PUMPED STORAGE FOR BALANCING AND GRID CONTROL IN PREDOMINANT RENEWABLE ENERGY SYSTEMS

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Abstract: According to the European Climate Package (20-20-20 until 2020) and the long term developing targets, until 2050 the European Electrical System will be predominantly supplied by renewable energy sources from wind, photovoltaic, hydro and biomass. The large amount of Wind and PV necessitates the extension of storage capacities in installed power and storage volume. If this target is not reached, alternative storage technologies have to be used or renewable energy will be partly lost.

1 Introduction

According to the European recommendation towards sustainable development (20-20-20 until 2020) and the European SET-Plan, electricity supply will be predominantly based on renewable energy in the future until 2050. Austria will start from a high level of 60% to reach 70% renewable until 2020. Germany has a target of 40% until 2020 and 80% until 2050. In Austria 60% of electricity is now based on hydropower, which shows a relative constant energy flow without short term fluctuations. Germany will have periods with up to 90% of its electricity generation coming from wind and photo voltaic (PV) until 2020, which both have tendency to fluctuations. Especially PV has a need for storage capacities to transfer day-peak-generation to evening-demand [1].
According to a new investigation of VDE “Flexibility of power generation for renewable energy systems” [2], it is shown, that the renewable generation is growing much faster, than the capacities of pumped storage power plants can follow.

2 Renewable electricity target in the EU

According to the European “Package of Implementation for the EU’s objectives on climate change and renewable energy for 2020” [3], each European member state was given an individual target, in reduction of green house gas emissions and improving the portion of renewable energy in the end-use and in the sector of electricity. The individual targets are related to the year 2005. Austria has for example to reduce its emissions by 16% and to increase the share of renewable energy sources (RES) in the final energy demand to 34% until 2020. Germany has targets of reduction of 14% and a share in final demand of 18%, France (-14% and 23%) and Spain (-10%, 20%). This is a small selection of member states. Additional targets are given for the share of RES in electricity generation.

According to fig. 1, Austria has to increase its share from now 60% to 71%, Germany from 10% to 40% and Spain from 18% to 40%. In Austria this target will be reached until 2020 by new hydropower and wind converters. Seen from the electrical energy system mainly hydro power generators with significant inertia mass will be integrated giving a stable frequency control scheme in Austria.
In Germany the renewable potentials for new hydro power are limited. Thus mainly wind and PV converters have to be installed. Wind generators have an inertia mass, but this cannot be used for system control, as most of the wind converters are interconnected via converters to the grid.

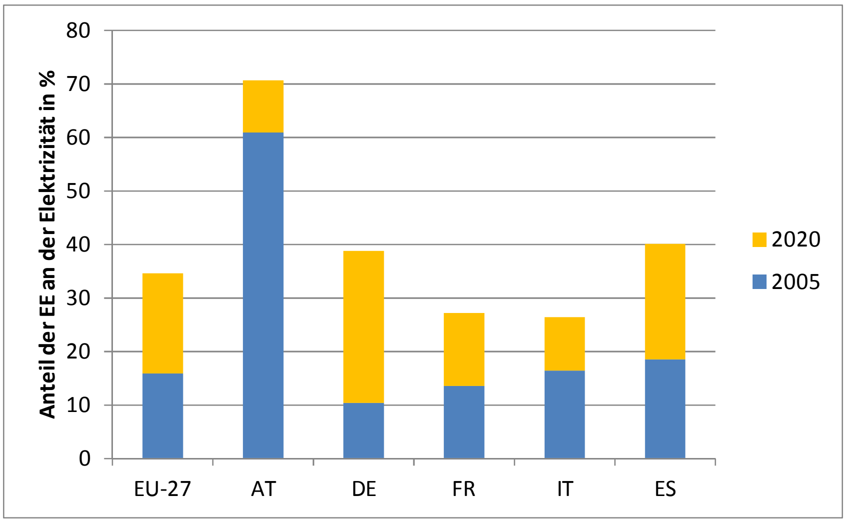

Fig. 1. Share of Renewables on Electricity in the EU member states until 2020

Because of the small number of full load hours, which are between 1,800 and 2,200 h/a for onshore Wind energy and 900 to 1,200 h/a for PV, for producing a given annual amount of energy, significant higher installed power is needed. In Germany there will be a need to install a total power of 58 GW of wind until 2020, of which will 42 GW onshore and 16 GW offshore. Photovoltaic has to be extended to 60 GW.

