	145	145	146	146	147	148	149	149	150	150
16,0	131	131	132	133	133	134	135	135	136	136	137	138	138	139	139	140	140	141	141	142	143	144	144	145	145
15,0	126	126	127	128	128	129	130	130	131	131	132	132	133	134	134	135	135	136	136	137	138	138	139	140	140
14,0	121	121	122	123	123	124	125	125	126	126	127	127	128	129	129	130	130	131	131	132	133	133	134	135	135
13,0	116	116	117	118	118	119	120	120	121	121	122	122	123	124	124	125	125	126	126	127	128	129	129	129	130
12,0	111	111	112	113	113	114	115	115	116	116	117	117	118	119	119	120	120	121	121	122	123	123	124	124	125
11,0	106	106	107	108	108	109	109	110	111	111	112	112	113	114	114	115	115	116	116	117	118	118	119	119	120
10,0	101	101	102	103	103	104	105	105	105	106	107	107	108	108	109	110	110	111	111	112	113	113	114	114	115
9,0	96	96	97	98	98	99	99	100	100	101	102	102	103	104	104	105	105	106	106	107	108	108	109	109	110
8,0	91	91	92	92	93	94	94	95	95	96	97	97	98	98	99	100	100	101	101	102	103	103	104	104	105
7,0	86	86	87	87	88	89	89	90	90	91	92	92	93	93	94	95	95	96	96	97	98	98	99	99	100
6,0	81	81	82	82	83	84	84	85	85	86	87	87	88	88	89	89	90	91	91	92	93	93	94	94	95
5,0	76	76	77	77	78	78	79	80	80	81	82	82	83	83	84	85	85	86	86	87	88	88	89	89	90
4,0	71	71	72	72	73	73	74	75	75	76	76	77	78	78	79	80	80	81	81	82	82	83	84	84	85
3,0	66	66	67	67	68	68	69	70	70	71	72	72	73	73	74	74	75	76	76	77	77	78	79	79	80
2,0	61	61	62	62	63	64	64	65	65	66	67	67	68	68	69	69	70	71	71	72	72	73	73	74	75
1,0	56	56	57	57	58	59	59	60	60	61	62	62	63	63	64	65	65	66	66	67	67	68	69	69	70

Green	$< 80[\mathrm{kWs}]$
Light yellow	$80[\mathrm{kWs}] \ldots 125[\mathrm{kWs}]$
Orange	$125[\mathrm{kWs}] \ldots 155[\mathrm{kWs}]$
Red	$> 155[\mathrm{kWs}]$

Calculated absorbed energy for the entire shelf
Optimization strategy 1 – Adapting dynamic parameters

Height [m] => / Width [m] =>	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0
25,0	126	127	128	129	130	131	132	133	134	136	137	139	141	142	144	146	148	150	152	153	153	154	154	155	156
24,0	121	122	123	124	125	126	127	128	130	131	133	134	136	138	140	142	144	146	147	148	148	149	149	150	151
23,0	116	117	118	119	120	121	122	123	125	126	128	130	131	133	135	137	140	141	142	143	143	144	144	145	146
22,0	111	112	113	114	115	116	117	119	120	122	123	125	127	129	131	133	136	136	137	138	138	139	139	140	141
21,0	106	107	108	109	110	111	113	114	115	117	119	121	123	125	127	129	131	131	132	132	133	134	135	135	136
20,0	101	102	103	104	105	106	108	109	111	112	114	116	118	121	123	125	126	126	127	128	128	129	130	130	131
19,0	96	97	98	99	100	101	103	104	106	108	110	112	114	117	119	120	121	121	122	122	123	124	125	126	127
18,0	91	92	93	94	95	97	98	100	102	104	106	108	110	113	115	115	116	116	117	118	119	120	120	121	122
17,0	86	87	88	89	90	92	93	95	97	99	101	104	106	109	109	110	111	111	112	113	114	115	116	117	118
16,0	81	82	83	84	86	87	89	91	93	95	97	100	103	104	105	105	106	107	108	109	110	111	112	112	113
15,0	76	77	78	79	81	82	84	86	88	91	93	96	98	99	99	100	101	102	103	104	105	106	107	108	109
14,0	71	72	73	74	76	78	80	82	84	87	89	92	93	94	95	96	97	98	99	100	101	102	103	104	105
13,0	66	67	68	70	71	73	75	77	80	83	86	88	88	89	90	92	93	94	95	96	97	98	99	100	101
12,0	61	62	63	65	67	69	71	73	76	79	82	83	84	85	86	87	89	89	91	92	93	94	95	95	96
11,0	56	57	58	60	62	64	67	69	72	74	77	79	80	81	82	83	84	85	87	88	89	90	91	91	92
10,0	51	52	53	55	57	60	62	65	67	70	73	75	76	77	78	79	81	81	83	84	85	86	87	87	88
9,0	46	47	49	51	53	56	58	60	62	66	69	71	72	73	74	76	77	78	79	80	81	82	83	83	84
8,0	41	42	44	46	49	51	53	55	58	62	65	67	68	70	71	72	73	74	75	76	77	78	79	79	80
7,0	36	37	39	42	44	46	48	51	54	58	62	64	65	66	67	68	69	70	71	72	73	74	75	76	76
6,0	31	33	35	37	39	41	44	47	51	54	58	60	62	63	64	65	66	66	67	68	69	70	71	72	72
5,0	26	28	30	32	34	37	40	44	47	51	55	57	58	59	60	61	62	63	64	65	65	66	67	68	69
4,0	21	23	25	27	29	33	36	40	44	48	52	54	55	56	57	58	59	59	60	61	62	63	63	64	65
3,0	16	18	20	22	26	29	33	37	41	45	49	51	52	53	54	54	55	56	57	57	58	59	60	60	61
2,0	11	13	15	19	22	26	30	34	38	42	46	48	49	49	50	51	52	52	53	54	55	55	56	57	57
1,0	6	8	12	15	19	23	27	31	35	39	43	45	46	46	47	48	49	49	50	50	51	52	52	53	54

