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National Mission on use of Biomass in Thermal Power Plants

Standard Operating Procedure for Biomass Pellet co-firing in PF Boilers

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1.0 Introduction

Biomass is an important energy source. Biomass is any organic matter—wood, crops, seaweed, stubble, animal wastes—that can be used as an energy source. Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food. Biomass gets its energy from the sun. All organic matter contains stored energy from the sun. Biomass is a renewable energy source as it can replenish in a relatively shorter time. Stubble is the straw-type material that remains after grains, like paddy, wheat, etc., have been harvested. Stubble burning is intentionally setting fire to the straw stubble to clear agricultural residue that is left on the land, to make it ready for the next round of seeding. Stubble burning in fields emits a large amount of ash/soot/ unburnt carbon to the atmosphere which is the real cause of air pollution and elevates the PM 2.5 and PM 10 level in the atmosphere. It is learned that farmers burn stubble as they find it the cheapest, quickest and easiest means to prepare the land for the next crop because of the short time available. Stubble burning in fields also reduces soil fertility by killing the critical bacterial and fungal populations.

But this stubble is a good biomass resource that has the potential to create efficient biomass-to-energy chains. Torrefaction of biomass stubble, combined with densification (Pelletisation or briquetting), is a promising step towards overcoming the logistical challenges in developing large-scale sustainable energy solutions, by making it easier to transport and store. Pellets or briquettes have higher density, contain less moisture, and are more stable in storage than the biomass they are derived from.

When agro residue-based fuel, in the form of pellets, is utilized in coal-fired power plants, it burns completely in the power plant, and ash emitted from its combustion gets absorbed in Electro Static Precipitator (ESP) which prevents air pollution while generating power from it.

The majority of power plants are running on coal. To reduce greenhouse gas emissions from its coal-based power plants, the Power plant intends to utilize agro residue-based pellets/torrefied pellets along with coal for power generation through biomass co-firing which is a technology recognized by UNFCCC to mitigate carbon emission. It is worth mentioning that the equivalent amount of CO2 (carbon-di-oxide) emitted from the combustion of agro residue-based pellets/ torrefied pellets in a power plant gets absorbed in the next crop cycle by photosynthesis. CO2 emission from agro residue-based pellets combustion does not increase CO2 concentration in the atmosphere and thus it is also termed as carbon neutral fuel which is a renewable source of energy. Further, CO2 emission from diesel and electricity consumption for agro residue collection, processing and transportation is quite negligible as compared to saving in CO2 emissions from its utilization in large coal-fired power plants having higher efficiency which makes biomass co-firing a greener alternative.

In addition to reducing carbon emission from the coal-based power plant, the utilization of agro residue-based pellets/ torrefied pellets in the power plant will also reduce air pollution due to the burning of stubble (i.e. paddy straw and other agro residues) in the fields by farmers. Emissions of sulfur and mercury are reduced by the co-firing percentage.

Ministry of Power on 17.11.2017 had issued a policy regarding Biomass utilization for power generation through co-firing in coal-based power plants. This was followed by an advisory dated 24.11.2017 from CEA to all the TPPs to utilize Biomass pellets in coal-based TPPs to the extent of 5-10%. Keeping the above in mind, the National Mission on use of Biomass in TPPs has been constituted by the Ministry of Power in July 2021.

NTPC has successfully demonstrated the co-firing of a 5-10% blend of biomass pellets with coal in its NCTPP, Dadri power plant and further expanded it to other Power plants. NTPC has already prepared and implemented the Operating guidelines for Biomass Pellet co-firing in PF Boilers based on its technical and operating experience of co-firing.

This Standard Operating Procedure for Biomass Pellet co-firing in PF Boilers has been prepared after deliberations with Sub-Group 2 of the Biomass Mission on R&D on Boiler design for Biomass co-firing & Safety aspects. This Standard Operating Procedure is being issued under the Mission for use by all the TPPs in Central Sector, State Sector, and Independent Power Producers. Taking this as reference, site should develop site specific SOP for compliance.

