The German Pumped Storage Paradox

Wind and solar power do not match the electricity demand profile. The result is a more irregular residual load[1] which must be covered by dispatchable units.

Pumped storage is supposed to be the perfect technology for creating a more smooth residual demand. However, according to "Der Spiegel" German pumped storage plants cannot be operated profitably under the current conditions[2]. The article says that the peaks of the residual load are too irregular for the profitable operation.

I made a few calculations in order to understand the role of pumped storage in a power system. A merit order model was used for simulating one year on an hourly basis. I selected Germany in 2020 for my analysis. Wind and solar power are supposed to inject 108 TWh and 48 TWh into the grid during the year.

I have assumed the German pumped storage capacity to be 5.4 GW with storage for 6 hours. The pumped storage capacity in the three cases: 0 GW, 5.4 GW and 16.2 GW ("0 x PS", "1 x PS" and "3 x PS"). The pumped storage efficiency is supposed to be 75%.

I must make the reservation that the model is simplified. It does not include congestion management. The results should be seen as indications rather than predictions.

The calculations confirm the losses if the economy is based on spot prices alone:

		0 x PS	1 x PS	3 x PS
Contribution	Mill. €	0	-31	-141

The pumped storage scheme in the model works by smoothing the residual load. The operational effects for the German power system are the following:

One year		0 x PS	1 x PS	3 x PS
Shortage	GWh	225	73	39
Overflow	GWh	839	498	293
Pumped storage production	GWh	0	7,529	13,195
Pumped storage losses	GWh	0	2,514	4,405

The losses are important in the economic evaluation because they are supposed to be paid by differences in marginal costs. I have assumed that the value of overflow is 0 and that the value of shortage is 10% above the most expensive unit in the merit order list.

The average values of the electricity demand based on system marginal costs are:

		0 x PS	1 x PS	3 x PS
Average demand value	€/MWh	48.13	47.84	47.42

The pumped storage operation seems to have some influence on the spot market price. So, how does the money flow?

[1] The residual load is the electricity demand less production from wind and solar power.
[2] http://www.spiegel.de/international/germany/high-costs-and-errors-of-german-transition-to-renewable-energy-a-920288.html#ref=nl-international

		0 x PS	1 x PS	3 x PS
Total market value	Mill. €	21,267	20,995	20,679
Variable cost	Mill. €	10,918	10,878	10,856
Producers' contribution	Mill. €	10,349	10,117	9,822

The pumped storage has caused a slight reduction in variable cost. However, it is more important that it has moved money from the producers to the consumers.

Differences		0→1 x PS	1→3 x PS
Total market value	Mill. €	-272	-317
Variable cost	Mill. €	-40	-22
Producers' contribution	Mill. €	-232	-295

Therefore it is understandable that a producer has no incentive to operate a pumped storage plant unless the plant itself can generate money.

It takes more than energy sources to operate a power system

The results confirm that the pump storage plants are losing money, but their economic value exceeds the losses.

There are strong indications that the pumped storage operation generates money for the consumers and for society in spite of the energy lost in conversion.

It is well-known that some traditional electricity producers are losing money. Moving money from the producers to the consumer may accelerate the closure of power plants. Several nations are concerned about the national capacity balance and consider capacity markets or other arrangements.

It is time to realize that safe operation of a power system requires not only energy sources, but also generating capacity and a broad range of system services such as operating reserves and reactive power.

The energy markets have not been designed for covering the cost of such services. Other arrangements must be introduced sooner or later. They may mean increasing consumer cost of electricity. Therefore political decision-makers are reluctant to the introduction of capacity arrangements.

There is no doubt that pumped storage plants and other load smoothing facilities are very useful contributions to a power system with an increasing share of non-dispatchable intermittent generation, such as wind and solar power.

Pumped storage plants have the ability to reduce peak loads. Therefore a suitable capacity arrangement may be a way to prevent undesirable closures of pumped storage systems and power plants.