Converting CFB boilers from coal to 100 % biomass combustion

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With the requirement to increase the share of renewables in the Czech Republic there is an aim as much as possible to utilise biomass for electricity generation. Scheme of subsidy was created with the different levels according to type of biomass and type of combustion. This differentiation is reflected in a level of subsidy, when the biomass with other utilisation with co-combustion was subsidised in level of 1,000 CZK per MWh (about 37 EUR per MWh) as minimum subsidy and biomass planted for combustion with 100 % biomass combustion in level of 2,800 CZK per MWh (about 103 EUR per MWh) as maximum subsidy.

ČEZ, a.s. evaluated this opportunity and decided to refurbish circulated fluidised bed boilers at Power Plant Poříčí and Power Plant Hodonín. Refurbishments enable to increase the amount of biomass to be burnt in the combustion chamber from 25 % to 100 % of heat value in fuel. These projects were focused to increase capacity to unload biomass from trucks, delivering biomass from storage yards to storage bunkers close to the boiler and delivering biomass from bunkers to the combustion chamber. Additionally, in the Poříčí power plant there was a change in the technology of ash cooling and ash transportation.

In Power Plant Poříčí this project enabled to increase the amount of biomass burned from 100,000 t/year to 170,000 t/year (2015), alternatively in Power Plant Hodonín from 160,000 t/year to 270,000 t/year (2015). This reconstruction means for both sites receiving of additional revenues which support positive financial results of power plants in market situation with low electricity price.

Burning biomass planted for combustion had impact to availability of these boilers. Cleaning of superheater of the boiler had to be done after several months of operation and hence was decided not to use only this biomass in Power Plant Hodonín. Forest residues burning in Power Plant Poříčí led to intensive abrasion in the area of the bottom belt of the membrane wall, and hence it was decided to cover it by metal coating material – Castolin 595. Each site has an opportunity to decide to operate boilers with fuel (biomass or lignite) which generates the highest gross margin from electricity and heat supply.

The state regulatory authority changed the subsidy scheme last year with the aim to support parallel combustion and co-combustion of biomass only with the precondition of electricity generation in high efficiency cogeneration.

Introduction

The Czech Republic has a renewable energy target with a share of 13 % in the year 2020. One of the supported area to achieve this goal is biomass utilisation in electricity generation.

ČEZ, a.s. has different kinds of boilers in its portfolio. Several tests and studies were carried out to understand limits and bottlenecks in the technology of pulverised coal and circulated fluidised bed boilers. There were found the limits of biomass co-combustion for both kinds of boilers with any technology modernisation. Limitation for PF was 5 to 10 % of the biomass in heating value and limitation for CFB was 20 to 25 % of the biomass in heating value.

On the other hand not only technological limitations was important to take into account, but also subsidy scheme legislation to achieve highest gross margin from electricity generation from biomass. The first steps to prepare biomass co-firing in the form of wood chips were done in 2003 when the government introduced an endowment system of so-called “green bonus” for a MWh of electricity generated from renewable sources, in this case from biomass. Now the subsidy scheme is quite complex. Subsidies are at different financial levels, according to type of biomass and type of combustion. First type (1) of biomass is defined as biomass with difficult other utilisation (e.g. wood chips and straw) and the third type (3) of biomass is subsidised in level of 1,000 CZK per MWh (about 37 EUR per MWH) as minimum and biomass planted for combustion with
100% biomass combustion in level of 2,800 CZK per MWh (about 103 EUR per MWh) as maximum, see Figure 1.

After the evaluation how to achieve the best utilisation of biomass in CEZ, a.s. portfolio fleet, it was defined, that reconstruction of two CFCB from 25% to 100% biomass combustion is the most effective way to increase electricity generation from biomass.

Reconstruction of CFCB in the Poříčí power plant

The Poříčí (EPO) power plant was built in 1950s to utilise black coal from the nearby mines for electricity production. In 1970s, it was reconstructed so that it could supply local towns and villages with as much as 200 MWt of heat in a combined cycle for power generation and heating. At present its installed electric capacity is 165 MWe and it provides the district heating network with 1,6 TJ of heat a year on average.