2.0 Superseded Documents

Nil

3.0 Scope

This SOP shall apply to all PF coal fired stations in operation.

4.0 Types and Properties of biomass pellets:

There are two types of pellets:

a. Non-torrefied biomass pellets
b. Torrefied biomass pellets

4.1 Non-Torrefied biomass pellets are pellets made from agro based residue without torrefaction. The main disadvantage with these pellets is that they are hygroscopic in nature and absorbs moisture readily.

The typical properties of non-torrefied pellets are as follows:

1. Carbon Content: 10-20 %
2. Volatile Matter: 60-66%
3. Moisture: 9-14%
4. Density: 700 kg/m3
5. Ash content: approx. 20%
6. GCV: 3400-4000 Kcal/kg

These properties are indicative in nature; however, the properties of pellets should be taken from torrefied pellets procurement terms and conditions.

The main constraints with these pellets are

1. Ignition temperature: 240 ^{O} Celsius
2. Moisture affinity: Very high

To overcome these constraints, the torrefaction process will greatly help.

4.2 Torrefied biomass pellets:

Torrefaction is a thermal process to convert biomass into a coal-like material, which has better fuel characteristics than the original biomass. Torrefied biomass is more brittle, making grinding easier and less energy-intensive. Compared to fresh biomass, storage of the torrefied material can be substantially simplified since biological degradation and water uptake are minimized. Torrefaction involves the heating of biomass in the absence of oxygen to a temperature of typically 200 to 400°C. The structure of the biomass changes in such a way, that the material becomes brittle and more hydrophobic. Although the weight loss is about 30%, the energy loss is only 10%. The main product is solid, torrefied biomass. During the torrefaction process combustible gas is released, which is utilized to provide heat to the process.

5.0 Handling, storage and blending of pellets:

a. The following steps are involved in handling
    i. Receipt
    ii. Unloading
    iii. storage
    iv. Feeding to Bunkers
b. Receipt and unloading:
    i. The truck containing Biomass pellets (app 20 T/day) enters plant premises
    ii. The vendor test report accompanied the lot shall be checked.
    iii. Sample collection and result at station end by chemistry group.
    iv. Necessary arrangements for safe sample collection like platforms etc., are to be ensured at the site.
    v. Acceptance of the lot based on the result given by the chemistry group
    vi. After acceptance, the truck shall be weighed.
    vii. After weighment truck to be unloaded at designated unloading point.

   viii. Truck unloading mechanism: truck unloader should be available at the site if more quantity of pellets is used for blending.
   ix. The empty truck shall be weighed.
   x. After weighment empty truck to be released from plant premises.

c. Storage:
   i. Biomass pellets area for storage needs to be identified by the site. This area should have firefighting facilities.
   ii. The volatile matter in biomass pellets is very high and can easily catch fire. Hence continuous monitoring of the area needs to be done.
   iii. The pellet storage area should be different from the coal stockyard.
   iv. Facilities should be developed to transport the biomass pellets from the storage area to the blending area.
   v. The maximum percentage of blending allowed is only 5% to 10% (blending by heat value) depending on plant operating conditions and combustion issues.
   vi. The bunkers in which blended coal with biomass pellets need to be identified along with the operation group and all necessary interlocks to be ensured before dumping coal in bunkers.
   vii. Avoid giving Hot work permits on/near pellets feeding path
   viii. Don’t spray water / dry Fog / plain water fogging system on the pellets and its bunker feeding path. The biomass pellets are hygroscopic in nature. After absorbing water or moisture, the pellets lose thier shape and converts to powdery form, so water cannot be used. However, the system for dust suppression like dry fog/plain water and spray water should be available and for use in case of emergency.
   ix. Don’t compact the pellets.

d. Bunkering and blending
   i. The bending ratio needs to be maintained at 5 to 10 % only (Blending by heat value).
   ii. Site-specific Bunkering methodology is to be formulated by considering the following points
      1. Point of blending
      2. Methodology of feeding pellets
      3. TP or chute where blending shall be done.
      4. Control methodology for blending like using belt weigh scales etc.,
      5. No of bunkers to be used for pellets blending

