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Co-Utilization of Coal and Biomass–A Review

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Abstract—*The energy sector in the global scenario faces a major challenge of providing energy at an affordable cost and simultaneously protecting the environment. The energy mix globally is primarily dominated by fossil fuels, coal being the major contributor. Increasing concerns on the adverse effect of the emissions arising from coal conversion technologies on the environment and gradual depletion of the fossil fuel reserves had led to global initiatives on using renewable and other opportunity resources to meet the future energy demands in a sustainable manner. Co-utilization of coal and biomass for energy production results in pollutant reduction. Most notable is the impact on NOx, SOx, volatile organic compounds (VOC), CO2 and polyaromatic hydrocarbons (PAH).*

1. INTRODUCTION

The co-utilization of coal and biomass for energy production results in pollutant reduction. Most notable is the impact on the emission of NOx, SOx, CO2 and volatile organic compounds (VOC) and polyaromatic hydrocarbons (PAH).These latter compounds arise largely from their formation and release during incomplete combustion/gasification. PAH are particularly toxic carcinogens and are listed by the United States Environmental Protection agency (USEPA) and European Community as priority pollutants. There is evidence that co-firing or co-gasifying coal and biomass results in a significant decrease in the emission of these compared to coal alone. The reduction in NOx is thought to be due to competitive char burnout, while the reduction in SO2 can be explained by sulphur fixation in the ash due to the increase in potassium and calcium from the biomass. Also biomass contains virtually no sulfur, so SO2 emissions are reduced in direct proportion to the coal replacement. In general, biomass is considered to be CO2-neutral fuel, meaning that combustion of biomass should not increase the CO2 level in the atmosphere, because the amount of CO2 emitted during conversion process equals C02 while was assimilated into the plants during the process of their growth (where both process took place within relatively small period of time.). Coal co firing was successful with up to a 20% biomass mix. Co firing may also reduce fuel costs, minimize waste and reduce soil and water pollution, depending upon the chemical composition of the biomass used. The oldest of all fuels, wood (or biomass) co firing with coal is being resolved through testing and experience.

Co firing technology has some technological problems. First, the issue of combustor fouling and corrosion due to the alkaline nature of the biomass ash needs attention. Ash deposits reduce heat transfer and may also result in severe corrosion at high temperatures. Compared to deposits generated during coal combustion, deposits from biomass materials are denser and more difficult to remove. Second, the maximum particle size of a given biomass that can be fed to and burned in a given boiler through a given feeding mechanism requires additional studies.

There is a trade-off between the emissions of nitrogen oxides (NOx) on one hand and hydrocarbons (OGC) and carbon monoxide (CO) on the other hand. Decreasing the excess air (oxygen concentration) results in increased emissions of unburnt (OGC and CO) and lower NOx emission. The efficiency increases, as the excess air is decreased until the losses due to incomplete combustion become too high.

However, using well-known techniques such as air staging, the NOX emission can be significantly reduced. The development of different chemical sensors is very intensive and recently sensors for CO and OGC have been introduced on the market. These sensors may, together with a Lambda sensor, provide efficient control for optimal performance with respect to emissions and efficiency. Lambda sensors are used to control the oxygen level in today's state-of-art boilers.

A number of techniques and methods have been proposed for reducing gaseous emissions of NOx, SOx, and CO2 from fossil fuel combustion and for reducing costs associated with these mitigation techniques. Some of the control methods are expensive and therefore increase production costs. Among the less-expensive alternatives, co firing has gained popularity with the electric utilities producers. Co firing, in this context, is defined as the firing of a renewable fuel (i.e. biomass) along with the primary fuel (coal, natural gas, furnace oil, etc.). Recent studies in Europe and the United States have established that burning biomass with fossil fuels has a positive impact both on the environment and the economics of power generation. The emissions of SO2 and NOx were reduced in most co firing tests.

2. THE WORLD SCENARIO OF BIO-ENERGY

There are about total 62 countries in the world currently producing electricity from biomass. USA is the dominant biomass electricity producer at 26% of world production, followed by Germany 15%, Brazil and Japan both 7%.

Up to 2010 more than 150 coal-fired power plants have experienced some co-firing activity (most in USA: 40, Sweden: 15, Germany: 27, and Finland: 14).

Most of the developed and developing countries are considering co-firing as an attractive option by providing incentives.

The present installed generating capacity in India is 223, 343, 60 MW (As on 31.03.2013).The share of hydro with 39, 491, 40 MW accounts for maximum share of 67.8% with 151,530, 49 MW. It comprises of 130, 220, 89 MW from coal, 20, 109, 85 MW from gas and 1119.75 MW from oil. The share of Nuclear power is about 2.1%. The share of Renewable Energy Source which includes small Hydro Projects, Biomass Gasifier, Biomass power, Urban and Industrial Waste Power is about 12.3%.

