Benefits of Static Var Compensator (SVC) at DC-EAF Steel plant

1) General

Static Var Compensator (SVC) is the system for the increasing the quality of electrical power from many respects of it. The reactive power compensation, higher constant voltage level and reduced distortion level can be transferred for many advantages of the end user. With the production increase, reduced total power losses and avoided reactive power penalties the pay back time of SVC investment is more likely counted in months than years.

The calculations and conclusions in this document are done for one heat (no 21677) for the DC-furnace plant. The plant has the power limitation for the furnace during melting 78 MW and during refining 68,3 MW. The reason for the limitations were because the control system of the rectifier could not work correctly in case of too high voltage variations. These limitations are taken into account in the following calculations.

2) Productivity

The SVC system can keep steel plant bus voltage practically at constant level. The voltage variation without SVC system can be calculated from formula:

$\Delta U = \Delta Q/Sk$

Where:
ΔU Voltage drop due the reactive power
Sk Short circuit capacity at steel plant bus
ΔQ Reactive power load variation of EAF

The voltage variation of the steel plant has been measured by UCAR. Please see the results for one melting cycle No 21677 in Appendix 1 for voltage. In Appendix 2 the power and reactive power variations are seen.

Using the UCAR measurements (Appendix 1 and 2) and using the average active power and reactive power at each melting stage the melting cycle chart shown in Appendix 3 can be got. The energy for the whole melting cycle can be calculated from the active power cycles and it is 48,89 MWh. See also the energy calculation at Appendix 4.

The voltage variation is from 19 kV to 23,1 kV (Appendix 1) i.e. 83,3 - 101,3% compared with the rated voltage 22,8 kV. The voltage drop is very high causing problems with the voltage control of the furnace. Especially during 4 - 7 minutes in the beginning of each melting bucket the voltage variations are very high and rapid. This is causing severe flicker.

With the SVC system the voltage drop can be avoided and due the constant voltage the active power increase for EAF can be calculated from the formula:

$$\Delta P(\%) = 100 * \left[100/(100 - \Delta U(\%))\right]^2 - 100$$

Where: $\Delta P(\%)$ Increase of power in percent
$\Delta U(\%)$ Voltage drop due the reactive power in percent

In Appendix 5 the SVC has been added. SVC will stabilise the voltage to 22,8 kV. The new total melting time has been reduced from 51,85 min down to 47,13 min which is 9,1 % reduction. The power-on time has been reduced from 48,37 min down to 43,65 min which is 9,8 % reduction. See Appendix 4, page 2/2.

The new melting times have been calculated assuming that furnace is able to transfer increased power into melting process by the similar efficiency than in the system without SVC. The energy consumption is 48,89 MWh like without SVC. Because of shorter melting times the productivity can be increased. It should also be noted that because of the shortened power-on-time the losses are reduced which has not been taken into account in the calculation.

The time reduction of one heat's power-on-time is 9,8 %. The total increase of the productivity can be transferred to the steel tons via saved time of each heat. The economical benefit can be calculated by the steel plant using its own economical figures (selling price of steel, cost of energy, cost of manpower etc.).

The stabilised voltage makes it easier for the operators to operate the furnace economically. The efficiency of the arc furnace is typically 65%. The energy losses to the gas, shell, water, dust and slag are typically 30 - 35%. These losses can be reduced with the reduced melting time. The calculated reduction in energy loss is 3,2% .

The wear of the electrodes and the refractory wear can also be reduced with stabile arc and shorter melting times. With the stabile bus voltage it is easier to operate the furnace with higher arc voltage.

The typical payback time in SVC installations is less than one year. Sometimes only the reactive power tariffs justify the SVC installation with 2 years payback time.

3) Other considerations, summary

Power Utility may give power quality regulations for steel plant in order to limit pollution of the network. Static Var Compensator shall solve all major power quality problems.

Reactive power

The SVC system shall hold reactive power demand from public network within allowed limits thus the penalties shall be avoided.

