ENERGY TURNAROUND AND CONSEQUENCES FOR CONVENTIONAL POWER STATIONS

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ABSTRACT

Hard coal fired power stations of STEAG had been operated in the past already in mid merit order while worldwide base load is typical. In the recent years low load operation became dominant. The new kind of operation of conventional power plants as partner of the renewables leads as shown to a completely new view on the technology.

Every component has to be checked considering the new mode of operation. STEAGs experience with technology from different power plant suppliers helps to be successful in this optimization process. The current challenges of the "Energy Turnaround" are asking for further improvement of the technology, due to the increasing part of renewable energy conventional power plants will have frequent outages and need higher ramp rates. All components of the power plant are highly stressed by this new boundary condition.

With increasing low-load operation high amounts of coal could remain at the coal yard over a longer period with the risk of self-ignition. The combustion system must be able to offer high flame stability also at low load without support fuel. Decreasing HP and IP temperatures accompanied by too high gradients can lead to ineligible stresses of the casings. Low overheating can lead to erosion effects by droplets in the turbine. As well the entire flue gas path is affected.

Experience with the new operation mode accompanied with good engineering tools and know how can manage the technical problems sufficiently. But the question how to pay for it is still open.

1. BACKGROUND

Considering reserves and resources like oil, gas and coal it is evident that electricity generation using these resources is limited. Oil reaches 40 years, gas 60 and coal some 200 years. Even if new technologies are used - which is a very optimistic view - these figures could be max. doubled. So a change to renewable energies is not a choice but a must. A question is what time is needed to change our electricity generation system. What we are looking for is a reliable and economic path from one energy source to the other. If the energy turnaround is too slow, energy prices will at a certain stage increase dramatically. A negative influence on the overall economic situation of countries could not be avoided. In case that it is too fast, subsidies for renewables make electricity very expensive and again the economy is influenced in a not acceptable way. A proper choice of the right speed considering all the influencing factors is of high importance. Conventional power stations are part of this game but in a different manner than yesterday.

In Germany, as part of the current energy transition process, a lot of experiences are gathered. The role of conventional power plants is important for grid stabilization and reliable electricity supply. Renewables are producing energy more randomly and thus cannot ensure electricity supply with interruptions.

A "together" of conventional and renewable generation technologies has to be developed. As well it has to be defined who is playing what role. Wind and solar energy are typically non dispatchable. So conventional back up power is needed. What are the consequences of this partnering with renewables for the conventional power plant?

- Low load operation
- Rapid start ups
- High ramp rates
- higher amounts of coal remaining in the coal storage
- additional corrosion problems and so on

Hard coal fired power stations of STEAG had been operated in the past already in mid merit order. Worldwide base load is typical. Based on the experience with mid load operation we extended our capabilities to extreme low load operation and made the plants very flexible regarding load changes. In this presentation experiences with this new boundary conditions and the new mode of operation are described.

2. BOUNDARY CONDITIONS OF THE CURRENT ELECTRICITY MARKET IN GERMANY

It has to be considered that wind energy is typically produced more in the winter time than in the summer time and that sun is shining highly at noon time and not at

night (**Figure 1**). Another problem is that wind generated electricity is produced more in coastal areas and not at the load centers.

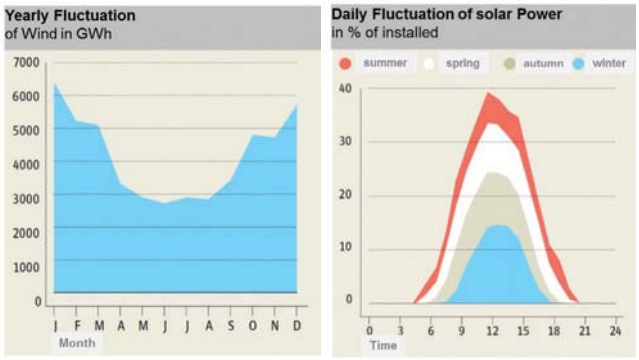


Figure 1. *What has changed in the German electricity market?*

These characteristics of renewables are leading to a new generation scheme:

- Yesterday
  Conventional, scheduled electricity generation centralized in load centers (coal, gas, nuclear and others)
- Today
  Few or none scheduled conventional generation in load centers, Sometimes high wind and PV where generated when not needed (Solar based mainly at noon, in summer more than in winter, wind based more in winter than in summer, heavy storm could be followed by calm periods)
  Partly far away from the load centers

These new boundary conditions have an enormous influence on the operation of conventional power plants.