6. Level to be maintained in bunkers in which pellets are bunkered

iii. The pellets do not require crushing; hence blending is to be done after crusher output.

iv. Feeding to be done only along with the coal, as the biomass pellets are highly inflammable as it has very low ignition point and high VM content. Hence conveyor interlock is to be modified so that pellets go only when coal is in the conveyor, and not otherwise.

v. Conveyor streams and chutes used for pellet firing must be thoroughly emptied after feed operations. Left-over pellet blends in conveyors and chutes must be emptied to minimize fire hazards.

e. Safety

During receiving and internal operations, special precautions should be taken so that ignition and explosion can be avoided.

6.0 Monitoring of chemistry parameters:

Biomass Pellets:

a. Sample collection:

   i. Done from every truck arriving at the station.

   ii. Sample collection is done from truck-top. The top 25 cm is removed and then randomly samples are collected from 4-5 spots.

b. Sample Preparation:

   i. The collected sample is brought immediately to the Chemistry lab premises and all portions collected are thoroughly mixed followed by coning-quartering until the sample quantity reduces to approximately 3 kg.

   ii. This 3 kg sample is divided into 3 equal parts - one part for power plant Owner, one part for the seller, third part for referee purpose.

c. The Power Plant Owner part of the sample is to be made homogeneous powder by mortar and pestle method. Moisture, ash and, GCV determination are done with this sample.

d. If moisture value (ARB*) exceeds Specified %, the consignment may be dealt as per contractual terms.

e. GCV value (ARB*) is less than Specified kcal/kg, the vendor is cautioned against any such deviation in subsequent lots. In case of repeated/frequent deviations in GCV or other technical parameters, the matter may be taken up with the vendor as per contractual terms.

ARB: As-Received Basis

7.0 Impact of biomass co-firing on combustion:

a. The process of biomass combustion may be associated with certain risks that do not occur during the combustion of coal. These include fuel pre-processing (fire-explosion risk), combustion e.g. including excessive slagging and ashing, and chlorine corrosion. Therefore, knowledge of the physicochemical properties of plant biomass helps to determine its potential application in heat or electricity production. The knowledge of these parameters allows proper selection of the amount of combusted biomass to ensure its minimal impact on the boiler system or the use of preventive measures minimizing the negative impact of biomass combustion.

b. The content of Oxygen in biomass is very high compared to coal.

c. The substantial proportion of volatile matter in the biomass fuel can be a positive factor in the improvement of ignition and flame stability. However, volatile matter enhances the fire explosion risk in the pre-processing system.

d. Biomass pellets may have a very low content of Sulphur and nitrogen compared to coal which makes them environmentally friendly by reduced SOX levels.

e. Burning biomass fuels or biomass-coal mixtures containing low Sulphur content is valuable for major reduction of SOx/SO2 emissions but might negatively influence the ash deposition behavior, in particular Chloride's deposition. It has been generally accepted that the occurrence of Sulphur can alleviate corrosion problems associated with chloride deposits via the following sulphation mechanism

f. In biomass, elements such as chlorine and potassium are mostly present as water-soluble inorganic salts, and primarily as chloride, nitrates, and oxides, etc. which can be easily volatilized during the combustion, resulting in high mobility for alkali materials and, consequently, high pollution tendency.

g. An important element in the use of biofuels in the power industry, in particular in the combustion process, is their adverse effect on the slagging and fouling processes. The chemical composition of biomass ash is significantly different from that of coal. The mineral material from biomass does not contain aluminosilicates but does contain quartz and simple inorganic salts of potassium, calcium, magnesium, and sodium in the form of phosphates, sulphates, and chlorides.