Harmonics

The filter circuit of SVC system shall be designed in order to absorb harmonics generated by load as well as harmonics generated by thyristor controlled reactors. Total harmonic distortion and individual harmonic voltages shall be limited below requirements. Typical requirement is 1,5% for total voltage distortion.

Voltage unbalance

The SVC is operating on single phase basis and thus it is balancing the voltage.

Voltage fluctuations

The SVC will stabilise the voltage. This is advantageous not only for the arc furnace itself but also for the control and protection system of the steel plant because modern electronics and process instruments are very sensitive to voltage fluctuations.

Flicker phenomenon

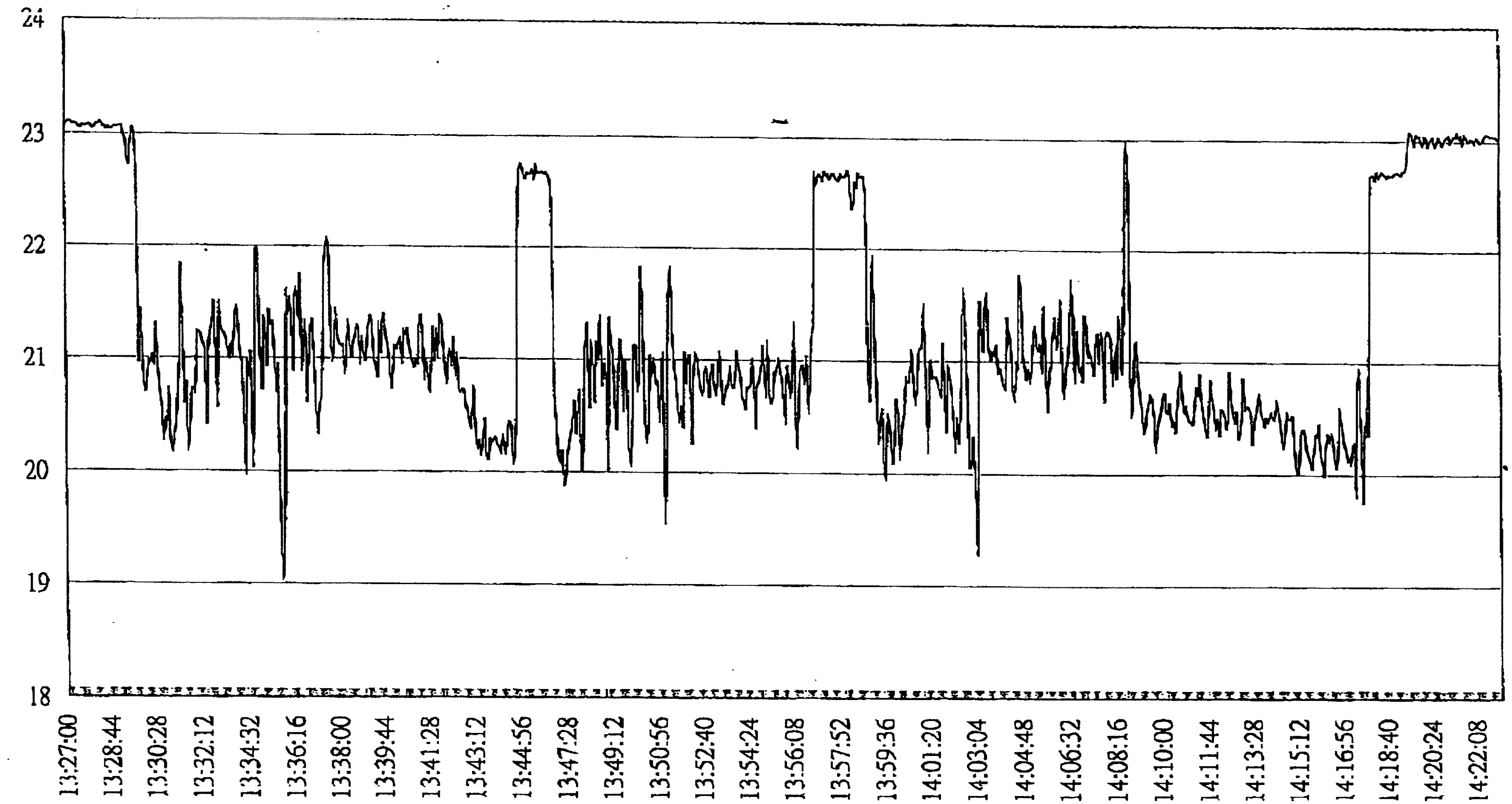
The SVC can reduce the flicker down to the value requested by the power utility.

