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Optimal placement of biomass fuelled gas turbines for reduced losses

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Abstract

This paper presents a method for the optimal location and sizing of biomass fuelled gas turbine power plants. Both profitability in using biomass and power loss are considered in the cost function. The first step is to assess the plant size that maximizes the profitability of the project. The second step is to determine the optimal location of the gas turbines in the electric system to minimize the power loss of the system.

Keywords: Biomass; Distributed generation; Optimal placement; Power loss

1. Introduction

Renewable electricity generation has emerged as one of the favored options for dealing with fossil fuel depletion, green house gas emissions and subsequent adverse effects like global warming. As an outcome of the Kyoto protocol, one of the European Union's objectives is to increase the contribution of renewable energy sources to 12% of the total energy supplied by 2010.

Distributed generation (DG) is electricity generation sited close to the load it serves, typically in the same building or complex. The DG embraces a palette of technologies in varying stages of availability, from entrenched to pilot. It is sometimes called a disruptive technology because of its potential to upset the utility industry's apple cart.

The concept of installing DG in a utility distribution or sub-transmission system is gaining interest in the industry. Research has suggested that the benefits of distributed resources could be substantial. However, these distributed benefits are site specific [1–3].

Biomass is one of the promising renewable sources in Europe, but more research is required to prove that power generation from biomass is both technically and economically viable. The main advantage of biomass based power generation is that the cycle of growth and combustion of the biomass has a net zero level of CO_2 production.

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However, this poses the problem of defining the optimal size for plants to convert the biomass into electric energy. In this work, a method has been developed to determine the optimal electric power to install in a given agricultural/forest area based on the biomass available in the area, the power losses and the economic objectives associated with the proposed investment.

2. Distributed generation

The history of electric power generation systems has been derived from large central station plants due to the economies of scale [4]. Fossil fuel plants have represented the majority of this power generation. According to tradition, there was strong yearly demand growth, which was stable at around 6–7%. Environmental issues and the oil crisis began to introduce new problems for the power industry in the 1970s. By the 1980s, these factors and changes in the economy had led to much smaller demand growth of around 1.6–3%. Simultaneously, transmission and distribution (T&D) costs have grown from a historical level of 25% to around 150% of generation costs. T&D costs now represent almost two thirds of the capital expenditure budget for the utility industry. Thus, as a result of the reduced demand growth, increased T&D cost, intensified environmental concerns and various regulatory and technological changes, large central station plants are often impractical. The utility industry's generation paradigm is shifting from economies of scale to something that has been coined economies of mass production [5].

Penetration means the proportion of the distribution load being supplied by the gas turbine plant [6]. In this paper, an initial load of P_{il} is assumed, and the penetration is thus,

$$\text{Penetration} = \frac{P_l}{P_l + P_{il}} \tag{1}$$

where P_l is the real power.

3. Biomass

The options for conversion of biomass into electricity are combustion, gasification, integrated gasification combined cycle (IGCC) and pyrolysis [7]. The biomass can be converted into producer gas by gasification (partial combustion). Thermochemical gasification involves burning the biomass with insufficient air so that complete combustion does not occur, and producer gas is formed. Producer gas is a mixture of carbonmonoxide and hydrogen. Gasifiers are classified as updraft or downdraft depending on the direction of flow of the biomass and the producer gas. In a downdraft gasifier, the biomass and the gases flow in the same direction (downwards).

In a typical downdraft gasifier, the biomass is fed from the top. It passes through the gasifier and undergoes the following sequence of processes—drying, pyrolysis, oxidation and reduction. The gas formed is passed through a cooling and cleaning sub-system that usually consists of a cyclone for particulates removal and a scrubber for cooling and cleaning the gas (removing the tar). Some ash is formed from the oxidation reactions. The ash moves through the reduction zone and gets removed from the ash disposal system (grate and ash collection system). The typical composition of producer gas is 20–22% CO, 15–18% H_2, 2–4% CH_4, 9–11% CO_2 and 50–53% N_2 (by volume). This is a low calorific value fuel with a calorific value of 1000–1200 kcal/Nm^3 [8].

4. Dimensioning

Several studies [9,10] have been developed in the past 30 years on the availability of woody and cellulosic residues usable for energy generation in various countries. The analysis of dimensioning proposed is based on the method of discounted cash flow [11].

4.1. Technical dimensioning

A study is presented for identifying the feasibility of biomass energy systems. This study is comprised of a conversion plant and the necessary equipment upstream for the accumulation of the unprocessed materials