h. One area of particular concern is the ash composition of biomass fuels. Most of these ashes are high in alkali and alkaline earth elements which are known to promote deposition in the boiler. Even though the ash quantity in the biomass is small, high alkali and alkaline earth materials tend to act as fluxing agents and reduce the melting temperature of the coal ash. This should be evaluated. One characteristic feature of the ashes yielded by biomass combustion is the considerable content of phosphorus, potassium and their compounds, calcium, magnesium, etc., Biomass ash is thus characterized by a low melting temperature and a high tendency to slagging and fouling. Ca and Mg compounds usually increase the ash melting temperature, while K and Na reduce it. In combination with potassium, silicon can induce the formation of low-melting silicates in volatile ash particles. These processes are highly important, given the risk of fouling and ash slagging on the walls of furnaces or heated surfaces.

i. The main effect of biomass co-firing with coal is the emission of vapours of potassium compounds and subsequent condensation on the surface of ash particles and boiler pipes.

j. The two most abundant alkali metals contained in the fuel are usually potassium and sodium. They exist in the original fuel in different forms. These alkali species are mostly volatilized with organic species or maybe released as metallic elements, although they then rapidly react. If fuel contains chlorine, alkalis probably appear as the salts KCl or NaCl. Some of the sodium and potassium are readily volatile even at relatively low temperatures. However, on the particle surface, where combustion takes place, temperatures may be considerably higher than the overall bulk gas temperature; this would suggest that most alkalis are vaporized during combustion and are available for reaction with other compounds. For example, sodium and potassium may react with SO_2 or SO_3 in the gas to form the alkali sulphates, K_2SO_4 and Na_2SO_4, which can condense and deposit. In this manner, the surface initially acquires a characteristic thin, dense, and reflective deposit layer observed in nearly all cases. The vaporization and subsequent chemical reactions are responsible for much of the fouling, corrosion, and silicate formation found in boilers. The addition of these alkalis tends to lower the fusion temperatures of the solids, making them more liquids and able to stick to water wall surfaces.

k. One method of estimating the amount of alkalis readily volatilized is to determine the “water-soluble alkalis.” This test is intended to measure the quantity of alkali present in the form of compounds that may be readily volatilized during combustion. Most sodium and potassium compounds are water-soluble; the assumption is that those that are not water-soluble are present in the form of large complex molecules such as clays and would not readily decompose on heating. The greater the fraction of water-soluble alkalis, the greater will be the potential for deposition.

l. Role of Calcium: Calcium and other alkaline earth materials are found in coal. Calcium in fuel is more refractory and less readily volatilized, although some may be released by similar mechanisms and in similar forms as the alkalis. In general, alkaline earth species form more stable compounds that are less volatile than materials formed from alkali materials. In addition, calcium may react with gaseous sulphur species and remove them from contributing to the formation of low-melting compounds.

m. Increased levels of potassium compounds in biomass are a highly unfavorable phenomenon due to the process of slagging and ashing. These components are characterized by the formation of low-melting eutectics, which contribute to a faster rate of ash melting and deposition on superheater tubes and heating surfaces.

n. Chlorine is an undesirable element in the process of fuel combustion due to the increased risk of high-temperature chlorine corrosion. The enhanced risk of corrosion is associated with the chemistry of ash deposits accumulated on boiler surfaces. The surfaces of superheaters are mostly at risk due to the high temperature of the operating factor, which results in an increased tendency of surface deposits to melt and react with the surface of superheated tubes. Changes in the ash composition and quality occurring during the co-firing process may also influence the use and storability of ashes. The methods applied in the energy industry for purifying solid-derived exhausts in electrostatic precipitators or wet desulphurization lead to the formation of by-products, which are used in other sectors, i.e. construction and cement industries. An increase in the amounts of undesirable substances may result in difficulties in management thereof and a necessity to store them, which significantly reduces the efficiency of power plants.

o. If fly ash and bottom ash are currently sold in the concrete market, an evaluation must be made since current standards are for coal ash only.