4) Appendices

Appendix 1:
Measurements, heat no 21677, primary voltage of furnace transformer
Appendix 2:
Measurements, heat no 21677, active and reactive powers
Appendix 3:
Active power, reactive power and voltage (averages) from Appendix 1 and 2
Appendix 4:
Energy calculations
Appendix 5:
Active power and voltage with SVC

APPENDIX 1

TR1--22.8KV BUS--V--1 HEAT (3/26 H21677)



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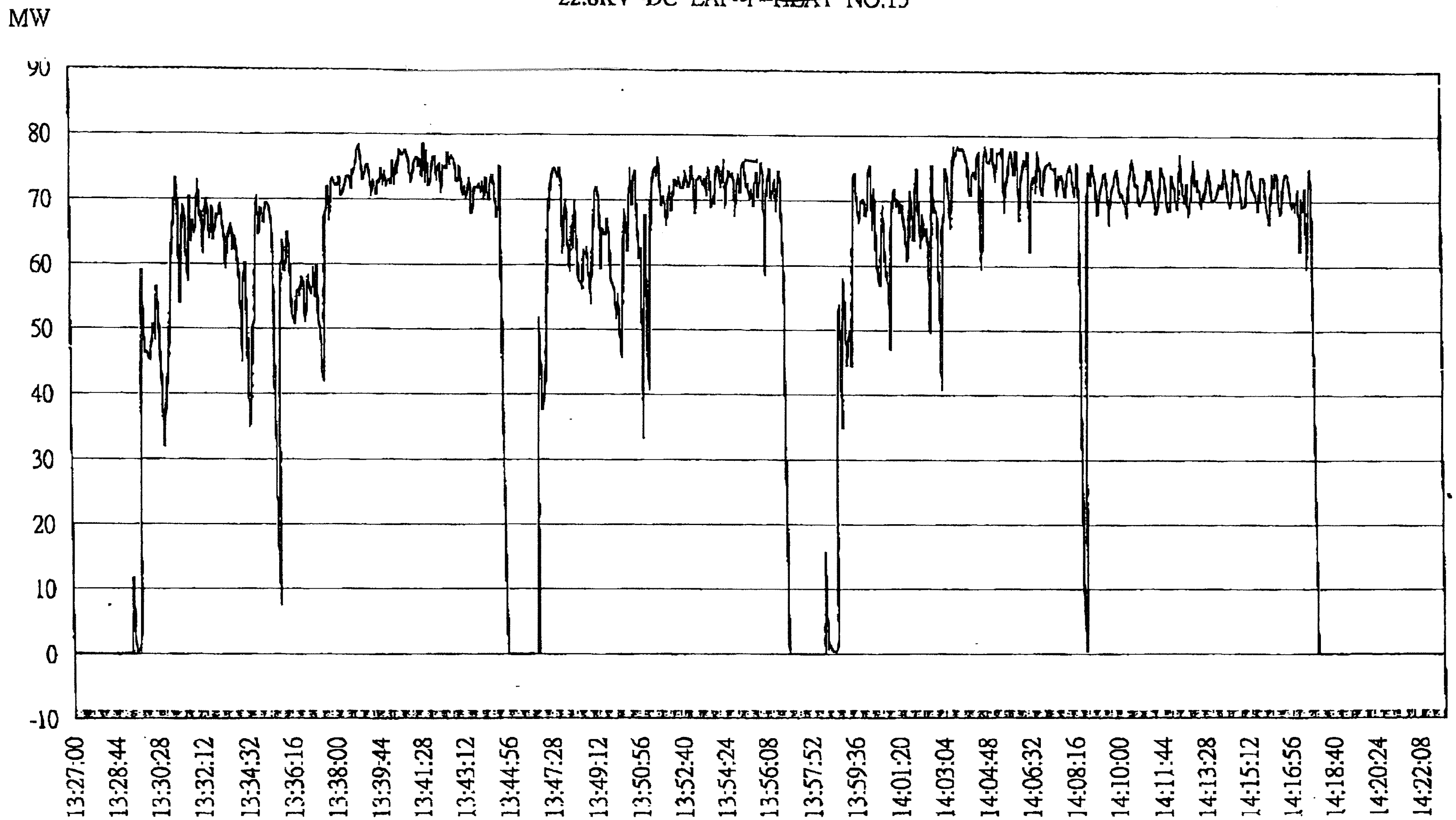
1 HEAT (3/26 H21677)

