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Hydrothermally-treated empty fruit bunch cofiring in coal power plants: a techno-economic assessment

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Abstract

Co-firing biomass with coal is believed to be able to improve the domestic energy security in Indonesia. Hydrothermal treatment process prior to the combustion is needed to convert raw biomass into coal-like product. The main objective of this research is to demonstrate the technological, economic and environmental feasibility of the cofiring coal with hydrothermally-treated empty fruit bunch (HT-EFB) through extensive laboratory investigations, simulations, system analyses and economic assessments from literature. Based on computational fluid dynamics (CFD) simulation, HT-EFB mass fraction of 10 to 25% seems to be the most preferable cofiring condition in term of temperature and produced gas compositions including CO_2, CO, NO and SOx. An aspen plus simulation showed combining hydrothermal treatment with cofiring in an integrated system power plant could be a positive way to generate electricity with overall energy efficiency 37.09%. Moreover, fuel production cost, EFB supply capacity from palm mills surrounding the power plants, and transportation cost are required parameters to be considered for developing large scale biomass cofiring and integrated supply chain.

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Keywords: co-firing; hydrothermal treatment; palm oil

1. Introduction

This study is focusing on the use of empty fruit bunch (EFB), which is a byproduct from palm oil industries, for energy generation. According to data from the Indonesian Ministry of Agriculture, the total area of oil palm plantations was around 8 million hectares in 2015 or twice as much as in 2000 (4 million Ha). This number is projected to increase to 13 million hectares by 2020 [1]. Annual production of crude

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palm oil in Indonesia was about 27.78 Million Ton in 2013 [2]. It is estimated that annual production of EFB was 24.82 Million Ton. The production is expected to reach 37 Million Ton in 2019 with annual growth about 4.59%. Almost 70% of palm oil production is located in Sumatera Island.

Huge amount of EFB was generated in Indonesia but poorly utilized, arising many problems associated with the improper disposal practices of EFB. Cofiring with coal has been identified as one of the least expensive and most efficient technologies for converting this palm oil waste to electricity. This requires biofuels with a uniform quality and high energy density, which can be processed in the fuel handling and combustion equipment of existing coal-fired power plants.

New techniques have also been studied to increase the cofiring rates to desired levels for biomass. Hydrothermal treatment (HT) as a pretreatment process prior to the thermo-chemical conversion of biomass offers significant merits such as high conversion efficiency, the elimination of energy-extensive drying process, and relatively low operation temperature compared to the other thermal processes [3].

The main objective of this research is to demonstrate a holistic analysis for: empty fruit bunch resource availability, cofiring technical and economic analysis in Indonesia case. This methodology is shown to be adequate for the determination of cofiring potential and emission reduction.

2. Methods

2.1. Modelling and proposed system

Fig.1 shows the conceptual diagram of the overall proposed cofiring system of HT-EFB and coal. Raw EFB from palm mill is initially hydrothermally treated converting the lignocellulosic material into solid carbon which has lower moisture content and characteristics near to the coal. HT-EFB is then ground to achieve smaller and uniform size of particles.

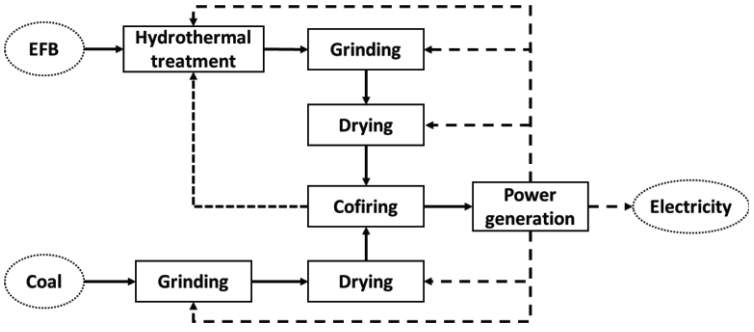

Fig.1. Flow diagram of the proposed cofiring system of hydrothermally treated EFB and coal

On the other hand, coal particles are ground initially before being fed to the dryer for water removal. Both HT-EFB and dried coal particles are then fed together to combustor for cofiring. The heat product of cofiring is utilized to generate steam in boiler which is further utilized for power generation. The rest of heat from cofiring is utilized for hydrothermal treatment. On the other hand, a part of generated electricity is consumed internally for drying (steam compression) and others, while the larger part of electricity can be sold to the grid.

To predict an appropriate cofiring mass fraction, a commercial CFD software ANSYS Design Modeller and Fluent ver. 16.2 (ANSYS Inc.) are used to build 3D combustor model and analyse the cofiring behaviour. In the simulation, a laboratory scale of DTF, which is a vertical tubular furnace, has a