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TECHNICAL ASSESSMENT AND MANAGEMENT IMPLEMENTATION OF TRIGENERATION SYSTEMS IN BUILDINGS

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Abstract. The assessment of energy economy and environmental impact of different energetic plants is the subject of many research studies. Fossil fuels such as petroleum, coal and natural gas have become limited resources. Since current living and economical standards depend strongly on energy sources, it is necessary to realize a new technology that utilizes renewable energy as a source of energy. Thus, trigeneration systems are more and more used for residential buildings.

Key words: trigeneration system; prime movers; renewable fuels; Stirling engines.

1. Introduction

Climate change and limited fossil resources call for a reduction of non - renewable primary energy input and greenhouse gas (GHG) emissions by 50 to 80% by 2050 (Chicco & Mancarella, 2006). One possible developmental path is decentralization of the electricity system.

Micro-trigeneration or residential trigeneration is an emerging technology with the potential to provide energy efficiency and environmental

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benefits by reducing primary energy consumption and associated greenhouse gas emissions. Distributed power generation in small, decentralized units is expected to help in reducing emissions and saving grid capacity, while also providing opportunities for renewable energy. It could thus form a constituent part of a more sustainable future (Kaarsberg *et al*., 2008; Kirillov, 2008; Li *et al*., 2006).

One objective of trigeneration systems is the diversification of energy sources, especially use of renewable ones, accordingly to the geographical location and possibilities. Integrated micro-CCHP system solutions represent an opportunity to address all of the following requirements at once: conservation of scarce energy resources, moderation of pollutant release into our environment and assured comfort for home-owners (Uzuneanu & Scarpete, 2011; Uzuneanu *et al*., 2010).

The trigeneration technology is a very good solution to supply energy to the building sector (residential houses, offices, hotels) (De Paepe *et al*., 2006; Haroldsen *et al*., 2005; Kaarsberg *et al*., 2008).

In industrial applications the energy demand is very regular across the year, but in buildings the energy demand is highly variable due to the external ambient conditions, the occupancy, the different building uses, etc.

The target customers are people with houses located outside the utilities distribution lines or in areas with unreliable electric grid service. Trigeneration system applied to residences cover the usual electrical power needs < 5 kW(e) and for the thermal needs <25 kW(th) (De Paepe *et al*., 2006; Haroldsen *et al*., 2005; Li *et al*., 2006).

Trigeneration systems are interesting due to their technical and performance features:

− High overall energy conversion efficiency (*e.g*., in excess of 90% for Stirling engines).

− Low maintenance requirements equivalent to a domestic gas boiler.

− Very low noise and vibration levels for installation at home.

Very low emissions of NO_x, CO_x, SO_x and particulates (Uzuneanu & Scarpete, 2011; Uzuneanu *et al*., 2010).

2. Prime Movers

A prime mover in a trigeneration system generates electricity and the waste heat is recovered downstream. Trigeneration technologies for residential, commercial and institutional applications can be classified according to their prime mover and from where their energy source is derived (Residential Micro-CHP, 2004; Project RO–0054/2009). The investment costs for trigeneration systems vary significantly depending on the kind of technology.

A trigeneration system comprise a prime mover, which generates electricity and the heat recovery and utilization components which use the heat rejected by the prime mover provide space heating, hot water, and/or even cooling.

The prime movers used in trigeneration systems are: reciprocating engines, Stirling engines, micro steam and gas turbines and fuel cells.

Fig. 1 shows the structure of a trigeneration system for domestic use application (Uzuneanu *et al.*, 2010).

Stirling engines can be used for primary power generation and as a bottoming cycle utilizing waste heat for power generation (Residential Micro-CHP, 2004).

Stirling engine is an external combustion which produces power by using an external heat source.

Due to the nature of external combustion, the Stirling engines can be operated on a wide variety of fuels, including all fossil fuels (*e.g.* natural gas (Homutescu *et al.*, 2003)), biomass (biomass can be used many ways, including direct combustion, two-stage combustion, and with a gasifer), solar, geothermal, and nuclear energy (Li *et al.*, 2006; Wu & Wang, 2006; Uzuneanu *et al.*, 2010).

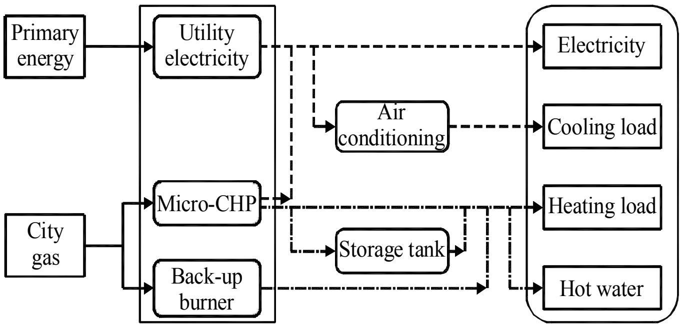

Fig. 1 − Structure of a trigeneration system (Uzuneanu *et al.*, 2010).