22.8KV--DC EAF--P--~~HEAT NO.15~~



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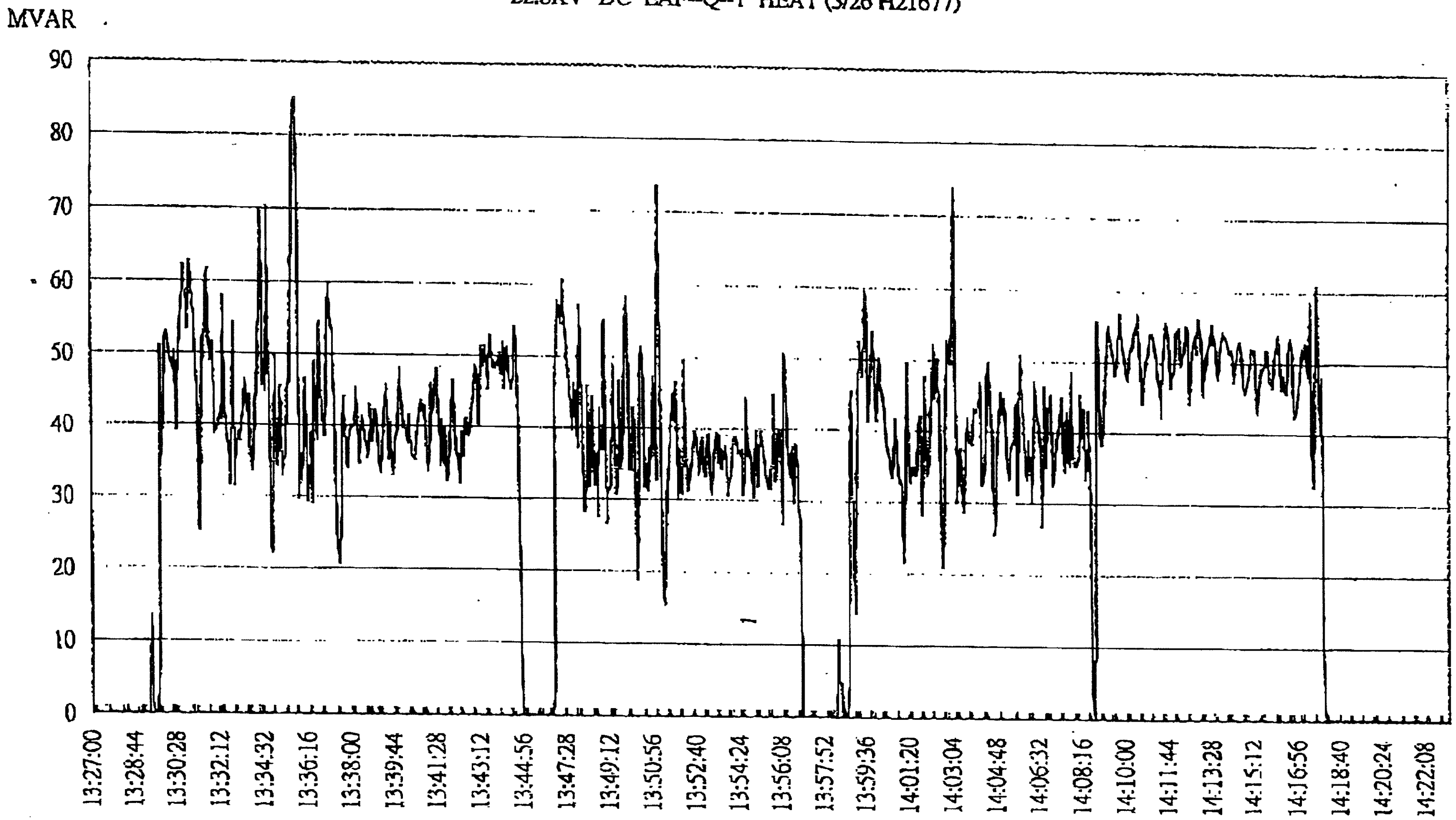
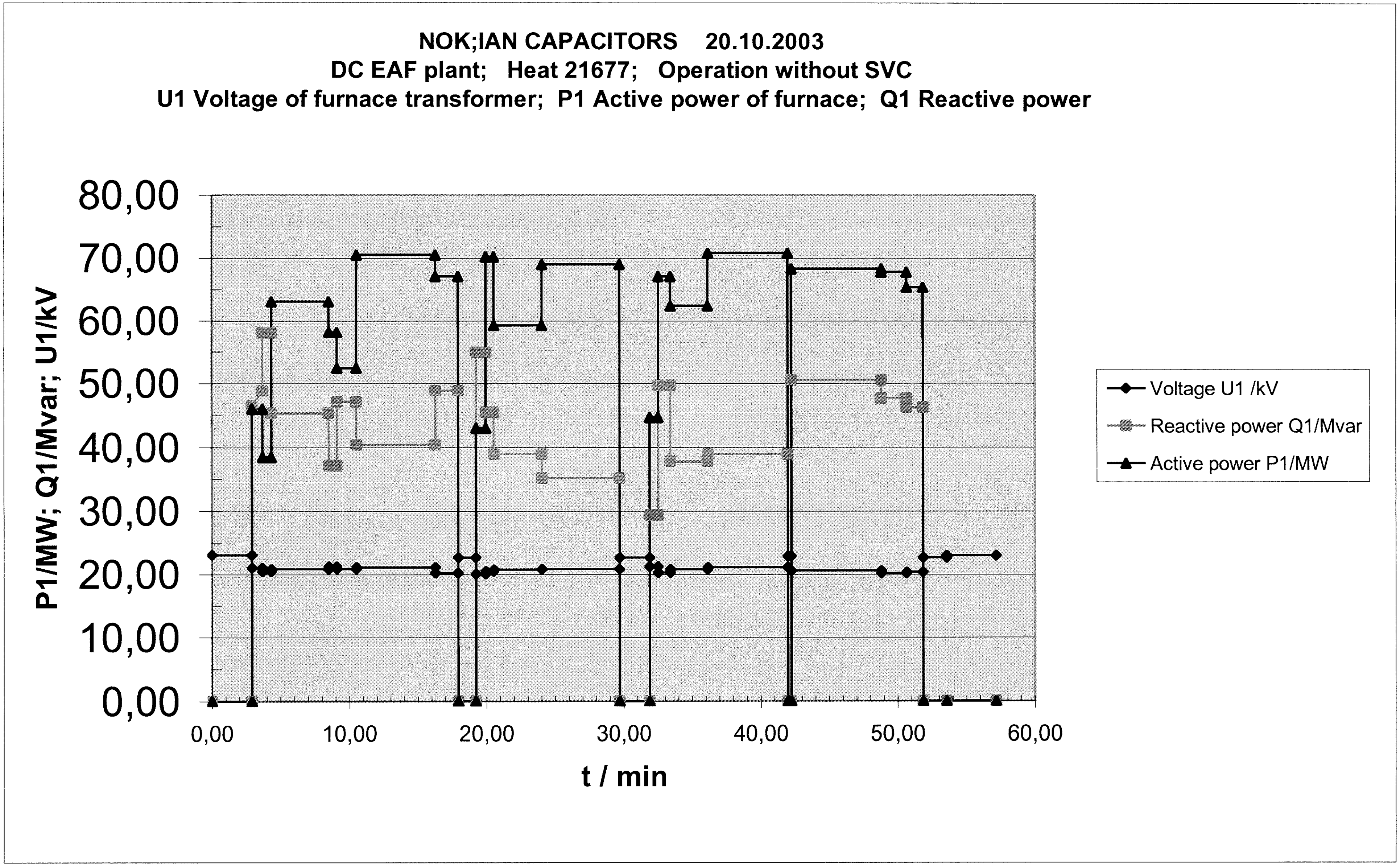
22.8KV--DC EAF--Q--1 HEAT (3/26 H21677)