3. FREQUENT START-UPS

For more than 20 years, hard coal fired power stations are operated by STEAG in the mid-range and not in base-load as practiced worldwide. As shown in **Figure 2**, sometimes daily start-ups and shut-downs are leading to high consumption of fuel oil and high stress for the power plant components.

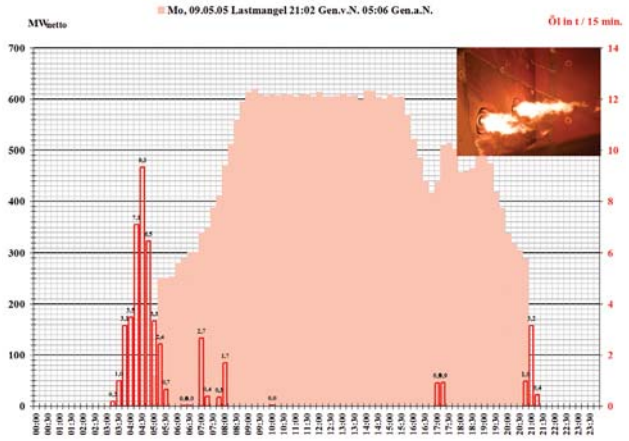


Figure 2. *Oil fire - the kind of fire we try to minimize in a coal fired power plant.*

For example, in the boiler of the two path boiler of Voerde power station (**Figure 3**) we had a higher number of cracks in the transition pieces from first to second path. Comparing the construction of this part of the boiler with others worldwide showed not a significant different design.

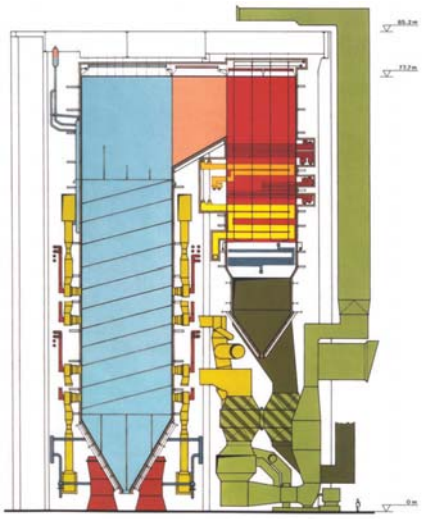


Figure 3. *Boiler PP Voerde, 761 MW Unit.*

The simple answer of this investigation showed that the number of start-up and shut-downs every year in this plant a typical hard coal fired power station has during the whole life time.

Figure 4 shows the generator rotor of the same unit. The winding bars have moved, destroyed partly the insulation and blocked the cooling openings. It could not be excluded that the frequent start-up and shut-downs had been responsible for this damage after 25 years of operation without any problems.

For the power plant operator additional checks and very careful operation is a result of this new load regime.

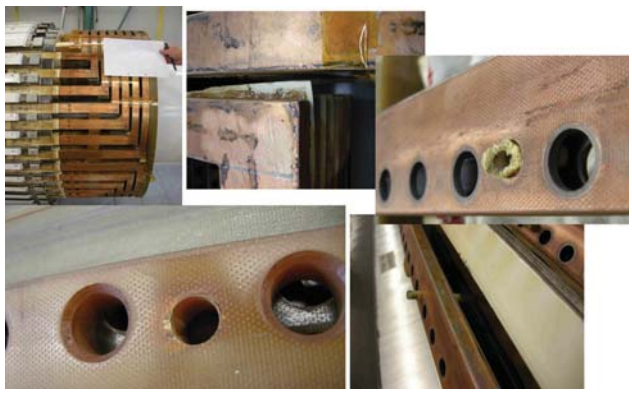


Figure 4. *Power Plant Voerde Generator rotor damages.*

4. REDUCTION OF MINIMUM LOAD

Reduction of minimum load allows holding a unit under operation in an economic way. So more frequent startups and shut downs could be avoided. Thus stresses causing

