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Economic Efficiency of Adiabatic Compressed Air Energy Storages participating in the German Market for Secondary Control Reserve

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Motivation & Methods

To integrate the increasing share of fluctuating power generation into the grid, storage technologies are required to handle two main tasks: Shifting large amounts of energy and buffering short-term peaks. With the exception of pumped hydro energy storages, current storage technologies are not able to serve both tasks because of their technical restrictions. Considering adiabatic compressed air energy storages (A-CAES), the restriction to spot market trade and tertiary control reserve arises from the possible start-up time of 15 minutes. To overcome this barrier and enable the additional participation in the market of secondary control reserve (SCR), Fraunhofer UMSICHT developed a new A-CAES concept. The so called low-temperature A-CAES (LTA-CAES) reaches a start-up time of less than 5 minutes. The aim of the here presented study was to quantify the advantages of the German SCR market for a LTA-CAES.

Fraunhofer UMSICHT has developed the generic optimization model GOMES® , based on the software GAMS and the solver CPLEX. This model is able to economically optimize the mode of operation of different storage technologies while operating at several energy markets simultaneously. To study the technical and economical effects on energy storages, GOMES® has been enlarged with an additional model component for SCR participation.

Additional model component

The participation in the SCR market leads to significant additional restrictions compared to the usual mode of operation. During the offered period the storage is restricted in its permissible power range according to Figure 1.

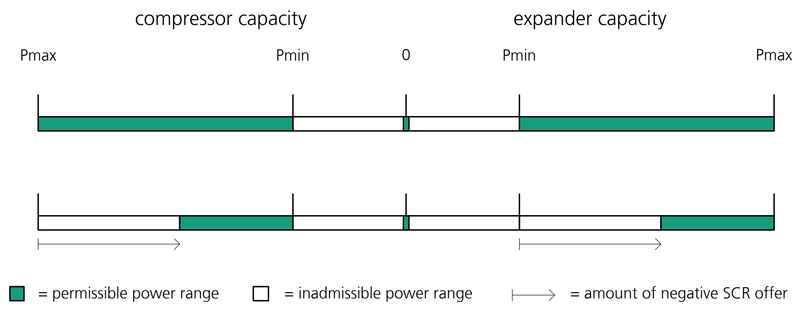

Figure 1: SCR-restricted power range

Another demand is the provision of sufficient storage capacity to serve every control reserve call. Calls which cannot be served by the storage itself are buffered by a background pool. To consider this fact in the economic results there are penalty costs for the use of this pool.

The perfect foresight for the optimization is restricted to 24 hours excluding the control reserve calls. These are considered in the second stage of a two-stage rolling horizon. The calls are unforeseen events affecting the optimized mode of operation afterwards as can be seen in Figure 2.

