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Abstract:

By 1973, low oil prices had provided the production of relatively cheap electricity. A sudden increase in gas prices caused a need for developing energy technologies as well as a need for increasing the efficiency of power plants. At the same time, increased environmental awareness as well as the awareness of the growing scarcity of energy sources required greater attention to preserving the environment and the existing resources, so small and micro cogeneration plants become efficient and competitive energy producers. The United States and Canada are currently lagging behind Europe and Japan in relation to the development of micro cogeneration units, partly because of differences in heating systems, energy prices and political framework. In accordance with the Kyoto Protocol, Japan is obliged to reduce its global warming i.e. gas emissions by 6% of the 1990 level. However, CO2 emissions continue to grow, which means that it is currently estimated that Japan must reduce emissions by 14% to meet the goal. Japan should promote all possible ways to effectively reduce CO2 emissions. In this regard, it continues to give support to micro cogeneration marketing, especially for models suitable for residential buildings. It is estimated that, in the next few years, energy production by cogeneration will reach 75% of the total production at the European level. In Italy, ecological energy makes 30% of the total consumption, in the Netherlands 33%, and in Denmark and the UK it is almost completely present.

Key words: micro cogeneration, small cogeneration.

Introduction

Cogeneration is the process of a combined production of heat and electricity. The reasons for the application of CHP plants are economic in nature and originate in energy efficiency. In practice, the maximum degree of efficiency that can be achieved when it comes to electrical power is 40%, and the rest of the useful energy is used for heating (Pehnt et al, 2006).

Decentralised installations for a combined production of heat and electricity can achieve a total degree of efficiency of 90%. There has been a significant increase in a total degree of efficiency in relation to the degree of usefulness of 36% achieved by centralized condensation plants for electricity production (Despotović & Babić, 2007).

Achieving sustainable development in the energy sector requires specific quality changes to be undertaken. This includes limiting the use of resources of fossil fuels and reducing emissions by 50-80% by 2050, i.e. their adverse impact on climate change.

Directive 2004/8/EC obliges the Member States to carry out an analysis of the potential of cogeneration efficiency in their country and to establish a system of incentives to apply cogeneration. For either small (< 1MWe) or micro (< 50kWe) cogeneration installations, the directive states that it is necessary to ensure a high level of efficiency for each new capacity. The directive clarifies that high efficiency must provide primary energy saving of at least 10% compared to separate production of heat and electricity.

Small and micro cogeneration plants

Today, there are several technologies used in cogeneration plants such as piston engines, gas turbines, Stirling engines and fuel cells. Advances in technology (Rosato & Sibilio, 2013, pp. 478-491) as well as a general trend towards smaller manufacturing units have led to an increased interest in small cogeneration units, in hope that they will be able to provide electricity and thermal energy for individual objects (de Paepe et al, 2006, pp. 3435-3446).

Small cogeneration plants driven by gas engines with internal combustion are fully adapted to the needs of consumers; they use 88% of natural gas energy, thus providing cheaper and better energy, as well as long-term planning of costs, all of which is in accordance with the strictest European environmental standards (Said et al, 2005, pp. 259-262).

The EU directive on cogeneration defines micro cogeneration as a unit with a maximum capacity smaller than 50kWe, while in Germany, micro cogeneration systems are those under 15kWe for the following reasons: these systems are clearly intended for use in family homes, apartment buildings, small businesses, or hotels (Pehnt et al, 2006).

Examples of commercially available CHP units

CHP units with piston engines are commercially available and are manufactured in many different companies around the world. The market leader is the German company Senertec. A Senertec model known as Dachs generates 5.5 Kwe and 14 kW of thermal energy (Figure 1) (Cummins Inc, 2014).

Figure 1 – Senertec Dachs
Рис. 1 – Senertec Dachs
Слика 1 – Senertec Dachs

Figure 2 – PowerPlus Ecopower
Рис. 2 – PowerPlus Ecopower
Слика 2 – PowerPlus Ecopower

Other companies that produce micro cogeneration units are Power Plus with a 4.7 kWe Ecopower module which is able to modulate the capacity of 5 kWe and 15 kWe, and Vector-based CoGen (US), which uses a Kawasaki engine for combustion. According to the product specification, the Vector CoGen unit reached an electrical efficiency of about 28 to 34 percent and an overall energy efficiency between 70 and 79%.

In Japan, YANMAR, Sanyo and AISIN companies have also developed technology with piston engines to produce micro cogeneration units.

There is an interesting development of a Honda small 1 kWe system for family houses called Ecowill (Figure 3). This Honda’s cogeneration unit uses the GE160V, the world's smallest engine on natural gas. The system is based on one Otto engine and a system for the control and reduction of NOx emission concentration (Pehnt et al, 2006).