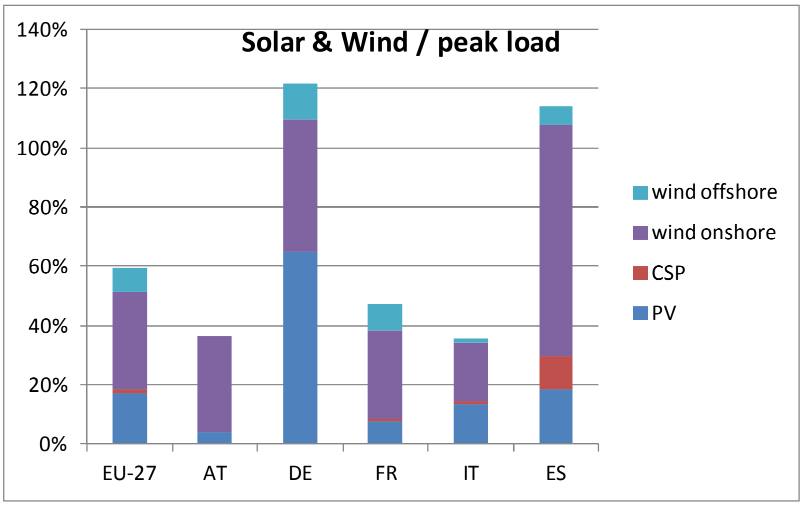

Fig. 2. Photovoltaic and wind related to the peak load in 2020

Related to a peak load of 80 GW and even considering, that wind and PV have a low probability for instantaneous full power generation, there will be periods of time, where wind and PV can support the full load of the grid.

In Germany and Spain the installed power of photovoltaic and wind converters will exceed the peak load in their electricity system (fig. 2.). Taking into account the probability of superposition, in reality these sources will touch the peak load.
In Europe about 60% of the peak load is reached.

3 Storage capacities development until 2020

In electrical energy systems with predominant RES, pumped hydro storage capacities form a valuable contribution to system support and ancillary services. Storing energy is without emissions at a high efficiency of about 80% in pumping and turbine cycle. The generators can contribute to voltage control and provide reactive power as a rotating condenser, even if they are in idle operation mode.
The inertia masses of the generators together with the turbine are valuable for the existing power-frequency control scheme.
During peak generation periods, power can be taken out of the grid (e.g. Photovoltaic power at noon) and fed in again during periods with low RES generation.

In a "National Renewable Energy Action Plan" (NREAP 2010) [4] each member state had to show, how the individual renewable targets will be reached until 2020. In the EU-27 in total the following generation power will be installed: hydropower 136 GW, photovoltaic 85 W, onshore wind 165 GW, offshore wind 42 GW, electricity from biomass 43 GW and concentrated solar power 7 GW.

