Enerstore 7000 Efficiency test
Version 0.3

Distributor	
LF	
MA	

Processor	**Date**	**Examiner**	**Date**
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1 Introduction

The overall energetic efficiency of the Enerstore 7000 is to be determined. This is a measure of the amount of energy that can be effectively stored in the system and how much the lost energy is. The efficiency is the ratio between input energy and output energy. The efficiency of the overall system consists of the energetic efficiency of the battery, the efficiency of the converter and the efficiency of the medium voltage transformer.

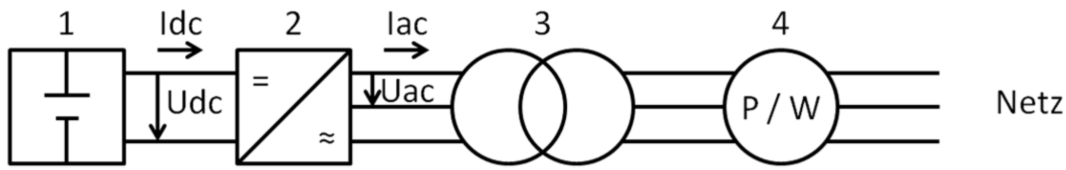
2 Symbols used

SOC	Charging state (depending on the discharge current)	%
Qentl	Removed charge quantity	Ah
Qlad	Input charge quantity	Ah
Idc	Battery current	A
Udc	Battery voltage	V
Pdc	Battery power	kW
Iac	AC current of the converter (low voltage)	A
Uac	Phase voltage (low voltage)	V
Pac	Effective power of the battery converter (low voltage)	kW
Wdc_entl	Extracted DC energy	kWh
Wdc_lad	Input DC energy	kWh
Wac_entl_MS	Extracted AC active energy (medium voltage)	kWh
Wac_lad_MS	Input AC active power (medium voltage)	kWh
eta_dc	Energy efficiency of the battery	
eta_ac_MS	Energy efficiency of the whole system	
Udc_mittel_entl	Average battery voltage during discharging	V
Udc_mittel_lad	Average battery voltage when charging	V
Idc_mittel_entl	Average battery current during discharging	A
Idc_mittel_lad	Average battery current when charging	A

3 Measurement method

In order to determine the overall efficiency of the energy storage device, this is discharged several times with a typical charging or discharging power and is again fully charged. At medium voltage the energy input and the energy output are counted with an electronic wattmeter. In addition, the battery converter records the measurement data from which information on the degree of partial efficiency of the battery can be taken.

3.1 Principle circuit diagram



1	Battery
2	Converter
3	Medium voltage transformer
4	Electronic wattmeter

3.2 Origin of the measured values

Qentl	Integration of the Idc measured values of the converter during discharging
Qlad	Integration of the Idc measured values of the converter during charging
Wdc_entl	Integration of the Pdc measured values of the converter during discharging
Wdc_lad	Integration of the Pdc measured values of the converter during charging
Wac_entl_MS	Counter value of the electronic wattmeter
Wac_lad_MS	Counter value of the electronic wattmeter

3.3 Procedure of the experiment

The battery is initially fully charged. Then the counters of the wattmeter are reset and then the discharging is started. When the minimum charge state is reached, the converter automatically terminates discharging.

Then, the charging is started manually. When the maximum charge level is reached, charging is terminated automatically. The counters of the wattmeter are then read off and the log data of the converter are evaluated.