Figure 3 – Honda Ecowill
Рис. 3 – Honda Ecowill
Слика 3 – Honda Ecowill

One of the technologies suitable for cogeneration is the application of gas turbines or micro-turbines. One of the advantages of using turbines in relation to modern engines with internal combustion is extremely low emission of harmful gases. They can use both liquid and gaseous fuel, i.e. fossil or renewable energy sources. Microturbine capacity ranges from 30 kW to 350 kW.

It is also possible to use biogas and waste gases (gases of refineries, industry) as fuel. However, the biogas chemical composition affects the operation of turbines - biogas must meet requirements i.e. percentage content of the composition of the gases that make up biogas must be adequate.

The Kawasaki company offers gas turbines from 0.61 MWe (Figure 4) which emit less than 3 ppm NOx.

Figure 4 – KAWASAKI Gas Turbine Europe
Рис. 4 – KAWASAKI Gas Turbine Europe
Слика 4 – KAWASAKI Gas Turbine Europe

Figure 5 – CAPSTONE Turbines
Рис. 5 – CAPSTONE Turbines
Слика 5 – CAPSTONE Turbines

The CAPSTONE Turbine (USA) is a microturbine with a capacity of 65 kW, which can use biogas as fuel and can reach 29% of electrical efficiency and 62% of total efficiency (Figure 5).

Stirling engines are still in the testing phase, but there are also some commercial ones that could soon be in serial production: e.g. the WhisperTech company (New Zealand) is developing Stirling engines called WhisperGen, with a capacity of up to 1.2 kWe and 8 kW of heat energy.

The Swiss company GmbH focuses on making Stirling engines of 1. 1kWe.

As for systems with a capacity exceeding 1 kWe, the German companies Solo (Figure 7), Mayer and the CLA and Sunmachine (Figure 6) are involved in the development of Stirling engines.

Figure 6 – Sunmachine
Рис. 6 – Sunmachine (Stirling двигатель)
Слика 6 – Sunmachine (Stirling мотор)

Figure 7 – Solo
Рис. 7 – Solo (Stirling двигатель)
Слика 7 – Solo (Stirling мотор)

The advantage of using these systems is that they can use biomass (Alanne et al, 2014, pp. 1-10), solar power, wind or fossil fuels as a source of energy. This flexibility and high engine efficiency mean that these systems can be used for a long term period. In addition, it is necessary to reduce the cost of these systems to make them commercially competitive with other cogeneration technologies. A typical

CHP units with a 7.5 kWe Stirling engine costs approximately €2600/kWe.

KWB, from Austria, has developed a Stirling engine using pellet as a heat source. Its capacity is 1 kWe.

Dutch Enatec (Figure 8) is developing a Stirling engine with a capacity of 1 kWe (4-35 kWt). The Enatec company is concentrated on the use of fossil fuels for Stirling units.

Microgen (Figure 9) from the UK has developed one of the first small CHP units for individual homes. The unit is small and quiet enough so that it can be mounted in the kitchen. It has a capacity of 1.1 and kWe 15-36 kWt. It is designed to use natural gas as fuel, and an oil version is in preparation. The overall efficiency is rated at 90%.

Figure 8 – ENATEC
Рис. 8 – ENATEC
Слика 8 – ENATEC

Figure 9 – The cross-section of the cogeneration plant, Microgen company
Рис. 9 – Поперечное сечение когенерационной установки компании „Microgen»
Слика 9 – Попречни пресек когенерационог постројења фирме Microgen

Steam turbines are not generally intended for use in small cogeneration plants, but are suitable for remote heating systems.

The Czech company TED produces a series of Micro-CHP plants that typically use natural gas as a fuel, but some have been modified to use biogas. There are eight models that use biogas (< 1MWe), from a range of models from 23 kWe (42 kWt) to 300 kWe (370 kWt). These units have efficiency between 76 and 85% (Figures 10 and 11).

The units are designed to work with the content of methane between 55-65%, but the absolute minimum is 50%. The pressure in the combustion chamber is in the range from 1.5 to 10 kPa. 22 kW is scheduled for operation of 4,000 hours per year.