NOK;IAN CAPACITORS 20.10.2003
DC EAF plant; Heat 21677; Operation without SVC
U1 Voltage of furnace transformer; P1 Active power of furnace; Q1 Reactive power
P1/MW; Q1/Mvar; U1/kV
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
0,00
10,00
20,00
30,00
40,00
50,00
60,00
t / min
Voltage U1 /kV
Reactive power Q1/Mvar
Active power P1/MW

	M	N	O	P	Q	R	S	T	U	V	W	X
1	**NOKIAN CAPACITORS**		**Power limitation 78MW taken into account**						20.10.2003			
2	**DC EAF plant, Melting cycle - Heat 21677**											
3												with
4				without SVC					P1 +			SVC
5							energies	with	Delta P	with	with	energies
6							per	SVC	with SVC	SVC	SVC	per
7		t1	U1	Q1	P1	W1	bucket				W2	bucket
8		min	kV	Mvar	MW	MWh	MWh	t min	P2 MW	U2 kV	MWh	MWh
9	Bucket 1	0,00	23,07	0,0	0,0			0	0,0	22,8		
10		2,91	23,07	0,0	0,0	0,00		2,91	0,0	22,8	0,00	
11	Initial melting	2,92	21,04	46,5	46,0			2,92	54,0	22,8		
12		3,68	21,04	48,8	46,0	0,58		3,57	54,0	22,8	0,58	
13	Bore down	3,69	20,49	58,1	38,5			3,58	47,6	22,8		
14		4,32	20,49	58,1	38,5	0,40		4,08	47,6	22,8	0,40	
15	Melting	4,33	20,87	45,3	63,1			4,09	75,3	22,8		
16		8,51	20,87	45,3	63,1	4,40		7,59	75,3	22,8	4,40	
17	Melting	8,52	21,25	37,2	58,2			7,60	67,0	22,8		
18		9,09	21,25	37,2	58,2	0,56		8,10	67,0	22,8	0,56	
19	Melting	9,10	20,89	47,1	52,4			8,11	62,4	22,8		
20		10,52	20,89	47,1	52,4	1,24		9,30	62,4	22,8	1,24	
21	Melting	10,53	21,14	40,4	70,5			9,31	78,0	22,8		
22		16,27	21,14	40,4	70,5	6,75		14,50	78,0	22,8	6,75	
23	End melting	16,28	20,23	48,8	67,1			14,51	78,0	22,8		
24		17,93	20,23	48,8	67,1	1,85	15,77	15,93	78,0	22,8	1,85	15,77
25	Finish Bucket 1	17,94	22,67	0,0	0,0			15,94	0,0	22,8		
26		19,22	22,67	0,0	0,0	0,00		17,22	0,0	22,8	0,00	
27	Initial melting/boring	19,23	20,09	54,9	43,0			17,23	55,4	22,8		
28		19,94	20,09	54,9	43,0	0,51		17,78	55,4	22,8	0,51	
29	Melting	19,95	20,52	45,4	70,2			17,79	78,0	22,8		
30		20,53	20,52	45,4	70,2	0,67		18,31	78,0	22,8	0,67	
31	Melting	20,54	20,78	38,9	59,3			18,32	71,4	22,8		
32		24,03	20,78	38,9	59,3	3,45		21,22	71,4	22,8	3,45	
33	Melting	24,04	20,86	35,2	69,0			21,23	78,0	22,8		
34		29,69	20,86	35,2	69,0	6,50	11,14	26,24	78,0	22,8	6,50	11,14
35	Finish Bucket 2	29,70	22,67	0,0	0,0			26,25	0,0	22,8		
36		31,89	22,67	0,0	0,0	0,00		28,43	0,0	22,8	0,00	