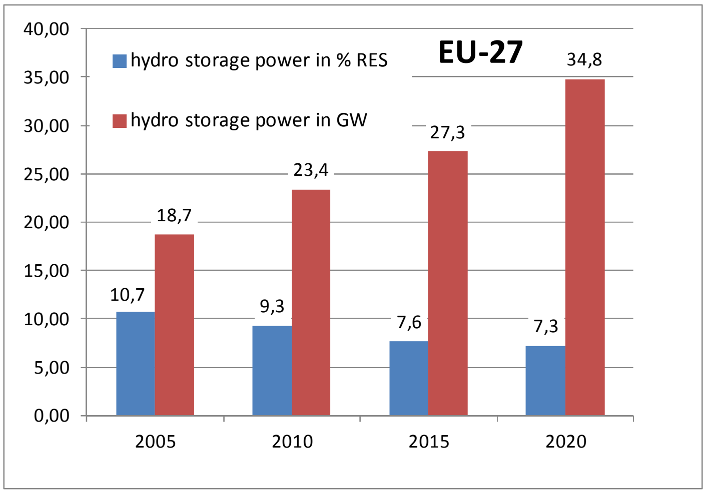

Fig. 3. Development of installed power of pumped storages in GW and in relation to installed RES in %

The installed pumped storage capacities will nearly be doubled from 18.7 GW in 1005 to 34.8 GW in 2020. But related to the total installed power of RES their portion will sink from 10.7 % to 7.3 % (fig. 3). According to this prognosis, given by the

member states in their NREAP, this will reduce the contribution of pumped storage capacities to system control and energy storing capability of the electrical energy system.
Looking at two member states Austria and Germany, in fig. 4 their prognosis is shown.

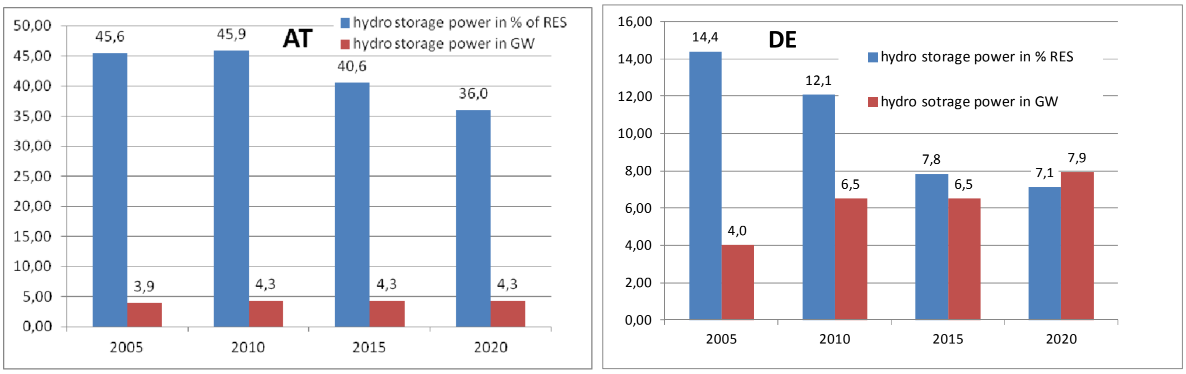

Fig. 4. Development prognosis of pumped storages in Austria (left) and Germany (right) [4]

Austria has given a prognosis of no extension of hydro storage capacities until 2020, due to low power installations in wind and PV and unknown investment risks in the future energy market. In Germany the pumped storage capacities will be doubled from 4.0 to 7.9 GW, but here because of the rapid growing power of wind and PV their relative portion will shrink from 14.4 to 7.1 % only.

In history the pumped storage hydro plants were operated by pumping cheap energy from base load power stations like nuclear and low rank coal fired ones. During peak load periods at noon, the stored energy was fed into the grid and from the difference base to peak the pumped storage capacities found their profitability.
The fluctuating characteristic of wind and PV will replace base load power stations by flexible ones. Additionally nuclear power will be shut down in Germany until 2022. Pumped storage capacities have thus in future to store during periods with renewable surplus generation. As PV has during noon a high probability of electricity generation, the period of feeding in energy will be more variable. Pumped storages have thus to be operated more flexible.
From view of energy economics, they represent short term storage capacities with a high number of pumping and turbine operations. In history pumped storages were operated about 1,000 hrs per year. Today some of them have 3,000 hrs in pumping mode and 3,000 hrs in turbine operation. Operation as long term storage seems not to be economic, as the fixed costs of a pumped storage have to be passed to a low amount of energy delivered, which will be uneconomic in the free electricity market.