From 1996 to 1998 the original technology of the boilers was replaced by two new fluidised bed boilers, with original design from Foster Wheeler with a steam output of 250 t/h, with the options for fuel: lignite, hard coal, wood chips and agro-pellets (original design of boiler FK 7 see Figure 2).

In spring 2004 both the fluidised bed boilers in the Porící power plant were tested for the first time with positive results, but the covering was limited to a mixture with coal containing 20 to 25% of the heat content of biomass. It was caused by the capacity of fuel transport lines and boiler input profiles, which were not able to transport enough fuel with lower heat content into the combustion chamber. The originally designed coal had a heat value between 16 and 18 MJ/kg and the real heat content of wood chips is based between 8 and 11 MJ/kg.

In the following years new improvements of the fuel lines for safe but limited co-firing were made. However, gradual legislative changes degraded co-combustion to the lowest level of support and thus made it economically ineffective. Unfortunately, all discussions about the lack of economic and ecological arguments failed. In 2008 new studies focused on the conversion of one of the boilers into a boiler for burning 100% of biomass.

The project was prepared with following design principles and conditions:

- The real heat content of wood chips, which is the most suitable fuel for the current plant location, as far as its sufficient supply and its price is concerned, is between 8 and 11 MJ/kg. The typical characteristics of wood chips (mostly forest residue) for conversion project were:
  - particle size: 50 x 50 x 50 mm, exceptional length 150 mm,
  - moisture: 35 to 60 %,
  - ash/soil/sand: 1 to 15 %.
- There is no dumping ground for 2 to 4 week’s operations, including a necessary handling area near the boiler. The only place meeting these demands is located at the distance of approximately 600 metres, and therefore it was necessary to solve the problem of fuel transport from that location to the nearest boiler No. 7.
- The boiler was not constructed for the combustion of fuel with the highest content of alkali salt in the ash. As the superheaters in the second duct could be clogged with that kind of ashes, the project submission did not take into account using these sorts of biomass (especially straw and hay) in the mixture with wood chips in a bigger rate than 20% (heat content).
- The fuel inputs connected to ash chutes from cyclones in the rear wall of the combustion chamber had to be retained. The only part for adding new chutes for biomass with sufficient output was the front wall of the chamber. However, it meant...
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Fig. 3. New conveyor line of the Poříčí (EPO) power plant for 100% biomass combustion.

Fig. 4. New bottom ash extraction and cooling system of the Poříčí (EPO) power plant for 100% biomass combustion.

Fig. 5. Fuel consumption, steam load and calorific value of the Poříčí (EPO) power plant during commissioning after reconstruction.

to remove the system of bottom ash outlets and coolers, which were originally installed there.

– The target project output of the boiler firing 100% of wood was set to 70 to 80% of the original rated output (for coal). The main reason for that, considering the increase of the specific volume of flue gases, was to avoid the capacity problems or even necessary reconstruction of the second duct and the following components (ESP, ID fan etc.).

From the technological point of view the whole project comprises the following parts:

– A new assembly of the conveyor line from the biomass dump, which included 2 push floor receiving bunkers for tracks, star screener, magnetic separator, weighing machine (belt type) and 550 m long covered belt conveyor up to the boiler biomass bunker with transport capacity 300 m³/hour and line transport time 8 minutes (see Figure 3).

– New daily biomass bunker (about 600 m³) next to the boiler with 4 extracting screw conveyors and following chutes to the combustion chamber.

– Reconstruction of the bottom ash extraction and cooling system by removing of original cooling system (fluidised bed coolers and screw coolers) and installation of new bottom ash outlets and vibrating coolers (see Figure 4).

Project time schedule was executed with the aim to reconstruct the boiler as fast possible:

– 2009 to 2011
  Approving the project and a detailed preparation of contractual documents with the main supplier

– 27.9.2011
  Signing the contract

– 1.9. to 30.11. 2012
  Trial operation with final guarantee test, including at least one week’s operation using only coal and then a week’s operation using only wood chips together with the overall load rate as well as dynamic change tests,

During guarantee and the trial operation period, no serious problems occurred and everything was according to the expectations. The tests verified the proper functions of the boiler in the load range from 30 to 100% for coal and from 30 to 75% of biomass. No troubles with “switching” between both fuels appeared.