Height [m] => / Width [m] =>	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	48.0	49.0	50.0
25,0	156	157	158	158	159	160	161	161	162	163	164	165	165	166	167	168	169	170	170	171	172	173	173	174	175
24,0	151	152	153	153	154	155	156	157	157	158	159	160	161	162	162	163	164	165	165	166	167	168	169	170	170
23,0	146	147	148	149	149	150	151	152	153	154	155	155	156	157	158	159	159	160	161	162	163	163	164	165	166
22,0	142	142	143	144	145	146	147	147	148	149	150	151	152	152	153	154	155	156	156	157	158	159	160	160	161
21,0	137	137	139	139	140	141	142	143	144	144	145	146	147	148	149	150	150	151	152	153	154	154	155	156	157
20,0	132	133	134	135	136	137	138	138	139	140	141	142	143	143	144	145	146	147	147	148	149	150	151	151	152
19,0	128	128	130	130	131	132	133	134	135	135	136	137	138	139	140	141	141	142	143	144	145	145	146	147	148
18,0	123	124	125	126	127	128	129	129	130	131	132	133	134	134	135	136	137	138	138	139	140	141	142	142	143
17,0	119	119	121	121	122	123	124	125	126	127	128	128	129	130	131	132	132	133	134	135	136	137	137	138	139
16,0	114	115	116	117	118	119	120	120	121	122	123	124	125	126	126	127	128	129	129	130	131	132	133	133	134
15,0	110	111	112	113	114	114	116	116	117	118	119	120	121	121	122	123	124	124	125	126	127	128	128	129	130
14,0	106	107	108	108	109	110	111	112	113	114	115	115	116	117	118	119	119	120	121	122	122	123	124	125	125
13,0	102	102	103	104	105	106	107	108	108	109	110	111	112	113	113	114	115	116	116	117	118	119	120	120	121
12,0	97	98	99	100	101	102	103	103	104	105	106	107	108	108	109	110	111	111	112	113	114	114	115	116	116
11,0	93	94	95	96	97	98	99	99	100	101	102	102	103	104	105	106	106	107	108	108	109	110	111	111	112
10,0	89	90	91	92	93	93	94	95	96	97	98	98	99	100	101	101	102	103	103	104	105	106	106	107	108
9,0	85	86	87	88	88	89	90	91	92	92	93	94	95	96	96	97	98	99	99	100	101	101	102	103	103
8,0	81	82	83	84	84	85	86	87	87	88	89	90	91	91	92	93	93	94	95	96	96	97	98	98	99
7,0	77	78	79	80	80	81	82	83	83	84	85	86	86	87	88	89	89	90	91	91	92	93	93	94	95
6,0	73	74	75	76	76	77	78	79	79	80	81	81	82	83	84	84	85	86	86	87	88	88	89	90	90
5,0	70	70	71	72	72	73	74	74	75	76	77	77	78	79	80	80	81	82	82	83	84	84	85	85	86
4,0	66	66	67	68	68	69	70	70	71	72	73	73	74	75	75	76	76	77	78	79	79	80	81	81	82
3,0	62	62	63	64	65	65	66	66	67	68	69	69	70	71	71	72	72	73	74	74	75	76	76	77	77
2,0	58	59	59	60	61	61	62	62	63	64	65	65	66	67	67	68	68	69	69	70	71	71	72	73	73
1,0	54	55	56	56	57	57	58	59	59	60	61	61	62	62	63	64	64	65	65	66	67	67	68	68	69

Green	< 80[kWs]
Light yellow	80[kWs] … 125[kWs]
Orange	125[kWs] … 155[kWs]
Red	> 155[kWs]

Calculated absorbed energy for the entire shelf
Optimization strategy 2 – Adapting starting time

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Height [m] => / Width [m] =>

Height [m] \ Width [m]	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0	25,0
25,0	126	127	128	129	130	131	132	133	134	136	137	139	141	142	144	146	148	150	152	153	153	154	154	155	156
24,0	121	122	123	124	125	126	127	128	130	131	133	134	136	138	140	142	144	146	147	148	148	149	149	150	151
23,0	116	117	118	119	120	121	122	123	125	126	128	130	131	133	135	137	140	141	142	143	143	144	144	145	146
22,0	111	112	113	114	115	116	117	119	120	122	123	125	127	129	131	133	136	136	137	138	138	139	139	140	141
21,0	106	107	108	109	110	111	113	114	115	117	119	121	123	125	127	129	131	131	132	132	133	134	135	135	136
20,0	101	102	103	104	105	106	108	109	111	112	114	116	118	121	123	125	126	126	127	128	128	129	130	130	131
19,0	96	97	98	99	100	101	103	104	106	108	110	112	114	117	119	120	121	121	122	122	123	124	125	126	127
18,0	91	92	93	94	95	97	98	100	102	104	106	108	110	113	115	115	116	116	117	118	119	120	120	121	122
17,0	86	87	88	89	90	92	93	95	97	99	101	104	106	109	109	110	111	111	112	113	114	115	116	117	118
16,0	81	82	83	84	86	87	89	91	93	95	97	100	103	104	105	105	106	107	108	109	110	111	112	112	113
15,0	76	77	78	79	81	82	84	86	88	91	93	96	98	99	99	100	101	102	103	104	105	106	107	108	109
14,0	71	72	73	74	76	78	80	82	84	87	89	92	93	94	95	96	97	98	99	100	101	102	103	104	100
13,0	66	67	68	70	71	73	75	77	80	83	86	88	88	89	90	92	93	94	95	96	97	98	94	95	95
12,0	61	62	63	65	67	69	71	73	76	79	82	83	84	85	86	87	89	89	91	92	93	89	89	90	90
11,0	56	57	58	60	62	64	67	69	72	74	77	79	80	81	82	83	84	85	87	88	83	84	84	85	85
10,0	51	52	53	55	57	60	62	65	67	70	73	75	76	77	78	79	81	81	83	77	78	79	79	80	80
9,0	46	47	49	51	53	56	58	60	62	66	69	71	72	73	74	76	77	71	72	72	73	74	74	75	75
8,0	41	42	44	46	49	51	53	55	58	62	65	67	68	70	71	72	66	66	67	67	68	69	69	70	70
7,0	36	37	39	42	44	46	48	51	54	58	62	64	65	66	67	60	61	61	62	62	63	63	64	65	65
6,0	31	33	35	37	39	41	44	47	51	54	58	60	62	63	54	55	55	56	57	57	58	58	59	60	60
5,0	26	28	30	32	34	37	40	44	47	51	55	57	48	48	49	50	50	51	52	52	53	53	54	54	55
4,0	21	23	25	27	29	33	36	40	44	48	52	45	45	46	47	47	48	48	49	50	50	51	52	52	53
3,0	16	18	20	22	26	29	33	37	41	38	42	43	44	45	45	46	47	47	48	48	49	50	50	51	51
2,0	11	13	15	19	22	26	25	29	33	37	41	43	44	44	45	45	46	47	47	48	48	49	50	50	51
1,0	6	8	12	12	16	20	24	28	32	37	41	43	43	44	44	45	46	46	47	47	48	49	49	50	50