4 The future role of flexible thermal power stations

Pumped storage power stations represent fully sustainable storage technology. Especially the rapid development of PV necessitates storage capacities. The nature of PV is, that it synchronized by the sunrise and sunset. In Germany for example the sunrise between east and west has only a delay of about 36 minutes as Germany is

situated between the degrees of longitude from 6 to 16. Austria has a delay of 56 minutes as it longitudinal limits are between 9 and 23 degree.
Seen from energy generation at high installation of PV collectors, during day there will be in future the potential of high over generation and after sunset the need for starting generating units. Pumped storage hydro power stations will have especially in this field a new opportunity to store during day and generate in the evening. But probably it will not be possible to build as much storage capacity as necessary.

The thermal power station can also contribute to balance the residual load (difference between demand and sustainable generation). For this purpose they have to be very flexible. This means:

- High number of starting and shut down procedures over the year
- Ability to operate at high power gradients
- Ability to operate at low minimal load

The flexible operation will also mean, that the full load hours (capacity factor) will dramatically go down from now 5,000 to 8,000 h/a to about 2000 h/a. This will reduce the profitability of thermal power stations.

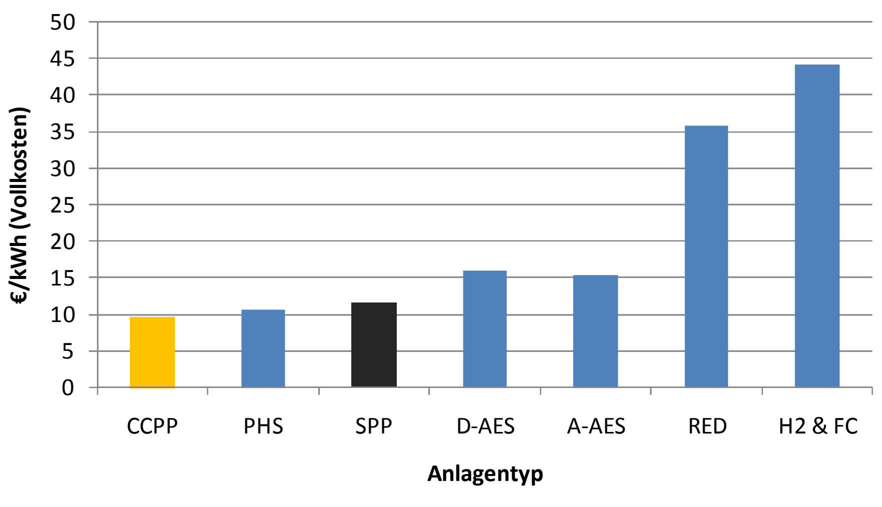

Fig. 5. Specific generation costs of storage technologies in comparison to flexible thermal power stations [2]

Explanation of abbreviations in fig. 5:

CCPP	combined cycle power plant
PHS	pumped hydro storage
SPP	steam power plant
D-AES	diabatic air energy storage
A-AES	adiabatic air energy storage
RED	redox battery
H2 & FC	hydrogen and fuel cell

With the pumped hydro storage for pumping and turbine operation 2000 h/a in each mode are used for calculation of costs. The thermal power stations CCPP and SPP have each also 2000 h/a operation.
From fig. 5 can be seen, that hydro power stations are competitive in this operational scheme. They have the advantage, that no additional cost (e.g. for hot stand-by of thermal power stations) and no emissions are valid.- 6 -

References

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Prof. Brauner worked in Electrical Power Industry as head of scientific power system department. From 1990 to 2010 he was professor for energy systems and worked in the fields of energy grid, integration of renewable energy, system control, electrical mobility and energy supply of smart cities.