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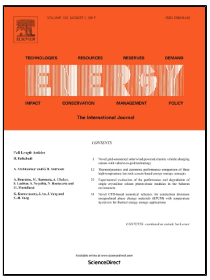

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Nonlinear multi-objective optimization model for a biomass direct-fired power generation supply chain using a case study in China

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Abstract

Using renewable resources to generate electricity is becoming increasingly common all over the world. As the largest energy consumer in the world, China has established many biomass direct-fired power plants in recent years. However, most of these power plants would not survive without government subsidies because of the high cost of fuel. This study focuses on the fuel supply chain of biomass direct-fired power generation, including the collection, transportation, processing, and storage of fuel; the study presents a nonlinear multi-objective optimization model. The purpose of this work is to determine the optimal quantity of electricity generation, as well as the ideal blending ratio, acquisition quantity and price of each kind of fuel so as to maximize the profit margins of biomass power plants and provide the most protection possible of social welfare considering environmental factors. The model we present was applied in a biomass direct-fired power plant in Heilongjiang Province in Northeast China; the subject plant was chosen from 13 biomass power plants that were investigated. Based on the case study, we obtained values for the optimal results and compared them with the actual situation. The optimal results confirmed that under the existing technical conditions, the overall benefit of biomass power generation leaves significant room for improvement, mainly by means of designing a more reasonable fuel supply mode. Finally, a sensitivity analysis showed that the best and most integrated efficiency in biomass power generation was achieved when the biomass electricity on-grid price was approximately 0.65 Yuan/kWh.

Key Words: biomass power supply chain, multi-objective optimization, renewable energy generation, social welfare, carbon dioxide emissions

1. Introduction

Biomass is organic matter derived from organisms, and using it as a source of energy is now a common practice in many countries, because of the rising issue of environmental deterioration and the emphasis on reducing the use of fossil fuels [1]. Biomass resources can be used as feedstock to generate electricity whenever required; it is stable and therefore does not rely on the use of fossil fuels as a back-up [2]. The main types of biomass resources used in power generation include agricultural residues (such as sugarcane, wheat straw, bean straw, rice husk, and corncobs) and forest residues (such as branches, bark, and wood chips). Several countries with large areas of farmland, such as Denmark, the UK, Spain, Sweden, China, and India have developed biomass power plants that use agricultural residues as fuels [3], and forest residues are used more extensively. There are many ways to use biomass to generate electricity: Gasification is a promising energy conversion technology for using biomass because of its high efficiency [4]; Co-combustion of biomass and coal is used as a way to reduce carbon emissions and fossil fuel consumption in some countries like Germany and the Netherlands [5]; Biogas power generation has no geographical limitations and the technology is not complex, and it has been successfully applied in many countries like Italy and Brazil [6]. Besides, different pre-treatment means could influence the power generation process and the efficiency of biomass power plant [7],[8].

China has become the world's largest energy consumer since 2010, and it used about 23% of all global energy consumed in 2014. The leading fuel in China is coal. As the environmental problems caused by extensive coal using have become acute, China has implemented many corresponding policies, and encouraging the application of renewable energy generation is one of them. Furthermore, China is rich in biomass energy resources, which provide enormous development potential for the biomass power generation industry [9]. As the most common biomass electricity generation method in China is biomass direct-fired power generation, we focused our attention on this power generation form.

In recent years, China has built many biomass power plants. However, compared with most developed countries,

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