Height [m] \ Width [m]	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0	37,0	38,0	39,0	40,0	41,0	42,0	43,0	44,0	45,0	46,0	47,0	48,0	49,0	50,0
25,0	156	157	158	158	159	160	161	161	162	163	164	165	163	164	165	165	166	166	167	168	168	169	169	170	171
24,0	151	152	153	153	154	155	156	157	157	158	159	158	158	159	160	160	161	161	162	163	163	164	164	165	166
23,0	146	147	148	149	149	150	151	152	153	154	152	153	153	154	155	155	156	157	157	158	158	159	160	160	161
22,0	142	142	143	144	145	146	147	147	148	146	147	148	148	149	150	150	151	152	152	152	153	154	155	155	156
21,0	137	137	139	139	140	141	142	140	141	142	142	143	144	144	145	145	146	146	147	147	148	149	150	150	151
20,0	132	133	134	135	136	137	135	135	136	137	137	138	139	139	140	140	141	141	142	142	143	144	145	145	146
19,0	128	128	130	130	131	129	130	130	131	132	132	133	134	134	134	135	136	136	137	137	138	139	139	140	140
18,0	123	124	125	126	123	124	125	125	126	127	127	128	129	129	129	130	131	131	132	132	133	134	134	135	135
17,0	119	119	117	118	118	119	120	120	121	121	122	123	123	124	124	125	125	126	127	127	128	129	129	130	130
16,0	114	112	112	113	113	114	115	115	116	116	117	118	118	119	119	120	121	121	122	122	123	124	124	125	125
15,0	106	107	107	108	108	109	110	110	111	111	112	112	113	114	115	115	116	116	117	117	118	119	119	120	120
14,0	101	102	102	103	103	104	105	105	106	106	107	108	108	109	109	110	110	111	112	112	113	113	114	115	115
13,0	96	97	97	98	98	99	100	100	101	101	102	103	103	104	104	105	105	106	107	107	108	109	109	110	110
12,0	91	92	92	93	93	94	95	95	96	96	97	97	98	99	99	100	100	101	102	102	103	104	104	104	105
11,0	86	87	87	88	88	89	90	90	91	91	92	92	93	94	94	95	96	96	97	97	98	98	99	100	100
10,0	81	81	82	83	83	84	85	85	86	86	87	87	88	89	89	90	90	91	92	92	93	93	94	95	95
9,0	76	76	77	78	78	79	80	80	81	81	82	82	83	84	84	85	85	86	86	87	88	89	89	90	90
8,0	71	71	72	73	73	74	75	75	75	76	77	77	78	79	79	80	80	81	81	82	83	83	84	85	85
7,0	66	66	67	68	68	69	69	70	70	71	72	72	73	74	74	75	75	76	76	77	78	78	79	79	80
6,0	61	61	62	63	63	64	65	65	65	66	67	67	68	69	69	70	70	71	71	72	73	73	74	75	75
5,0	56	56	57	57	58	59	59	60	61	61	62	62	63	64	64	65	65	66	66	67	68	69	69	69	70
4,0	53	54	54	55	56	56	57	57	58	58	59	59	60	61	61	62	62	63	64	65	65	66	66	67	67
3,0	52	52	53	54	54	55	56	56	57	57	58	58	59	60	60	61	61	62	62	63	64	64	65	66	66
2,0	51	52	53	53	54	54	55	55	56	57	57	58	59	59	60	60	61	62	62	63	63	64	65	65	66
1,0	51	51	52	53	53	54	55	55	56	56	57	57	58	59	59	60	60	61	61	62	63	63	64	65	65

Green	$< 80[kWs]$
Light yellow	$80[kWs] \dots 125[kWs]$
Orange	$125[kWs] \dots 155[kWs]$
Red	$> 155[kWs]$

Comparison of strategies 1 and 2
Average values for the entire shelf

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	Initial state	Strategy 1 – Adapting dynamic parameters	Strategy 2 – Adapting starting time
Average value of motoric peak power [kW]	53.7	44.6	41.2
Savings in %	-	17 %	23.3 %
Average value of energy absorbed [kWs]	108	100	95
Savings in %	-	7.4 %	12.1 %