3. ENVIRONMENTAL ASPECTS OF BIOMASS CO-COMBUSTION

Pinto F et al, has been reported that biomass gasification on its own produces plenty of particulate matters and tar emissions, which may be reduced in case of co-gasification with coal.

Hartmann D, Hein KRG, Spliethoff H, Kubica K et al in their different studies and experiments proved that co-utilization of coal and biomass for energy production results in pollutant reduction. Most notable is the impact on the emission of NOx, SOx and volatile organic compounds and polyaromatic hydrocarbons.

Tillman DA, Sweeten JM et al reported that biomass co-combustion represents a low cost, sustainable and renewable energy option that ensures reduction in net CO2, SOx, and often NOx emissions and also in the anaerobic release of CH4, NH3, H2S, amides, volatile organic acids, mercaptans, esters, and other chemicals.

Baxter L, in their research find that compared to dedicated biomassorwaste fired plants, the addition of biomass or waste to high efficiency coal- fired plants can greatly increase the efficiency of utilizing these fuels..

Spliethoff H et al, in their study suggested that besides, the cost of retrofitting an existing coal-fired power plant to a co-combustion plant can be considerably lower than building a new dedicated biomass or waste-fired plant.

Leckner B suggested that to minimize the fluctuating supply of some secondary fuels (such as straw) and to secure the power generation, co-combustion can be operated in a flexible mode (i.e. with different shares of secondary fuel).

Hughes E, in their research paper considered biomass to be CO2 neutral fuel, meaning that combustion of biomass should not increase the CO2 level in the atmosphere, because the amount of CO2 emitted during conversion process equals CO2 which was assimilated into the plants during the process of their growth.

Skodras et al, Hartmann D et al, Malkki H et al, Benetto E et al,Rousseaux P et al, Heller MC et al,Volk TA et al, in their Life Cycle Assessment studies shows that the use of biomass for electricity generation results in environmental benefits in comparison with coal based system. These environmental profits include reduction in CO2 emissions.

Baxter et al, IEA, investigated that co-firing of biomass with coal reduces the emissions of greenhouse gasses and traditional pollutants (SO2, NOx).SOx emissions almost always decrease due to co-firing of biomass with coal, often proportionally to biomass thermal load, as most biomasses contain less sulfur than coal. NOx emissions can increase, decrease or remain the same when co-firing biomass with coal and effect varies with biomass type, firing and operating conditions. For example wood contains relatively little nitrogen and therefore co-firing of coal with wood tends to decrease the total NOx emissions

Hein KRGet al, Bemtgen JM et al, found that co-firing of biomass residues, rather than crops grown for energy, brings additional greenhouse gas mitigation by avoiding CH4 release from the otherwise landfilled biomass. It is believed that CH4 is 21 times more potent than CO2 in terms of global warming impact. In addition, most of the fuel nitrogen in biomass is converted to NH radicals (mainly ammonia, NH3) during combustion. Ammonia reduces NO to molecular nitrogen. Hence lowering of NOx emission level was also reported in co-firing of biomass. Stored biomass wastes anaerobically (i.e. in the presence of bacteria and moisture) release CH4, NH3, H2S, amides volatile organic acids, mercaptans, esters and other chemicals. By combusting the biomass, ambient emissions of these pollutants are reduced.

Liu et al studied the influences of co-combustion of coal and biomass on N2O emission in a bench-scale fluidized bed reactor system. They found that co-combustion of biomass and coal can reduce the emissions of N2O and NOx. The emission of N2O and NOx was found to decrease with increase of the ratio of biomass to coal. The mechanism explanation of the reduction of the emissions of N2O and NOx by co-combustion of biomass and coal was reported to be due to quick release of volatile in biomass in the lower part of the fluidized bed, which produces a lotof radicals causing consumption of local oxygen and de-oxidation of N2O and NOx.

Pedersen et al studied the effect of co-firing of straw and pulverized coal in a 2.5 MWt pilot-scale burner and a 250 MWe utility boiler. They experienced that an increased fraction of straw in the fuel blend resulted in a reduction of NO and SO2 emissions. The lower SO2 emission was partly due to a lower sulfur content of the straw and partly due to retention of sulfur in the ash, probably present as solid alkali sulfates. The reduction of NO emissions was due to lower conversion of fuel –bound nitrogen. Increasing the straw fraction resulted in a larger release of volatiles including NO precursors, leading to conditions that can suppress formation of NO from fuel nitrogen.