Figure 10 – Modlany, CZ, TEDOM Cento 150 SP BIO 150 kWe, 192 kWt
Рис. 10 – Modlany, CZ, TEDOM Cento 150 SP BIO 150 kWe, 192 kWt
Слика 10 – Modlany, CZ, TEDOM Cento 150 SP BIO 150 kWe, 192 kWt

Figure 11 – Petruvky, CZ, TEDOM Cento T 300 SP 300 kWe, 370 kWt
Рис. 11 – Petruvky, CZ, TEDOM Cento T 300 SP 300 kWe, 370 kWt
Слика 11 – Petruvky, CZ, TEDOM Cento T 300 SP 300 kWe, 370 kWt

BODERUS, from Belgium, produces Micro-CHP units (Figure 12) that use biogas and natural gas. Commercially available units are in a range of capacities from 10 to 383 kWe. For units using biogas, the minimum criteria for chemical composition of bio gas are set, primarily for a methane content of 80%. These units achieve 94% efficiency and are designed to operate for 8,000 hours per year (Cummins Inc, 2014).

Figure 12 – BODERUS
Рис. 12 – BODERUS
Слика 12 – BODERUS

The Italian ENERGIA NOVA company (Figure 13) produces small gas engines for CHP units of 20 kWe, 47 kWt, based on the FIAT 1200 cc engine. The overall efficiency is 97% (29% - electric power, 68% - heat power). Maintenance is recommended after every 1,500 operating hours. NOx emission is very low. An ENERGIA NOVA report says that users can save up to 40% of fuel per year using this CHP system.

Figure 13 – ENERGIA NOVA
Рис. 13 – ENERGIA NOVA
Слика 13 – ENERGIA NOVA

Figure 14 - COGENCO (300kWe)
Рис. 14 – COGENCO (300kWe)
Слика 14 – COGENCO (300kWe)

COGENCO (Figure 14), headquartered in the UK, produces and sells CHP biogas units. Cogeneration units are from 116 to 1750 kWe and from 186 to 1,737 kWt.

TOPEC BV (Figures 15, 16), from the Netherlands, produces small-CHP biogas units from 100 to 1000 kWe. A TOPEC report states that fuel saving is about 30%, and the overall efficiency is 90% (Cummins Inc, 2014).

Figure 15 – TOPEC BV (190 kWe)
Рис. 15 – TOPEC BV (190 kWe)
Слика 15 – TOPEC BV (190 kWe)

Figure 16 – TOPEC BV (340 kWe)
Рис. 16 – TOPEC BV (340 kWe)
Слика 16 – TOPEC BV (340 kWe)

Techno-economic analysis of the application of CHP technologies

Investment costs for maintenance and costs of CHP technology and condensation boilers can be found in Table 1 (http://www.erec.org).

Table 1 – Investment and maintenance costs of CHP plants
Таблица 1 – Стоимость инвестиций и содержания ТЭС
Табела 1 – Цене инвестиција и одржавања CHP постројења

	Installation price (€)	The cost of maintenance (€/y)
Senertec	13750	100
Ecopower	11750	100
Solo	25000	75
Whispertech	9000	75
Idatech	140000	35
Condensing boiler	2000	35

A feasibility analysis is done for a QSK60 plant as an illustration, based on the existing prices of energy products (Zukić et al, 2005, pp. 259-262).

Table 2 – QSK60 Specification
Таблица 2 – Спецификация QCK60
Табела 2 – Спецификација QCK60

Gas-generator set QSK60		1.16 MWe
Annual exploitation		8000 sati
The total investment	500 €/kWe	580.000 €
Operating and maintenance costs		7 €/MWhe
Electrical efficiency	33 – 40%	38%
Thermal efficiency	40 – 50%	47%
Gas prices		16 €/MWh
Heat versus gas costs		1.1
Price of electricity	2,5 / 3,5	36 €/MWhe
The government initiative	10 / 25 €/MWhe	0 €/MWhe

Table 2 provides the input data and the plant costs (Zukić et al, 2005, pp. 259-262).

Table 3, on the one hand, shows the total cost of the exploitation by MWh of electricity produced, and, on the other hand, shows the costs of a classic, separate production. After about 5.5 years, the return on investment is completely achieved. Note that this is a facility meant to operate over 100, 000 hours (Said et al, 2005, pp. 259-262).

Table 3 – Example of assessing the cost-effectiveness
Таблица 3 – Пример прогноза экономической эффективности
Табела 3 – Пример процене исплативости

Gas	39.5 €/MWhe	Heat	21.8 €/MWhe
Service	7 €/MWhe	Electric energy	36 €/MWhe
Back-up	0 €/MWhe	Initiative	0 €/MWhe
	46.5 €/MWhe		57.8 €/MWhe
Bonus	11.3 €/MWh		104.864 €/year
The cost-effectiveness coefficient	18.08%		
Period of cost-effectiveness	5.53 years		

Therefore, in addition to energy efficiency and environmental acceptability, small CHP plants are economically viable in the current circumstances. The government initiative can help to reduce the time and cost effectiveness to two or three years, because, in circumstances where care is taken of strategy of use of natural resources, clean and efficient technologies, this system is additionally subsidized for every MWh produced.