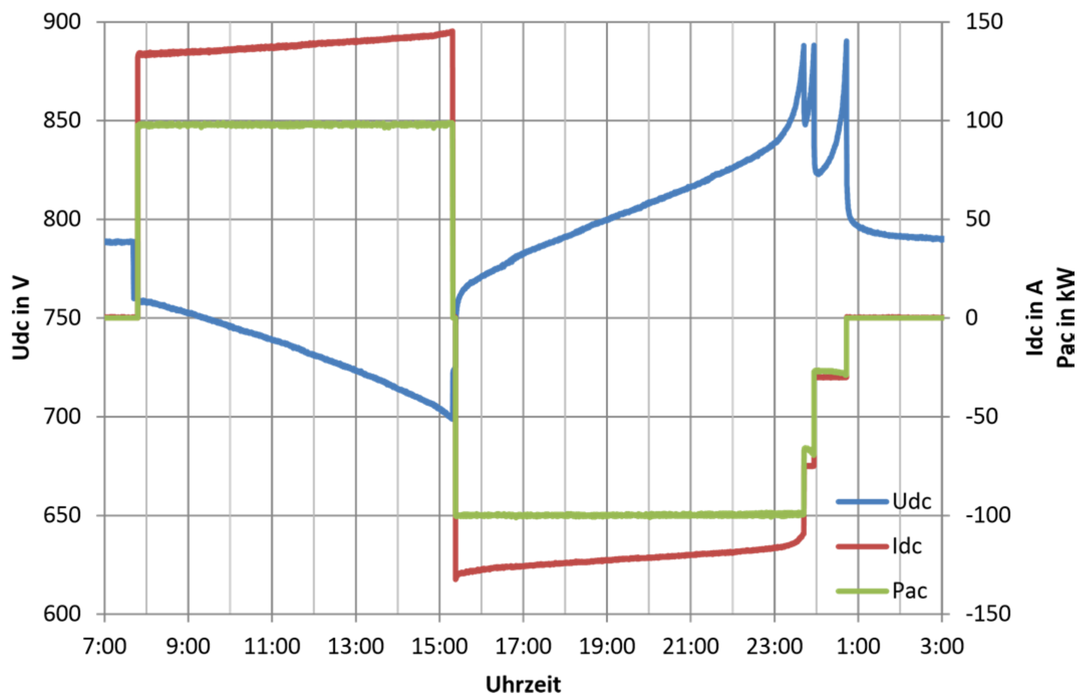


Figure 1: Log file of the converter (Test1, 100kW)

3.4 Parameter of the experiment

	Test 1	Test 2	Test 3	Test 4	
Size	**Value**	**Value**	**Value**	**Value**	**Unit**
Feeding setpoint	100	150	200	50	kW
Loading setpoint	100	150	200	50	kW
Minimum state of charge	30	30	30	30	%
Maximum state of charge	100	100	100	100	%

4 Measurement results

4.1 Wattmeter

Size	Test 1 (100 kW)	Test 2 (150 kW)	Test 3 (200 kW)	Test 4 (50kW)	Unit
Wac_entl_MS	731,84	651	571,09	734,72	kWh
Wac_lad_MS	862,09	801	718,81	867,47	kWh

4.2 Battery converter

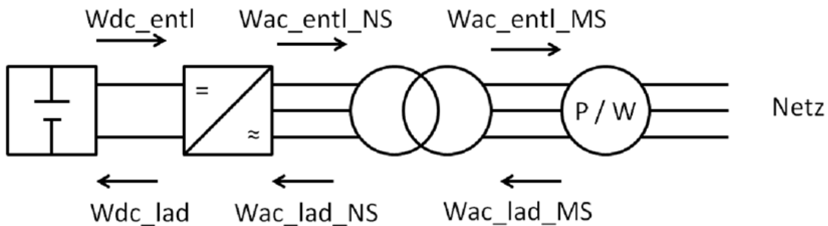
Size	Test 1 (100 kW)	Test 2 (150 kW)	Test 3 (200 kW)	Test 4 (50kW)	Unit
Qentl	1040,3	933,3	824,0	1049,4	Ah
Qlad	1055,5	952,7	846,2	1080,9	Ah
Wdc_entl	762,5	675,2	592,1	779,9	kWh
Wdc_lad	850,9	787,0	707,7	859,3	kWh
Udc_mittel_entl	733,4	723,7	718,1	743,5	V
Udc_mittel_lad	809,4	836,1	850,9	797,6	V
Idc_mittel_entl	138,2	214,0	290,0	64,5	A
Idc_mittel_lad	113,0	128,7	143,8	57,6	A