Test reading at a real small parts ASRM
Absorbed energy

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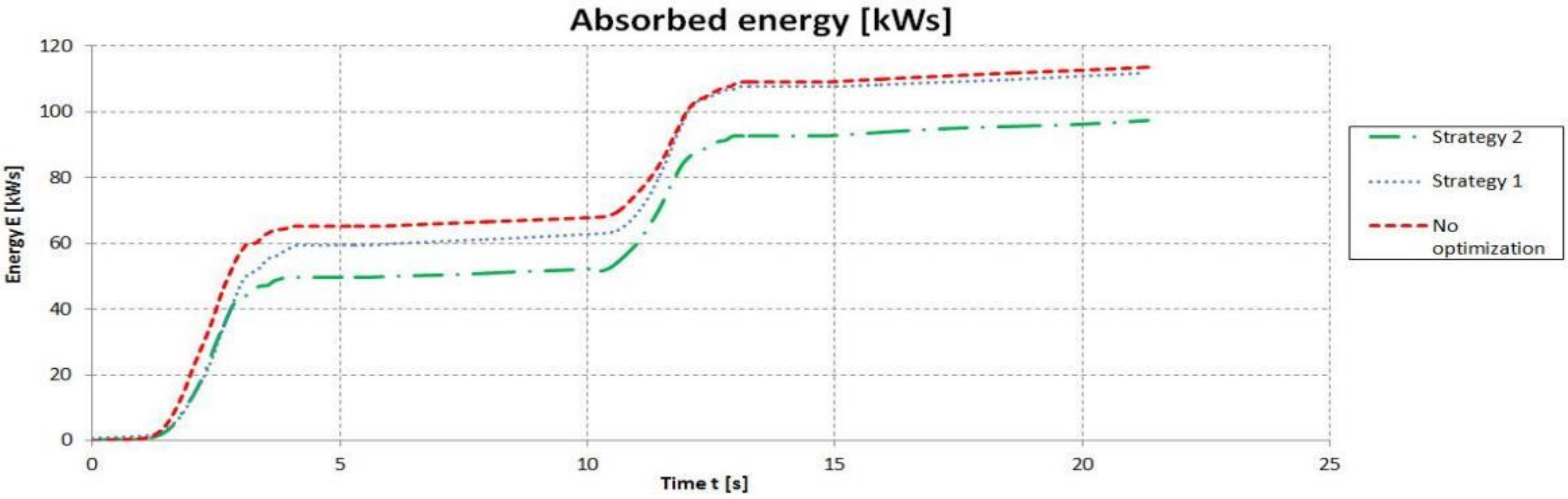
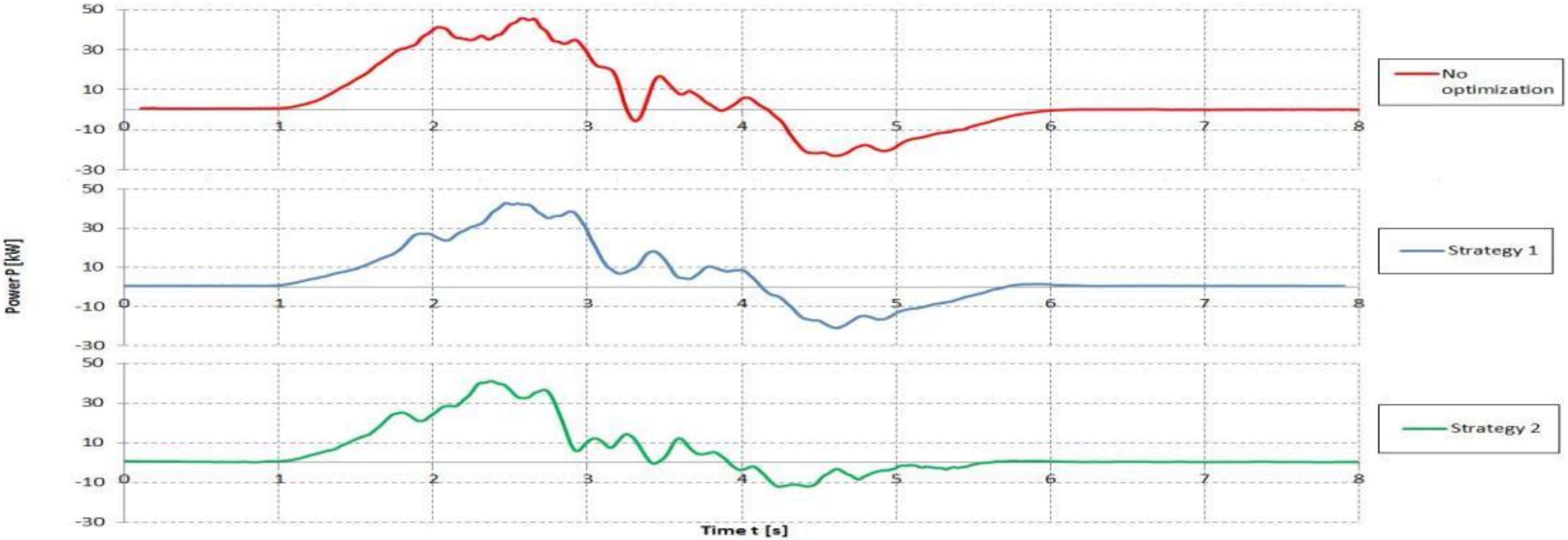


	Initial state	Strategy 1 – Adapting dynamic parameters	Strategy 2 – Adapting starting time
Energy absorbed [kWs]	116	115	98
Savings [kWs]	-	1	18
In %	-	0,9 %	15,6%

Test reading at a real small parts ASRM
Electrical power



	Initial state	Strategy 1 – Adapting dynamic parameters	Strategy 2 – Adapting starting time
Motoric / regenerative power [kW]	51 / 25	46 / 21	43 / 12
Savings in %	-	10% / 16%	16 % / 52%