Conclusion

Micro cogeneration is a technology of the future. It will definitely find its wider application in Serbia if the Republic of Serbia decides to keep up with global energy trends. Creating favorable conditions for the realization of wider application would mean arranging legislative framework, desirable new forms of financing, and the price of electricity purchase should be included as well as environmental components.

CHP plants in Serbia could make three times more energy for heating, so the existing number of approximately 450,000 central heating customers could rise to more than one million. This would save 52% of primary energy and pollutant emissions would be reduced by 72% compared to the production of electricity from power plants and boiler heat.

Stirling engines as part of CHP plants have the best possibility of primary energy saving and CO2 emission reduction.

Solid biomass remains the main potential for a wide application for cogeneration systems at small and micro levels. The development of biogas supply systems should be developed to meet different requirements in terms of the chemical composition of biogas and its impurities. Gas originating from biomass and used in gas engines or gas turbines is another area of interest to small and medium-sized cogeneration plants. The Stirling engine combined with a pellet burner offers a solution that should be soon available.

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ПРИМЕНЕНИЕ МАЛЫХ И МИКРО-КОГЕНЕРАЦИОННЫХ УСТАНОВОК

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Резюме:

До 1973 года низкие цены топлива позволяли производство относительно недорогой электроэнергии. Однако резкий рост цен на топливо привел к разработке новых энергетических технологий и к повышению эффективности установок. Одновременно, повышение экологической осведомленности, в том числе и осознание проблемы исчерпаемости природных энергоресурсов, требовали повышенного внимания к охране окружающей среды и оставшихся ресурсов, таким образом малые и микро-ТЭЦ стали конкурентоспособными и более востребованными в области энергопромышленности. США и Канада на сегодняшний день в этом плане отстают от европейского и японского развития микрогенерации, частично из-за различий в системе отопления, стоимости электроэнергии и в связи с политическими рамками. Подписанием Киотского протокола, Япония обязалась сократить воздействие на глобальное потепление, то есть, выбросы на 6% от общего уровня выбросов за 1990 год. Однако уровень выбросов CO2 все еще продолжает расти, а это значит, что в настоящее время Япония для достижения своей цели должна сократить выбросы на 14%. В данной связи Япония пропагандирует все возможные способы эффективного снижения выбросов CO2. Япония будет активно продолжать поддерживать маркетинг микрогенерации, особенно модели, подходящие для отопления жилых зданий. Прогнозируется, что в ближайшие несколько лет в Европе производство электроэнергии с помощью когенерации достигнет 75% от общего объема производства в целом. Так, например, в Италии производство возобновляемой энергии составляет 30% от общего объема потребления; в Нидерландах – 33%; а Дания и Великобритания почти полностью перешли на данный вид энергопроизводства.

Ключевые слова: микро-когенерация, малые ТЭЦ.

ПРИМЕНА МАЛИХ И МИКРОКОГЕНЕРАЦИОНИХ ПОСТРОЈЕЊА

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ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: стручни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

До 1973. године ниске цене горива омогућавале су производњу релативно јефтине електричне енергије. Нагли пораст цена горива изазвао је потребу за развијањем енергетских технологија и повећањем ефикасности постројења. Истовремено, повећана еколошка свест, као и сазнање о све сиромашнијим изворима енергије, захтевало је посвећење веће пажње очувању околине и преосталих ресурса, па су мала и микрокогенерациона постројења постала ефикасни и конкурентни произвођачи енергије. Сједињене Државе и Канада тренутно су у заостатку у односу на развој европских и јапанских микрокогенерација, делимично због разлика у системима грејања, цене енергије и политичких оквира. Кјото протоколом Јапан је у обавези да смањи своје глобално загревање, односно емисију гасова за 6% од нивоа из 1990.године. Ипак, емисија CO_2 и даље расте. Процењује се да Јапан мора да смањи емисију за 14% како би испунио циљ, као и да промовише све могуће начине да ефикасно смањи емисију CO_2. С тим у вези, Јапан ће наставити да даје подршку маркетингу микрокогенерације, посебно оних модела који су погодни за стамбене објекте. Процењује се да у неколико наредних година производња енергије когенерацијом достигне 75% укупне производње на нивоу целе Европе. Еколошка енергија у Италији чини 30% укупне потрошње, у Холандији 33%, а у Данској и Великој Британији готово је потпуно заступљена.

Кључне речи: микрокогенерација, мала когенерација.

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