APPENDIX 4

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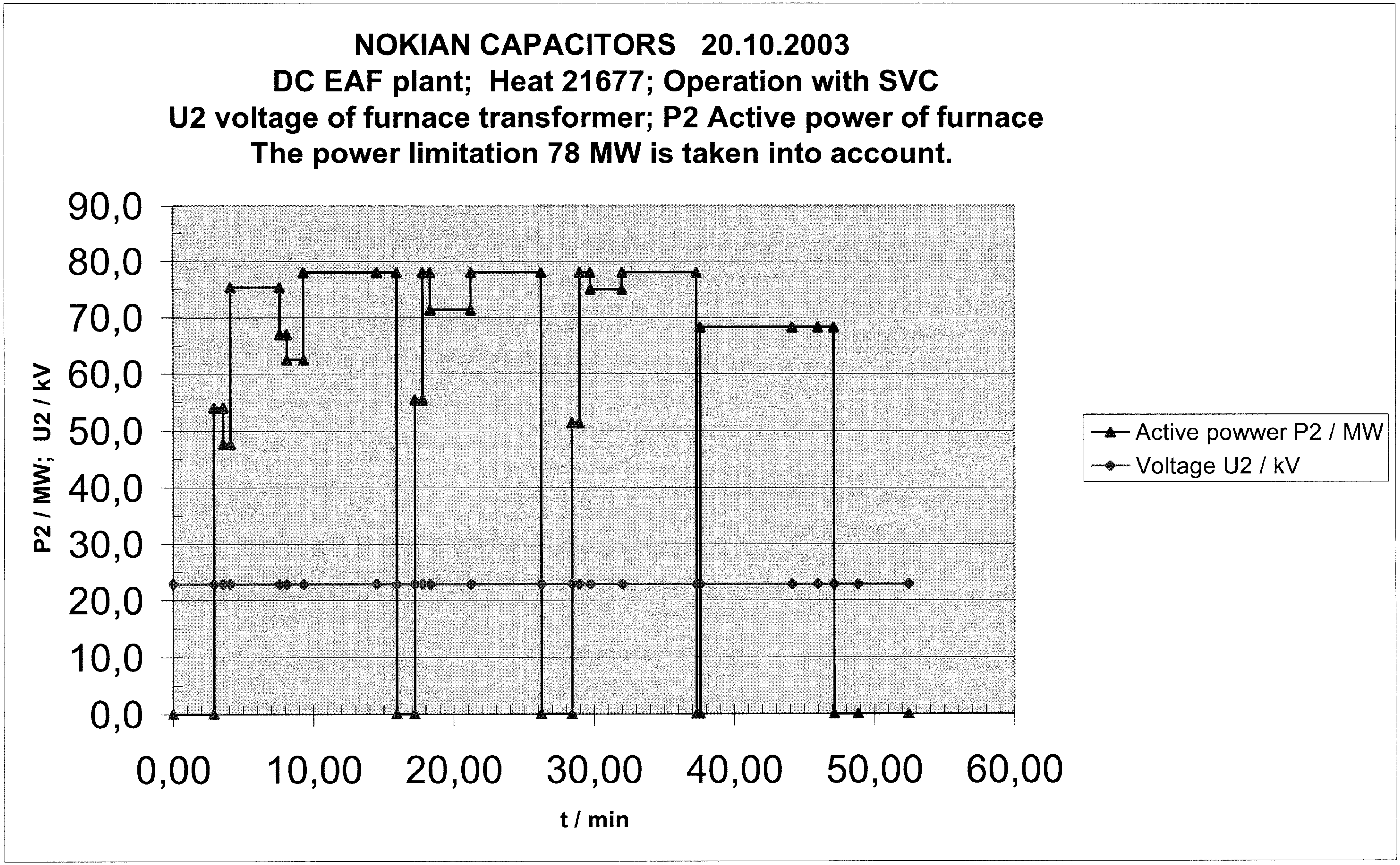
	M	N	O	P	Q	R	S	T	U	V	W	X
37	Initial melting	31,90	21,27	29,3	44,7			28,44	51,4	22,8		
38		32,51	21,27	29,3	44,7	0,45		28,97	51,4	22,8	0,45	
39	Bore down	32,52	20,30	49,7	67,1			28,98	78,0	22,8		
40		33,40	20,30	49,7	67,1	0,99		29,74	78,0	22,8	0,99	
41	Melting	33,41	20,80	37,8	62,4			29,75	75,0	22,8		
42		36,13	20,80	37,8	62,4	2,83		32,02	75,0	22,8	2,83	
43	Melting	36,14	21,12	38,9	70,8			32,03	78,0	22,8		
44		41,97	21,12	38,9	70,8	6,88		37,32	78,0	22,8	6,88	
45	Melting	41,98	22,88	0,0	0,0			37,33	0,0	22,8		
46		42,23	22,88	0,0	0,0	0,00		37,57	0,0	22,8	0,00	
47	Melting	42,24	20,58	50,5	68,3			37,58	68,3	22,8		
48		48,80	20,58	50,5	68,3	7,47		44,15	68,3	22,8	7,47	
49	End melting	48,81	20,20	47,6	67,8			44,16	68,3	22,8		
50		50,64	20,20	47,6	67,8	2,06		45,97	68,3	22,8	2,06	
51	End melting/superheating	50,65	20,37	46,2	65,4			45,98	68,3	22,8		
52		51,84	20,37	46,2	65,4	1,30	21,98	47,12	68,3	22,8	1,30	21,98
53	Finish Bucket 3	51,85	22,69	0,0	0,0			47,13	0,0	22,8		