Agenda

Limitation of electrical power
Benefit and side effect

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+ Reduction of ASRMs maximum electrical connecting power (cost savings)

- Possible usage of smaller infeed modules
- Smaller dimensioning of transformer and grid periphery possible
- Limitation of maximum power for ASRM depending on actual situation, e.g. at simultaneous start of several ASRMs

- Reduced performance for some positions in the shelf (approx. 5 to 10%)

- Dynamics of drives will we reduced if actual motion profile will exceed the power limitation
  → Increased cycle time for the actual motion profile
- Number of involved positions must be taken into account when defining the power limit
  Goal: max. 5 to 10% of positions with reduced performance

Limitation of electrical connection power
Calculated power peaks for the entire shelf

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Height [m] => / Width [m] =>

Height [m]	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0
25,0	24	24	24	24	24	24	25	25	26	28	29	31	32	34	36	38	40	42	45	46	47	49	51	53	56
24,0	24	24	24	24	24	25	25	26	27	28	30	32	33	35	37	40	42	45	46	48	50	51	54	56	59
23,0	24	24	24	24	25	25	25	26	28	29	31	33	35	37	39	42	44	47	48	50	52	54	57	60	60
22,0	24	24	24	24	25	25	25	27	28	30	32	34	36	39	41	44	47	49	50	53	55	58	60	59	59
21,0	24	24	24	24	25	25	26	27	29	31	33	36	38	41	44	47	49	51	53	55	58	60	59	58	58
20,0	24	24	24	25	25	25	26	28	30	32	35	37	40	43	46	50	51	54	56	59	60	59	58	57	57
19,0	24	24	24	25	25	26	27	29	31	34	36	39	43	46	50	52	54	57	60	59	59	58	57	56	56
18,0	24	24	24	25	25	26	28	30	33	35	39	42	45	49	53	55	58	60	59	58	57	57	56	55	55
17,0	24	24	25	25	26	27	29	32	34	38	41	45	49	53	56	58	60	59	58	57	56	56	55	54	54
16,0	24	24	25	25	26	28	30	33	36	40	44	48	53	56	59	60	58	57	57	56	55	55	54	53	53
15,0	24	24	25	26	27	29	32	35	39	43	47	52	57	60	59	58	57	56	55	55	54	54	53	53	52
14,0	24	25	25	26	27	30	33	37	42	46	52	57	60	59	58	57	56	55	54	54	53	53	52	52	40
13,0	24	25	26	27	28	32	36	40	45	51	57	60	58	57	56	55	54	54	53	53	52	52	40	40	40
12,0	24	25	26	28	30	34	38	43	49	56	58	58	56	55	55	54	53	52	52	51	51	40	40	40	40
11,0	24	25	27	29	32	36	42	48	54	55	56	56	55	54	53	52	52	51	51	50	40	40	40	40	40
10,0	24	26	28	31	35	40	46	50	51	53	54	54	53	52	52	51	51	50	50	40	40	40	40	40	40
9,0	24	26	29	33	39	46	47	48	49	51	52	52	52	51	50	50	50	40	40	40	40	40	40	40	40
8,0	25	27	31	37	44	44	44	45	47	49	51	51	50	50	49	49	40	40	40	40	40	40	40	40	40
7,0	25	28	33	39	41	39	41	43	45	47	49	49	49	48	48	40	40	40	40	40	40	40	40	40	40
6,0	25	29	34	37	35	37	39	41	43	45	47	48	47	47	40	40	40	40	40	40	40	40	40	40	40
5,0	24	28	32	30	32	34	37	39	41	44	46	46	40	40	40	40	40	40	40	40	40	40	40	40	40
4,0	22	27	26	27	29	32	35	37	40	42	45	40	40	40	40	40	40	40	40	40	40	40	40	40	40
3,0	19	20	21	24	27	30	33	36	38	37	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40
2,0	15	15	18	22	25	28	28	31	34	37	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40
1,0	8	12	16	17	21	25	28	31	34	37	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40

Height [m]	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	48.0	49.0	50.0
25,0	58	60	59	59	58	57	57	56	56	56	55	55	40	40	40	40	40	40	40	40	40	40	40	40	40
24,0	60	59	58	58	57	57	56	56	55	55	55	40	40	40	40	40	40	40	40	40	40	40	40	40	40
23,0	59	58	58	57	56	56	56	55	55	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
22,0	58	57	57	56	56	55	55	54	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
21,0	57	56	56	55	55	54	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
20,0	56	55	55	54	54	54	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
19,0	55	55	54	54	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
18,0	54	54	53	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
17,0	53	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
16,0	53	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
15,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
14,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
13,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
12,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
11,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
10,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
9,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
8,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
7,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
6,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
5,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
4,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
3,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
2,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
1,0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

- Limitation of ASRM maximum electrical power to 55kW (instead of 60kW)
- 20kW BLM infeed instead of 40kW can be used
- 10% of shelf positions with reduced performance (increased cycle time)