All the stations should get the biomass pellets ultimate analysis done before the start of the biomass pellets co-firing and understand the impact on the combustion based on the ultimate analysis. Ash elemental analysis is also to be done during the initial days of firing in the boiler and furnace temperature measurement is to be done frequently during the initial days of biomass co-firing. The Boiler is to be monitored for the ash build-up and slagging during the biomass co-firing. Combustion has to be monitored closely while biomass co-firing takes place.

8.0 Unit Operational issues while handling pellets:

a. The following systems are to made ready before going for pellets operation

    i. The mill inerting system is charged up to the mill inlet. The valve provided at mill inlet should be operable from UCR (either motorized or pneumatic) along with the local pressure gauge after the valve.

    ii. An orifice is provided in the common header to maintain mill inerting steam pressure 02-04 ksc.

    iii. All individual mill outlet pipes are to be provided with RTDs and the temperature of coal pipes to be hooked up to UCR.

    iv. Logic modifications as follows are required before starting the firing pellets in the mills

v. For the operator's ease, Biomass ON/OFF buttons must be provided on individual Mill screen. This button shall be used for change over to Biomass mode and vice-versa.

  a. Whenever Biomass firing is ON, the following changes should happen in the Mill logics: Mill temperature control by CAD (cold air damper) of the mill to be shifted to Mill inlet temperature control as per the Inlet temperature set point. Mill inlet temperature set point increase/ decrease button may be provided in the control interface

  b. Mill inlet temperature set point should be controlled in such a way that operator cannot give more than 180 ^{O}C set point.

  c. Mill HAG (hot air Gate) shall close on protection if Mill inlet temperature reaches 195 ^{O} C. Alarm for Mill inlet temperature to be provided at 185 ^{O} C.

  d. Mill protection at mill outlet temperature 95^{O} C & 110^{O} C will also remain in service irrespective of Biomass ON/OFF mode.

  e. Alarm for mill outlet temperature >70 ^{O} C to be provided

b. Mill Operating Parameters and Operation Procedure: -

  i. Maintain Mill outlet temperature ≥ 55 ^{O} C

  ii. Mill inlet temperature should be ≤ 180 ^{O} C

  iii. Observe all coal pipe temperature of Mills with biomass every shift. In case of any deviation from the rest of the pipes (any abrupt rise or fall), stop the mill and give PTW for inspection of coal pipes

  iv. Initially, periodic internal inspections of mills should be done during biomass co-firing to observe any possible accumulation of biomass inside mills. Initially, the periodic inspection may be carried out in shorter frequency say every 1 hour and gradually it may be increased based on experience. This is a vital aspect from the safety point of view.

  v. Pre-start and post-shutdown purging of the mill is mandatory. In case of Mill Trip, the Mill must be emptied at the earliest to avoid fire in the mill.

  vi. Continuous monitoring of mill parameters most importantly mill inlet air temperature (Mix Air Temperature), Mill outlet temperature, mill current, and mill DPs.

  vii. Mill inlet temperature should not be more than 180^{o} C in any case

  viii. Mill reject system to be kept under observation.

  ix. Deployed Mill Operator must monitor for any kind of Fire in the rejects and intimate control Room immediately in wake of fire hazard.

    x. In case of fire, the mill should be tripped and steam inerting should be done immediately by opening steam inerting motorized valve, keeping watch on furnace pressure. Fire tender may also be used if required.
    xi. View glass of Mill feeders should be periodically cleaned and seal air arrangement shall be provided to prevent dust deposition on view glasses. Illumination inside feeder shall be revived/ provided to keep track of biomass and coal blend.
    xii. Regularly watch flue gas exit temperature and adjust SAPH/PAPH flue gas dampers, if required, so that increase in overall flue gas exit temperature can be minimized to the extent possible.

c. Step by step procedure for going to biomass mode shall be provided to all desk engineers and proper training to these people essential before going for pellet firing.
d. Changes in the logbook and log sheets are to be done before going for pellet firing and the operator should monitor the parameters and record them in the log sheets.
e. Put the CAD & HAD control in manual mode.