54		53,56	22,69	0,0	0,0	0,00		48,84	0,0	22,8		
55		53,57	23,00	0,0	0,0			48,85	0,0	22,8		
56		57,17	23,00	0,0	0,0	0,00		52,45	0,0	22,8		
57		57,18	23,00	0,0	0,0			52,46	0,0	22,8		
58	**Sum**					48,89	48,89				48,89	48,89
59												
60												
61												
62			**Total melting times:**					**Power-on times:**				
63												
64			without	with SVC				without	with SVC			
65			SVC					SVC				
66			min	min				min	min			
67			51,85	47,13			bucket 1	17,94	15,94			
68			reduction in time	**9,1**	%		bucket 2	10,47	9,01			
69							bucket 3	19,95	18,69			
70							total	**48,37**	**43,65**			
71								reduction in time	**9,8**	%		
72												
73		**Reduction in energy loss** (typical losses are 35%, only 65% of energy goes to steel):									**-3,2**	**%**


NOKIAN CAPACITORS 20.10.2003
DC EAF plant; Heat 21677; Operation with SVC
U2 voltage of furnace transformer; P2 Active power of furnace
The power limitation 78 MW is taken into account.
P2 / MW; U2 / kV
90,0
80,0
70,0
60,0
50,0
40,0
30,0
20,0
10,0
0,0
0,00
10,00
20,00
30,00
40,00
50,00
60,00
t / min
Active powwer P2 / MW
Voltage U2 / kV