Limitation of electrical connection power
Calculated additional cycle time

Height [m]	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	16,0	17,0	18,0	19,0	20,0	21,0	22,0	23,0	24,0	25,0
25,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5
24,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,2
23,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,3	0,3
22,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,3	0,3	0,2
21,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,2	0,3	0,2	0,2	0,2
20,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,1	0,2	0,2	0,2	0,1	0,1
19,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,2	0,2	0,2	0,1	0,1	0,1	0,0
18,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,0	0,0
17,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,2	0,2	0,1	0,1	0,1	0,1	0,0	0,0	0,0	0,0
16,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,1	0,1	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0
15,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,1	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
14,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
13,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
12,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
11,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
10,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
9,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
8,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
7,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
6,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
4,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
3,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Height [m]	26,0	27,0	28,0	29,0	30,0	31,0	32,0	33,0	34,0	35,0	36,0	37,0	38,0	39,0	40,0	41,0	42,0	43,0	44,0	45,0	46,0	47,0	48,0	49,0	50,0
25,0	0,2	0,3	0,3	0,3	0,2	0,2	0,2	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
24,0	0,3	0,3	0,3	0,2	0,2	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
23,0	0,3	0,2	0,2	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
22,0	0,2	0,2	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
21,0	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
19,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
18,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
17,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
16,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
15,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
14,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
13,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
12,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
11,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
10,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
9,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
8,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
7,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
6,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
4,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
3,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Height [m] =>

Width [m] =>

- Power limitation of 55kW (20kW BLM)
- Start of movement at X=0 (chassis) and Y=0 (hoist)
- 0.5sec as maximum increase of cycle time
- Average increase of hoist movement 0.18%
- No increase of cycle time for chassis movement

Agenda

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Function block "EffMcProfiles"
Overview input- and output signals

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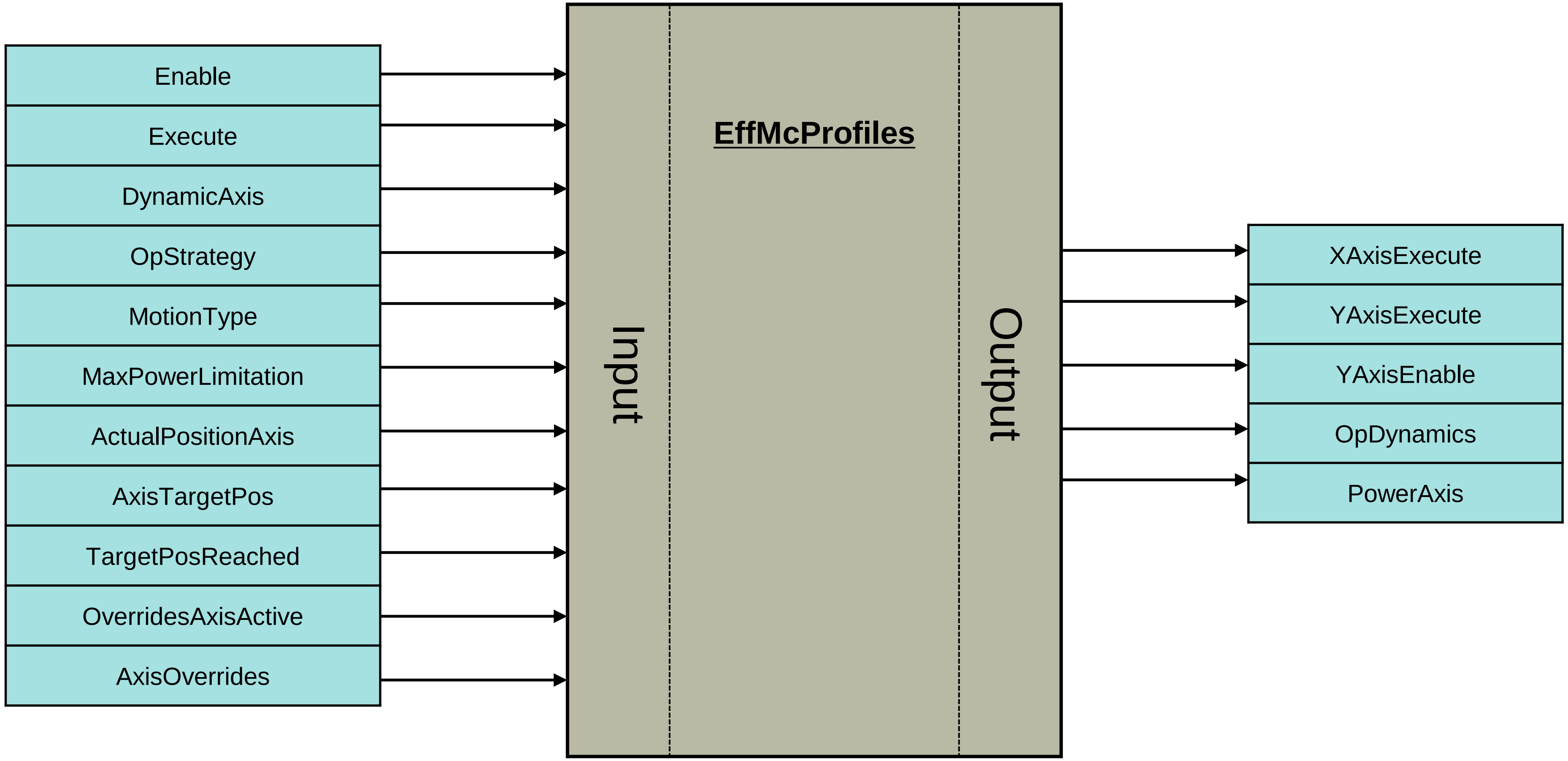

Function block “EffMcProfiles”
Input signals

Variable	Description	Data type
Enable	Enabling of the function block (edge-triggered)	Bool
Execute	Start of calculation	Bool
DynamicAxis	Dynamic parameters of the axis	PLC data type
OptStrategy	Selection of optimization strategy – default setting: strategy 2	Integer
MotionType	Selection if ASRM motion is done by TOs (PLC based) of by EPOS in S120	Integer
MaxPowerLimitation	Maximum electrical power limitation	Real
ActualPositionAxis	Actual position of X/Y axis (new initialized after Execute command)	Real
AxisTargetPos	Target position of X/Y axis	Real
TargetPosReached	Target position reached	Bool
OverridesAxisActive	Selection of overrides should be used	Bool
AxisOverrides	Overrides for dynamic parameters of X/Y axis	Integer