Spliethoff et al on the other hand investigated the effect of co-combustion of biomass on emissions in pulverized fuel furnaces. The investigation revealed the positive effect of biomass addition on emissions. Since biomass in most cases was found to contain considerably less sulfur than coal, an increasing biomass share in the thermal output made the SO2 emissions to decrease proportionally. For sewage sludge, the emissions of SO2 correlate with the sulfur content of fuel. Rise in SO2 emission was observed with an increasing share of this biomass. In all the cases ash formation was considered to be of serious concern. An evaluation of CO2 balance shows that, compared with the combustion of hard coal, the CO2 emissions can be reduced by approximately 93%.

Kazagic et al recorded significant reductions for both NOx and SO2 emission as the process temperature was decreased. For both of the coal-biomass blends tested reduction of NOx of 50% as the process temperature was reduced from 1400 C to 960 C. At the same time, no clear relationship was detected between NOx emissions for the different coal-biomass blends. On the other handless SO2 was measured for coal-biomass combustion compared to brown coal alone; at 1140 C.

Several researchers [Narayan KV et al, Nussbaumer T et al, Pedersen LSet al, Savolainen Kati, Baxter LL et al, Hein K et al, Demirbasayhan, Battistajr et al, and Molcan P et al] investigated effect of co-combustion on plant operation. The positive effects are that SOx and NOx emissions usually decrease due to the lower sulfur and nitrogen content in biomass than in coal. Furthermore, alkali components in biomass ash can have an effect of SOx removal. Since biomass has a high volatile content, it can also be used as reburn fuel for NOx reduction from the coal combustion, which gives a further potential for significant decrease of NOx emissions. Besides NO and NO2, N2O also was reported to be reduced significantly by co-firing of biomass in coal-fired fluidized bed boilers.

Narayan KV et al, DemirbasAyhan, Battistajr et al some applications results reflected that co-firing of biomass with coal have accomplished the following:

Increase boiler efficiency,
Reduced fuel costs and
Reduced emissions of NOx and fossil CO2.

4. TECHNICAL LIMITATIONS OF CO-UTILIZATION OF COAL AND BIOMASS

Ayhan Demirbas investigated that co-firing technology has some technological problems. First, the issue of combustor fouling and corrosion due to the alkaline nature of the biomass ash needs attention. Ash deposits reduce heat transfer and may also result in severe corrosion at high temperatures. Compared to deposits generated during coal combustion, deposits from biomass materials are denser and more difficult to remove. Second, the maximum particle size of a given biomass that can be fed to and burned in a given boiler through a given feeding mechanism requires additional studies. Third, practical pulverizer performance needs to be examined. Biomass fuels may require separate pulverizers to achieve high blend ratios and good combustion performance.

Heizel et al. studied slagging behavior in co-combustion of coal and biomass. The co-combustion experiments in the pilot scale test facility revealed that the co-combustion tests with a 25% share of biomass resulted without causing slagging and fouling problems. In contrast to the experiments with 25% of biomass, a sintered layer covering the probe was observed when firing with 50% share of straw and similar slag layer was also found on the cooled metal probe when firing pure straw.

Kazagic et al. studied ash deposition behavior of different Bosnian coal types and biomasses fired in an electrically heated entrained pulverized fuel flow experimental reactor. They observed that in the co-firing test trials, there was no significant difference recorded in ash deposition characteristics of the coal-biomass ash samples against the single coal ash samples at temperature up to 1250 C. Above this temperature, fouling was significant for the coal-biomass blends.

Teixeira et al. evaluated slagging and fouling tendency during biomass co-firing with coal in fluidized bed combustor. They concluded that the woody biomass can be successfully used as bio-fuel without significant slagging and fouling problems. Generally it was concluded that though co-firing of biomass increases the fireside slagging hazard, experiments indicate certain percentage of bio-mass can be utilized without slagging and fouling problems.

Kupka T et al, Abreu T et al. observed some of the secondary fuels with relatively low deposition rate, such as saw dust, were relatively safe, since co-firing coal with these secondary fuels would not significantly influence or even decrease the ash deposition rate.

K.V.Narayanan et al investigated that the SO2 and NOx emission is the lowest for coal: wood combination and for a 40:60 proportion, with decrease of around 50% for SO2 and around 45% for NOx, in comparison to 100% bituminous coal only firing. The figure also indicates clearly, the drastic reduction in above emission as the biomass proportion is increased.

Capacity is about 17.7%. Thermal

5. CONCLUSION

The using of biomass in boilers with coal has the capability to reduce CO2, NOx and SOx, CO, Increased combustion efficiency. However, co firing technology faces some technological problems. Thus, further studies are very much needed to be conducted.

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