5 Evaluation

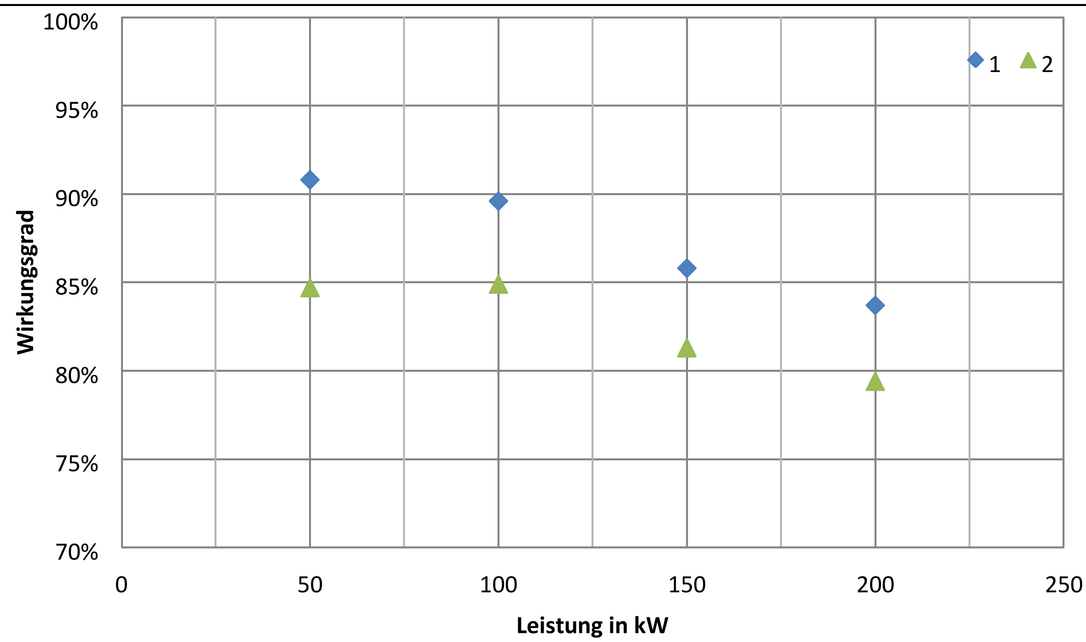
The energy efficiency is defined as the quotient of the input (Wzu) and the output (Wab) energy.

$$\eta = \frac{Wab}{Wzu}$$

Depending on which subsystem you are looking at, you select the measurand Wab and which Wzu.



Subsystem	**Wab**	**Wzu**	**eta Test 4 (50 kW)**	**eta Test 1 (100 kW)**	**eta Test 2 (150 kW)**	**eta Test 3 (200 kW)**
Batterie	Wdc_entl	Wdc_lad	90,8%	89,6 %	85,8%	83,7%
Gesamtsystem	Wac_entl_MS	Wac_lad_MS	84,7%	84,9 %	81,3%	79,4%



1	Battery
2	Overall system

6 Conclusion

The efficiency of the transformer cannot be determined with this test because of a lack of measuring accuracy. However, it is negligible compared to the other partial efficiencies.

The most important aspect is the energy efficiency of the lead-acid battery. This is due to the fact that (a) the supplied current is somewhat greater than the discharged factor and (b) the average load voltage is substantially greater than the discharge voltage. The difference between charging and discharging voltage is dependent on the released power, so that a lower power is followed by a better battery efficiency.

In comparison to the battery efficiency, the efficiency of the converter is much better. However, since the overall efficiency is composed of the partial efficiencies, the converter with medium voltage transformer reduces this by a further approx. 5%.