Function block “EffMcProfiles”
Output signals

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Variable	Description	Data type
XAxisExecute	Start movement X axis	Bool
YAxisExecute	Start movement Y axis	Bool
YAxisEnable	Pulse enabling for Y axis (only used for brake management)	Bool
OpDynamics	Output of optimized parameters	PLC data type
PowerAxis	Output of 14 points for power values of X/Y axis and total power in combination with the time stamp -> Use case: e.g. condition monitoring or external power calculation	PLC data type

Agenda

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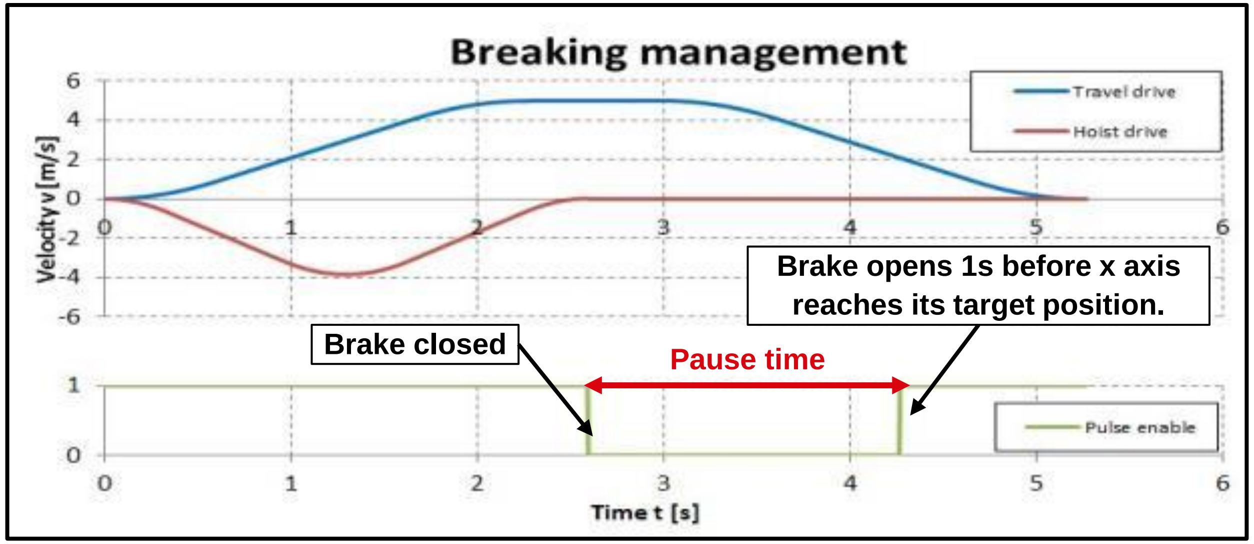
Additional functions
Brake management

At standstill of hoist drive most power is needed for holding the LHD incl. payload.

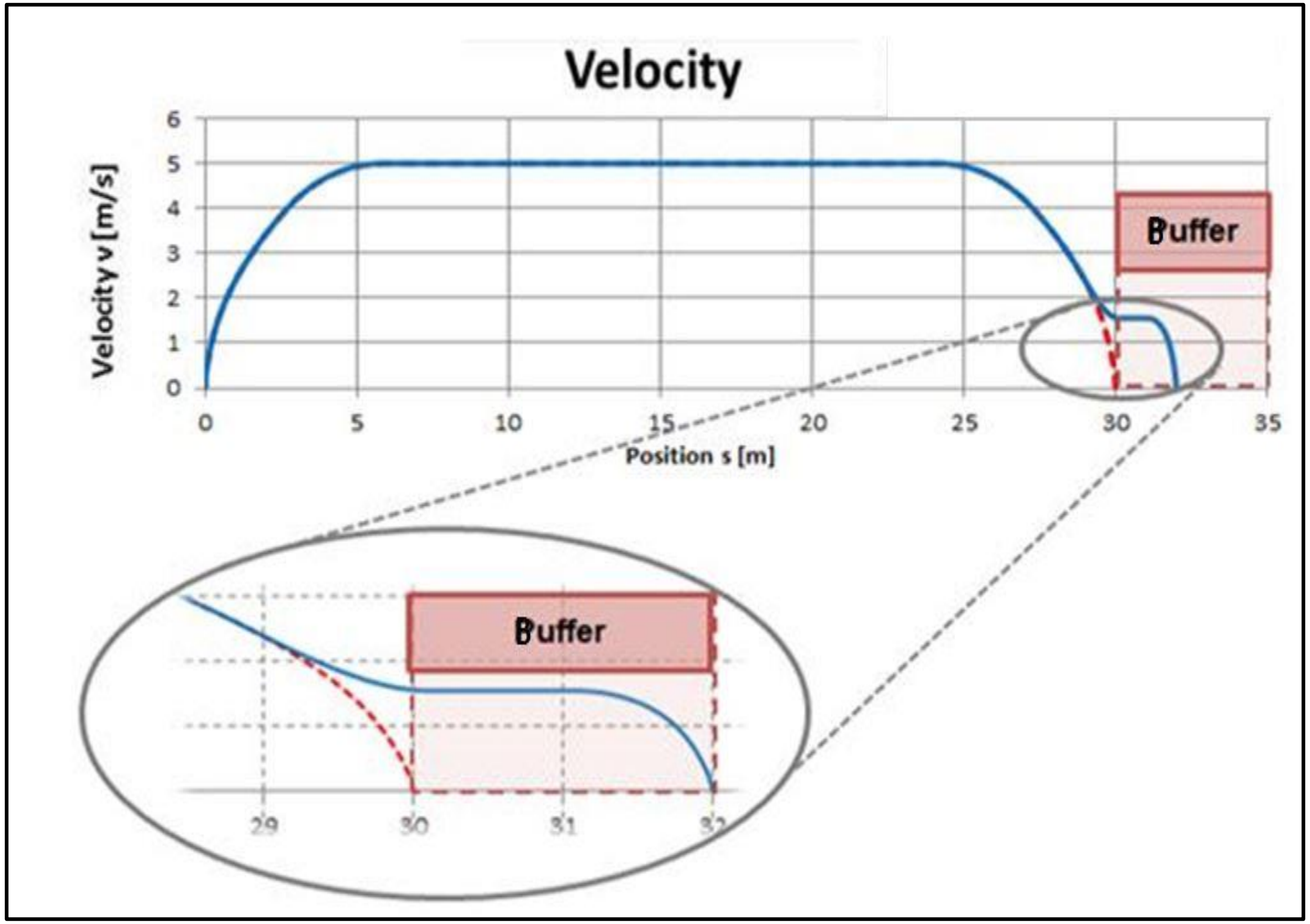
- With closed brake no electrical energy is needed.
- Potential of energy saving at e.g. long chassis movements and rest periods
- Time for opening and closing break is taken into account
- To avoid sagging of the load the electrical hold function will stay active during opening and closing time of the brake
- Goal: No losses in performance



