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Perspectives of Stirling engines use for distributed generation in Brazil

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Abstract

This work presents an evaluation of the development of Stirling engines and the advantages and the main obstacles against their widespread introduction in energy-generation practices. It also shows how the economic, technical and environmental characteristics presented by these engines support their insertion in the energy sector. An economic and environmental evaluation of this technology aiming at introducing it in the Brazilian energy scenario is also presented. Changes in legislation, financing and technology within the next few years must encourage the implementation of alternative generation technologies that present lower environmental impacts. Also, tendencies and economical studies are presented, trying to find the optimal condition for this technology to be feasible. The option regarding the trading of carbon credits when biomass is used as fuel is analyzed as well.

Keywords: Stirling engine; Distributed generation; Biomass

1. Introduction

In 2002, Brazil has experienced maybe the most serious electric energy shortage of its history since the early 1950s. A 20% compulsory reduction in consumption, which lasted for 9 months, was imposed on the most populous regions of the country: the Southeast and the Northeast. The problem occurred because the generating park was not expanded to the necessary levels. This coincided with a summer that presented highly adverse hydrological conditions. The system, then, became vulnerable and could not meet the market's needs. The management of the energy crisis was conducted with considerable efficiency and with the consumers' full cooperation, who voluntarily replaced several pieces of equipment presenting high energy consumption for others that were more efficient. They also changed processes and habits in an attempt to reduce consumption. Moved by these problems and trying to reduce the dependence of the present electric supply system on rainfall, the government decided to make changes in the energy model so as to assure its sustainable development. Aiming for this goal, several laws encouraging the use of alternative sources are being implemented. But this alone is not enough to lead to a robust technological paradigm approach in a country such as Brazil, where more than 90% of the electricity supplied by the energy matrix comes from hydroelectricity. In addition, the recovery of the water levels at the hydroelectric plants reservoirs to theoretically safe margins, only 1 year after the crisis, has caused these incentive policies to advance in a slower pace.

On the other hand, there is another problem that regards the electricity tariffs, whose values have ballooned substantially and must be inflated even more because of several factors: a higher marginal cost of the new generation capacity, currency devaluation, which has a significant influence on sectors that have many imported items and foreign capital, additional costs and loss of income as a result of the energy crisis.

Within this scenario, surrounded by uncertainties regarding supply and the electricity prices, several consumers, mainly the ones coming from the industrial and commercial sectors, have started to look towards

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other energetic supply alternatives, especially cogeneration, which can assure a much safer energy and, in many cases, is a much cheaper alternative.

These other alternatives, generally, refer to different technologies that are able to generate energy separately from the conventional electric grid presenting similar or even better quality and reliability. It is the so-called distributed power generation (DG).

DG is any small-scale electrical power generation technology that generates electric power at a site that is closer to customers than the central station generation and is usually interconnected to the distribution system or directly to the customer's facilities. Currently the world's distributed generation installed capacity is about 75 GW (ABI Research, 2003). According to Kreider and Curtiss (2000) and Thompson (2002), the distributed power is able to capture about 7–20% of the world's increase in generating capacity, or 55–110 GW, over the next two decades (Brown, 2003). Fig. 1 show the prognoses in relation to electricity coming from distributed generation in the period 2010–2030 based on data from the world energy outlook 2002 from IEA (Fraser, 2003).

DG technologies include small combustion turbine generators, internal combustion reciprocating engines and generators, photovoltaic panels, wind turbines, fuel cells and other technologies, including solar dishes and biomass-fuelled Stirling engines.

The purpose of this paper is to present an evaluation of the evolution and development of Stirling engines, as well as the advantages and main obstacles against their widespread introduction in energy generation practices. It will also show how the economic, technical and environmental characteristics of these engines support their insertion in the energy sector. An economic and environmental evaluation of this technology aiming at introducing it in the Brazilian energy scenario is also presented.

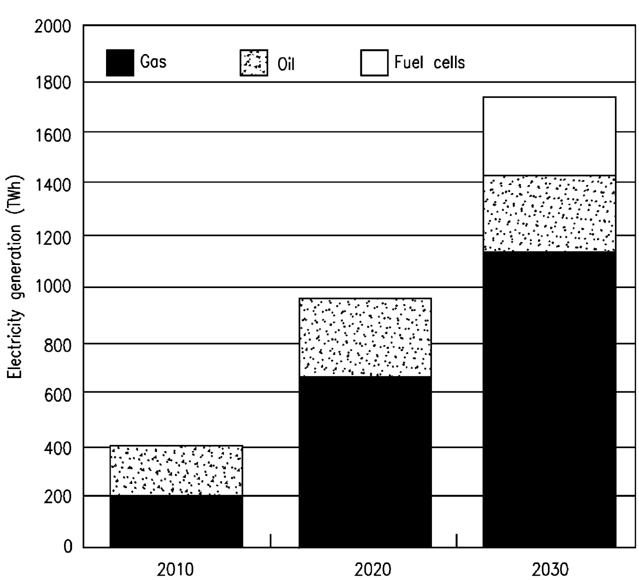

Fig. 1. Distributed energy technologies—electricity generation prognosis for 2010–2030 (Fraser, 2003).

2. The Stirling engine (SE)

The Stirling engine is an external combustion reciprocating engine developed by Robert Stirling in 1817. It uses an external source of energy to heat the gas located inside a cylinder. This gas, under pressure, expands when heated, driving a piston to perform work. The expanded gas volume, having released much of its energy, is then cooled and compressed before the next heating cycle.

The Stirling cycle engine is well suited for stationary power. It is inherently fuel-efficient—having a high theoretical efficiency among small capacity heat engines. And it is inherently "green", for it can use different types of renewable sources of energy including solar and geothermal energy, biomass and biogas from animal waste and garbage. As it involves continuous burning of the fuel rather than the intermittent burning presented by internal combustion engines, it burns the fuel more completely, producing far lower unwanted emissions (Thompson, 2002; Mc Kenna, 2003).

Stirling engines constructions can be classified in tree types: alpha, beta and gamma. The alpha-type engines consist of two-independent cylinders, placed in an angle of 90°, with two pistons. One of the cylinders is heated up and the other is cooled down through a finned transfer surface using air or water. Fig. 2 shows the cycle stages using engine schemes and a pressure/volume diagram. Fig. 3 shows an ideal cycle and a real cycle in a pressure/volume diagram.

The beta-type engine is based on Stirling's original engine. It consists of a cylinder with a hot zone and a cold zone. The displacer is inside the cylinder. The gamma-type engine is derived from the beta, but it is easier to build. It consists of two separate cylinders. The displacer is placed inside one of them and the power cylinder is inside the other. Fig. 4 displays an outline of each type of engine.

3. Attractiveness, obstacles and opportunities

Among the main advantages presented by Stirling engines

- Global efficiency of about 30%, which makes them competitive against other small capacity generation technologies. According to Carlsen et al. (1996) for a 40 kW Stirling engine, an increase in the heating gas