9.0 Actions to be taken in a milling system having a fire during Biomass firing:

a. Call the fire personnel in the plant for immediate assistance.
b. Site-specific SOP to be prepared for handling mill fires in stations
c. Do not expose any part of the mill (roller, scrapper chamber and tramp iron gate for any inspection until the mill temperature comes down to normal value)

10.0 Combustion issues in pellet firing

a. Clinkering and slagging tendency to be observed by any rise in SH zone FG temperatures. Frequency of Soot blowing and LRSB to be determined accordingly.
b. Flue gas temperature profile increased unburnt, changes in Spray and metal temperature to be monitored, and any abnormality to be discussed with Corporate Operation services.
c. Elemental analysis of biomass for each sample/lot to be done to keep a check on the chlorine content and alkali content like Sodium, potassium, etc. which have high slagging and fouling tendencies due to sodium and potassium compounds formed and mixing with bottom ash. Similarly, chlorine content is to be kept under control which tends to corrosion.

11.0 Impact of ash and usage in the cement industry

Currently, the American Society for Testing and Materials (ASTM), ASTM Standard C618, does not allow ash from a co-firing installation to be used in the concrete arena. If fly ash from a plant is currently being sold to this market, that impact needs to be studied during co-firing.

12.0 Safety aspects of pellet-firing:

a. Pellets have got very high amount of volatile matter

b. The storage area must be predefined and proper barricading is to be ensured. No cutting and welding works should be carried out near that area. The area should be clearly demarcated a “No Smoking Area”.

c. Conveyor firefighting system should always be healthy as the fuel is highly inflammable; hence all protection needs to be healthy.

d. The storage areas should have proper firefighting provisions like hydrants and water monitors.

e. MSDS for these pellets are to be displayed near the storage area

13.0 Infrastructural requirements of biomass pellet handling

a. Truck tippler – 60 tons two nos.

b. Closed shed (from sides also) covering feeding Area as well as Storage space as the fuel is highly susceptible to atmospheric moisture if left in open for a reasonable amount of time. The Shed should cover the feeding point and the storage yard and should allow the movement of dozing equipment like pay-loader or bob-cat. The site team shall decide the dimensions / size and location of the shed. The shed should be provided with flameproof lighting

c. Weighbridges calibrated for weighing of the trucks

d. Belt weighing scales for proper blending

e. Pay-loader or more preferably by Skid Steer Loaders for feeding and for achieving finer control over the feed rate.

f. Safe Working Platform for collecting a sample from the truck.

g. Methane, CO, Multi-gas detectors at the storage location

h. CCTVs for monitoring at different points like unloading Points, Blend points, Feed points, and conveying path.

14.0 Site-specific SOPs to be prepared against this Model SOP

a. SOP for unloading, storage and bunkering, and blending for use in CHP with all precautions to be taken.

b. SOP for main plant operation activities from Mills to ESP including parameters to be monitored, Emergency instructions and logic modification, etc., is to be done.

c. SOP for chemistry for sample preparation to analysis.

15.0 Further actions required:

a. Ultimate analysis of biomass pellets to be done.

b. Ash elemental analysis after biomass firing and ash fusion temperature monitoring.

c. Impact of biomass on the quality of ash as required for cement industries.

d. Effect of pellet-ash on the performance of wet/dry ash handling system to be checked periodically by stations. (like scaling inside pipes, hoppers, sumps, silos, etc. and evacuation & flowability of dry ash from hoppers)

e. All parameters impacting heat rate shall be recorded and Heat rate before the start of biomass co-firing and during biomass co-firing should be recorded to analyse its commercial impact.

16.0 Combustion and clinkering issues

a. An important element in the use of biofuels in the power industry, in particular in the combustion process, is their adverse effect on the slagging and fouling processes.

b. Units with clinkering tendency to be put last on priority for biomass firing

c. Mill capacity is reduced in biomass firing therefore it should be kept in consideration when deciding extant of biomass blending.

d. PA header pressure to be kept 50 mm higher to avoid mill settlement.

17.0 Review

The Head of the respective TPP, will be responsible for reviewing this SOP on yearly basis or as necessary.