The diagram of fuel consumption, steam load and calorific value is in Figure 5.

Regarding to emissions, there were achieved expected results during biomass combustion: SO₂ emissions almost zero and NOₓ/dust emissions mostly below future limits, see Figure 6.

After several years of operation there is no evidence of any troubles with salty ash de-
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posits on superheaters or any other parts of the chamber or ducts. As a result of slight abrasion, which appeared in January 2013 (due to a high content of sand in the bottom ash), the bottom belt part of the membrane wall around the combustion chamber was covered in June 2013 by arc-spraying material Castolin 595, according to EN 14616 (the metal coating, high-alloy iron by chromium and boron, with an amorphous structure). Thickness of coating was min. 0.7 mm. (see Figure 7). The bottom ash during biomass-only firing (forest residue) contains 70 to 80% of sand and gravel with surplus balances of bottom material between 20 and 50 tonnes per day).

In September 2012 the “cold” end of the air preheater (in the length up to 1,000 mm from the tube plate) was covered by spray- ing ceramic material BG HitCoat 200 as a protection against low temperature corrosion. Thickness of coating: 0.2 to 0.25 mm and protected area : 700 m².

Reconstruction of CFCB in Hodonín power plant

The Hodonín (EHO) power plant was constructed in 1951 to 1957 to utilise lignite from nearby mines for electricity generation. In 1963 it was reconstructed so that it could supply local towns and villages with as much as 250 MWt of heat in a combined cycle for power and heat. At present its installed electric capacity is 105 MWe and the plant provides the district heating network with 1,1 TJ of heat a year on average.

From 1994 to 1998 the original technology of the boilers was replaced by two new fluidised bed boilers, the original design from Austrian Energy and Environment with steam output 170 t/h, with possible fuel – lignite (original design of boiler FK 7 see Figure 8).

After several trials of biomass co-combustion from 2000 it was decided to prepare a new project in year 2008 to achieve 100% biomass combustion in boiler FK7.

The scope of the project was defined for several technological areas:
- Modernisation of biomass unloading place and screw conveyor, see Figure 9.
- New hopper with rotary valves, screw conveyors and bunkers for biomass.
- Biomass classifier, see Figure 10H

Fig. 10. Biomass classifier at Hodonín (EHO) power plant.

Fig. 9. Modernised biomass unloading place and screw conveyor at Hodonín (EHO) power plant.

Fig. 8. Hodonín (EHO) power plant boiler design.

Fig. 7. Bottom belt part of the membrane wall after covering by arc-spraying.

Fig. 6. SO₂, NOₓ, CO and dust emissions.
The project time schedule was prepared according to internal rules to focus on achieving a CAPEX as low as possible:

- 2006 to 2007
  Approving the project and a detailed preparation of contractual documents with the main supplier
- 5/2008
  Signing the contract
- 12/2008 – 3/2013
  Trial operation with final guarantee test, including at least one week’s operation using only coal and then a week’s operation using only wood chips together with the overall load rate as well as dynamic change tests,
- 10/2013
  Installation of biomass classifier

After several months of using energy crops the availability of boilers decreased due to fouling on superheaters, see Figure 11. It was decided to reduce the amount of this type of biomass and increase amount of wood chips to eliminate the severity of fouling on superheaters.

**Summary**

The CFCB technology was evaluated as most suitable for 100% biomass combustion in the power plant portfolio of CEZ, a.s. The CFCB in Power Plant Poříčí is the most powerful CFCB in the Czech Republic with the ability to burn 100% of biomass. Technically, it is possible to burn 300,000 t/year. So far this limit is not utilised, because the amount of biomass combustion is dependent on subsidy scheme and market conditions. Nevertheless, for both sites 100% biomass combustion means to “keep sites on money” with low electricity market price.

These two reconstruction projects enable CEZ to generate electricity from biomass in the range of 325 MWh in 2015 (117 MWh in Power plant Poříčí and 208 MWh in Power plant Hodonín). This is about 98% of electricity from biomass of the CEZ, a.s. fleet. About 400,000 t of biomass are combusted, which is delivered mainly from suppliers from the Czech Republic.
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