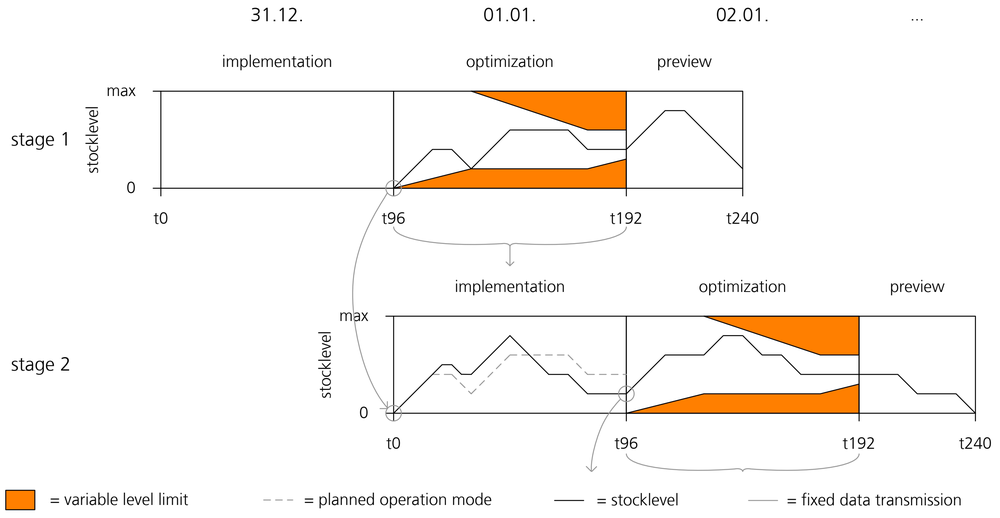

Figure 2: Two-stage rolling horizon

Case study: Low-temperature A-CAES

Using the described optimization model and assuming a LTA-CAES, different SCR offers have been considered. The dimensioning of the LTA-CAES was set to a 50 MW compressor and 35 MW turbine power with a storage capacity of eight full load hours. One result is that the participation in this market dominates the operation mode of the LTA-CAES according to the placed offer.

The absolute present values shown in Figure 3 are discounted over 20 years with an interest rate of 5%. For each of the four analyzed plant layouts different SCR offers with regard to the bid period, direction and value have been studied. As can be seen, the global maximum (red arrow) is, independent of the plant design, always located at a negative SCR offer in the off-peak period. In contrast the optimal bid value changes depending on the part load ability. The cycle efficiency has no further effect on the optimal bid value of the global maximum, but on the level of the absolute present value.

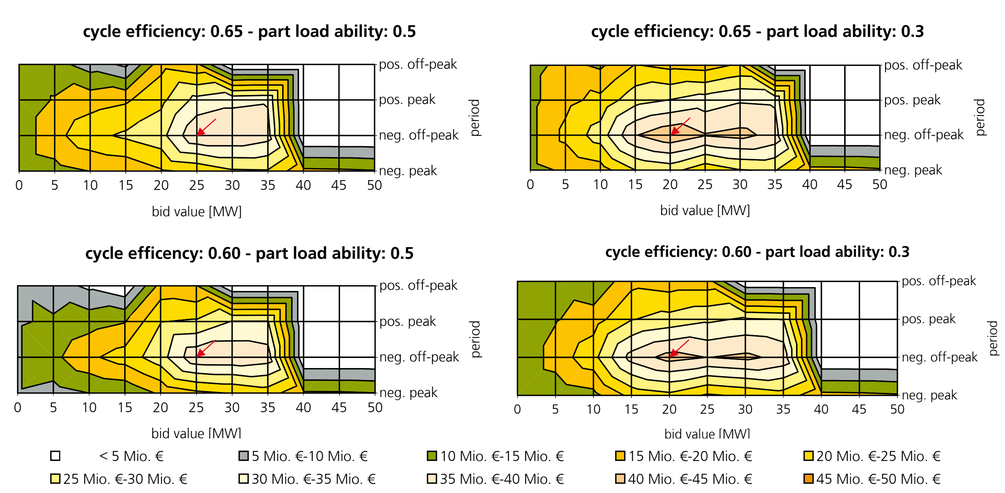

Figure 3: Topographical representation of the absolute present values

Table 1 shows the specific values for the target capital costs discounted over 20 years with an interest rate of 5%. Compared with the results of the same storage only trading at the spot market the specific target costs are three to four times higher. This is a clear benefit of SCR market participation for a LTA-CAES.

Table 1: Specific target capital costs

Cycle efficiency	Part load ability	Spot market trade		SCR market participation	
[%]	[%]	[€/kWh]	[€/kW$_{Turb}$]	[€/kWh]	[€/kW$_{Turb}$]
60	30	22	290	116	1,197
	50	20	272	108	1,115
65	30	31	387	126	1,249
	50	28	342	113	1,124

Acknowledgement

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Further information on GOMES® or the LTA-CAES project are given in the presentations »Optimized Operation and System Design of an Energy Storage Device for Post-feed-in-tariff Sales of Wind Energy at the Spot Market« by Annedore Kanngießer and »LTA-CAES – Low-temperature Adiabatic Compressed Air Energy Storage« by Daniel Wolf and the associated papers.

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