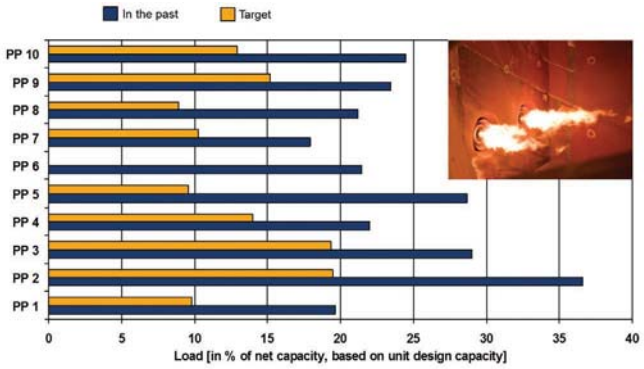


Figure 5. *Reduction of minimum load.*

damages as described can be reduced as well as fuel oil consumption.

Yesterday we had been proud to come down to some 40 % load in two mill operation mode. By a bundle of measures we reduced this dramatically down to 10 to 15 % in one mill operation mode without any support of oil fire.

Figure 5 shows what tremendous reduction had been achieved by our measures.

5. FLEXIBLE OPERATION

Frequent load changes with high ramp rates for the conventional power stations are required by the unpredictable renewable energies. A benefit of a coal fired power station is that there are a lot of internal storages available. Like:

- Mill
- Preheaters
- Tubes and pipes
- and so on

While reducing the efficiency a coal fired power plant can react very fast on load changes for some minutes. Fine grinding in the mill is stopped and coarse coal can go immediately to the burners. The regenerative feed water preheating is stopped. Thus a coal fired power station can behave like formula one racer for some minutes (**Figure 6**). This is especially of help if wind generators have to be shut down from one minute to the next due to too high wind speed.

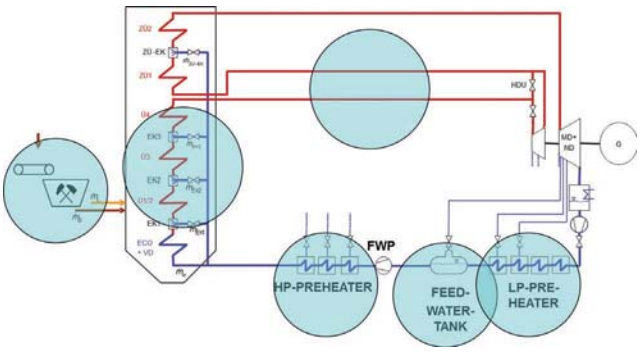
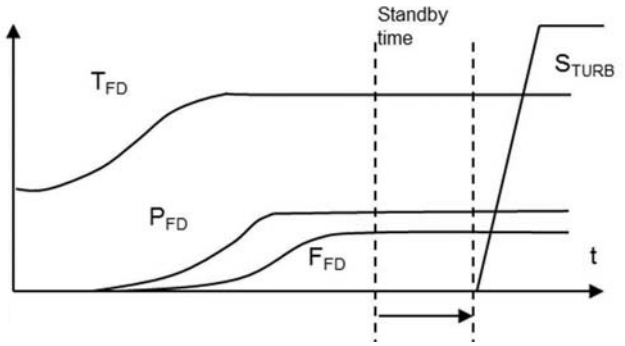


Figure 6. *Increasing ramp rates by using internal storages.*

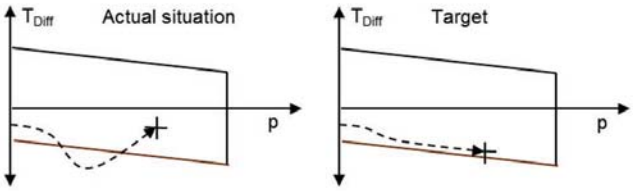
6. OPTIMIZATION OF START-UPS

Under the described boundary conditions, a more precise operation is asked for. If a power plant should deliver electricity at 6 o'clock in the morning, it could have a benefit ensuring supply to have the needed power already at 5 o'clock available. But this is very expensive. Some minutes before the asked supply are sufficient but this needs a very reliable C+I system and actuators working perfectly.