Trigeneration systems based on natural-gas Stirling engines permit 40% reduction in fuel consumption relative to centralized power systems (Zeiler *et al.*, 2007; Uzuneanu *et al.*, 2010). The cost of 1 kWh of power from a cogeneration system is 3–4 times less than for centralized power systems. The Stirling engines are 15-30% efficient in converting heat energy to electricity, with many reporting a range of 25 to 30%. The heat generated is free (Zeiler *et al.*, 2007).

3. Management for Implementation of Trigeneration System in Buildings

In order to integrate a trigeneration system in a residential building they have to follow the steps (Project RO–0054/2009):

− Obtaining the legal conditions to design a building;
− Establishing local aspects for the building using a trigeneration system;
− Designing the technical system and choosing the prime mover and the fuel.

To establish legal conditions it means to obtain the Land Register Approval, the Urban Certificate and all others approvals. All these represent the legal document which gives the beneficiary the permission to locate, to design and to build the construction (Project RO–0054/2009).

The local aspects for the building equipped with trigeneration system are:

• Climatic conditions of the region,

• Energy resources, especially renewable ones, available in the region.

The climatic parameters that influence the construction of a building are temperature, humidity, sunshine and wind speed.

From the analysis of statistical data about these parameters the climatic conditions for space heating and the specific heat needed were determined.

From the analysis of urban and rural conditions for space heating and the potential of renewable energy it is identified the type of renewable energy that can be used to achieve a trigeneration system (Micro-CHP Systems, 2006). Now they deceide to use biomass pellets (Project RO–0054/2009).

The simplified model of the residence meets the current standards for a living area and space volume.

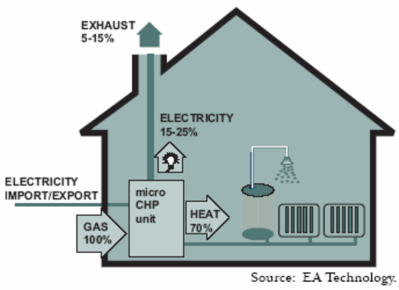

Fig. 2 − Model of a residence (Project RO–0054/2009).

In order to design the technical system it was necessary to organize the structural-functional analysis, according to criteria (Uzuneanu & Scarpete, 2011; Uzuneanu *et al*., 2010; Project RO–0054/2009):

− the type of primary mover,

− the type of fuel,

− refrigeration cycle carried out,

− the type of the electric generator employed,

− construction materials.

The design, development and implementation of trigeneration systems in buildings are heavily dependent on primary mover efficiency.

The construction materials have to be identified in order to make possible to build a residence of an upper energetic class.

The influence of the material on the energy balance of a building is important to reduce the heat losses.

4. Conclusions

1. In choosing the optimal architecture of the trigeneration system they have to take into account the consumer energy demands, which strongly depend on building location. Thus, it results a large variety of trigeneration systems architectures.

2. The technical analysis and management assessment of urban and rural conditions for space heating, cooling and electricity in residential building shows the type of renewable energy that can be used to achieve a trigeneration system, namely biomass pellets and solar energy.

3. Domestic trigeneration systems which use renewable energies are worth developing in isolated areas where the costs are lower than classic systems.

4. The evaluation of various trigeneration systems, regarding the prime mover technology for producing electricity, heat and cooling for residential use, indicated that the trigeneration units with Stirling engines are more appropriate for the micro-CCHP having the best value for overall system efficiency.

5. Combining absorption and adsorption technologies allows for increased reliability of the refrigeration systems and increased energy efficiency.

6. The major benefits of trigeneration system include significantly increased energy efficiency and reduced consumption of fossil fuels, by using renewable energies.

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EVALUAREA TEHNICĂ ŞI MANAGEMENTUL IMPLEMENTĂRII SISTEMULUI DE TRIGENERARE ÎN CLĂDIRI

(Rezumat)

Evaluarea economiei de energie şi impactul asupra mediului a diferitelor instalații energetice fac obiectul multor studii şi cercetări. Viața noastră curentă şi standardele economice impuse depind de resursele energetice. Combustibilii fosili ca petrolul, cărbunii şi gazul natural sunt limitați şi de aceea este necesară implementarea unor noi tehnologii care să utilizeze energii regenerabile ca surse energetice.

Astfel, sistemele care produc simultan căldură, electricitate şi climatizare sunt potrivite de a fi implementate în reşedințe individuale, mai ales în zonele izolate. Sistemele care folosesc motoare Stirling pot utiliza drept combustibili peletele, ceea ce constituie o economie de resurse clasice.