Example:

- **Power to hold the load electrically 0.8kW**
  => Brake is closed for 2 seconds = savings of 1.6kWs of energy
- **A minimum rest time can be defined**
  below that time a brake will not be closed

Additional functions
Driving into buffer



Managment of chassis movement in the buffer area

Inside buffer area the speed must be reduced to avoid a damage of the buffer

- More storage space available when buffer area can be used

Additional functions
Energy saving mode for ASRM

Activation of energy saving mode depending on the actual level of capacity

User definable override values for each axis (X and Y)

- Acceleration
- Deceleration
- Speed

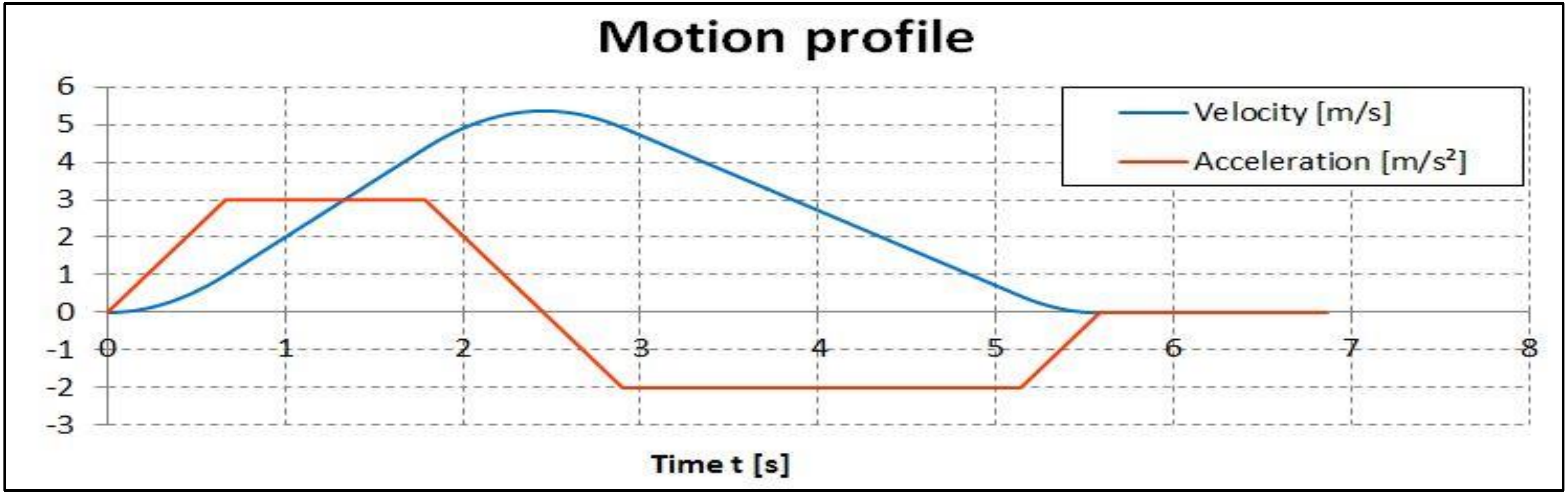
Possible use cases:

- Energy and power efficient operation mode at times with lower workload
- Adaption to environmental conditions e.g. to save energy for cooling the cabinet during summer time or to save cooling energy in deep freeze applications
- Less electrical losses due to operation of motors at best degree of efficiency
- Reduction of electrical and mechanical losses
- Reduction of mechanical wear

Additional functions
Asymmetrical motion profiles

Asymmetrical motion profiles

- In some cases asymmetrical motion profiles have higher saving potentials
- Acceleration can be different from deceleration



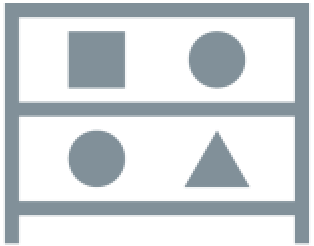
Additional functions
Power calculation and time based motion optimization

<u>Power calculation</u>

- Before starting the movement the needed power of X/Y axis can be calculated
- Two different modes available
  - Simple power calculation
    Only one value for electrical and mechanical efficiency is used
  - Extended power calculation with additional functions:
    - Calculation of needed energy for the ASRM
    - More exact results that can be used e.g. for condition monitoring or a comparison of different ASRMs or plants

<u>Time based optimization</u>

- Space time selection (default value 0 seconds)
  Target position of optimized axis will be reached with that space time
- Use case: Reducing the waiting time before LHD can exchange load with the shelf



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