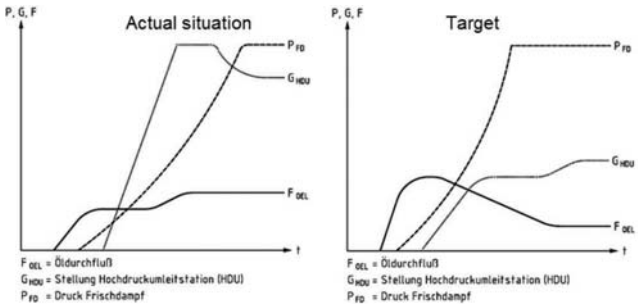
Start-up "to the point"

As well currently thick walled components are not used close enough to its permissible stress limits. Optimization of the C&I system allows more rapid load changes without forbidden material stresses.



Utilization of permissible stress limits of thick-walled components.

As well the start-up process via HP bypass can be optimized to avoid unnecessary steam and so also energy losses.



Start-up with the HP bypass station less open.

Figure 7. *Optimization of start-up.*

It has to be considered that decreasing HP and IP temperatures accompanied by too high gradients can lead to ineligible stresses of the casings. Low overheating can lead to erosion effects by droplets in the turbine.

7. COAL STORAGE

Out of economic and technical reasons, the amount of coal laid down in the coal yard is limited. If due to high amount of renewable energy being available, conventional power plants are not used unscheduled, more coal than desired could be in the storage. If high volatile coal should be consumed, the risk of self-ignition is increasing (**Figure 8**). What are the recommendations to handle this problem?

- Compaction in layers of coal
- Build heap side not to steep
- Adjustment of the stock pile to main wind direction
- Avoidance of water in the stock pile underground
- Regular, or as well continuous temperature monitoring

Measures in case of fire:

- Clear sections with hot spots (T>50°C)
- Spread thin and let it cool down
- Do not extinguish with water (s.a.)

Figure 8. *Burning coal.*

8. BOILER AND PLANT EFFICIENCY

Conventional power plants being partner of renewable energy have to be operated more often in part load than full load. But typical, power plants are optimized to have highest efficiency at full load. In future it makes sense to have highest efficiency may be at part-load operation.

Manly the boiler is affected but also the efficiency of the entire plant is decreasing (**Figure 9**). The efficienc decrease could be limited for example by:

- Optimization of air ratio in part load operation
- Use of speed controlled drives
- e.g.

9. FLUE GAS TREATMENT AND STACK

Not only the boiler and the water steam cycle are influenced by low load operation. The complete flue gas treatment plant is affected by low load operation. Low velocities

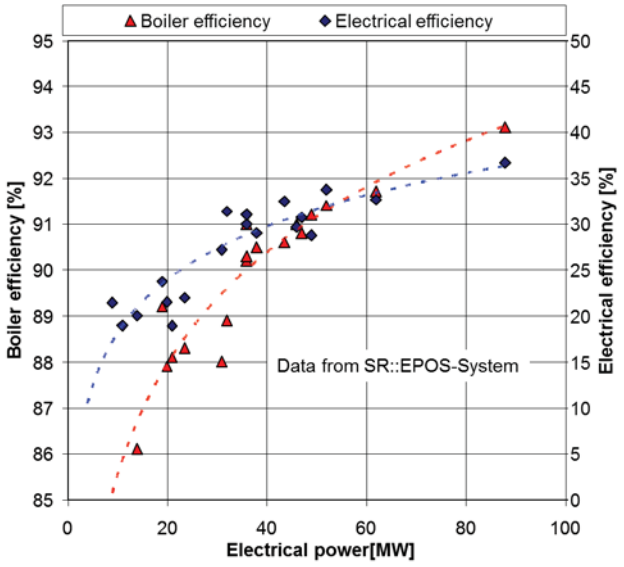


Figure 9. *Plant efficiency at part load.*

Figure 10. *Stack, agglomeration of ash particles.*

and low temperatures can lead to undesired plugging and fouling. The separation efficiency of ESP and FGD itself is not influenced negative. For DENOX plant the optimum temperature window can no longer be caught. Blocking of the air preheater by sticky substances in the flue gas could be the case.

At the stack due to very low load operation, particles can agglomerate and lead to undesired emissions at load increase.