

UNIVERSITY OF ŽILINA



TRANSCOM 2013

**10th EUROPEAN CONFERENCE
OF YOUNG RESEARCHERS AND SCIENTISTS**

PROCEEDINGS

SECTION 6

**MACHINES AND EQUIPMENT
APPLIED MECHANICS.**

**ŽILINA June 24 - 26, 2013
SLOVAK REPUBLIC**

TRANSCOM 2013

10th European conference of young researchers and scientists

TRANSCOM 2013, the 10th international conference of young European researchers, scientists and educators, aims to establish and expand international contacts and co-operation. The 10th international conference TRANSCOM is jubilee. It will be held in the year when the University of Žilina celebrates 60 years since her constitution (1953 – 2013). The main purpose of the conference is to provide young researchers and scientists with an encouraging and stimulating environment in which they present results of their research to the scientific community. TRANSCOM has been organised regularly every other year since 1995. Between 160 and 400 young researchers and scientists participate regularly in the event. The conference is organised for postgraduate students and young researchers and scientists up to the age of 35 and their tutors. Young workers are expected to present the results they had achieved.

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Application of fuel cell in micro-cogeneration units

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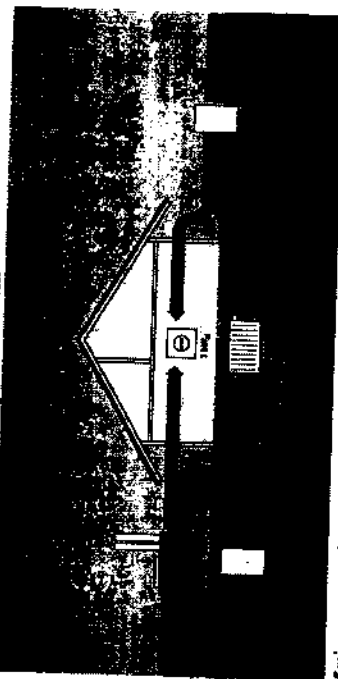
The aim of the article is micro-cogeneration for family houses. It is aimed at perspective and fast kind of micro-cogeneration with small performance. High sophisticated technology for combined heat and electric power is application of fuel cell which uses natural gas as a fuel. Combined heat and electric power is one of the best way how utilize energy which is contained in fuel. The article is verification of availability of micro-cogeneration units with fuel cell applying in houses. The verification was evaluated through total fuel price and difference between total fuel price produced electric power.

micro-cogeneration, fuel cell, natural gas

Introduction

Micro-cogeneration means combined production of heat and electric power (CHP - combined heat and power), eventually heat and mechanical power, or heat power and combination of electric and mechanical power. Combined production of heat and electric power is one of the best way how utilize energy which is contained in fuel. The principle of cogeneration is heat utilization that would be best utilization during electric power production. This heat would be heat loss, but it is used for heating or for heating of domestic hot water. Thankfulness of this technology we can utilize energy which is contained in fuel. The article is verification of availability of micro-cogeneration units with performance up to 50 kW_e.

Today, all devices on the market offered for family houses technologies which provide production of heat (condensing boiler, heat pump, solar collector,...) or electric power (photovoltaic panel, small hydroelectric power plant, wind-power plant,...). On the market offers micro-cogeneration units (micro-CHP) with small performance, which are used in single family houses. These units work on the principles of combustion engine, gas engine, steam engine or on the principle of fuel cell.



Principle of micro-cogeneration

The usage philosophy of these units is in production of thermal energy for domestic hot water and electric power getting is as a bonus. Produced electric power is home consumption, not for sale to distribution grid. Sale to electric distribution grid in amount of licensees, administration and dues which are not suitable. The performance of units and the resulting low expectation of electric power selling. The price of electric power for losses is approximately double lower than price of electricity bought from distributor in the case of higher consumption.

The principle of micro-cogeneration for family houses is shown in the figure 1. The harmonization of heat and electric power requirement. The problem is partly minimized by the heat accumulating tank. Micro-CHP unit can partly work in case when we need without thermal power at the same time. Next problematic season is summer when we only for domestic hot water preparation but electric power requirement is practically during all year. This season reduces quantity of working time of micro-cogeneration thereby extends pay-back period. The ideal working condition is continuous running. Insufficiency of some technologies especially fuel cells is low thermal production, it is source of heat requirement. This source of heat covers peak heat demand.

2. The fuel cell

The fuel cell is electro-chemical device which transforms chemical energy of fuel into electric power. It utilizes oxidation-reduced reaction. The principle of operation is based on electrolysis. Oxygen O_2 is supplying to cathode, cathode reduces oxygen into oxygen ions. After that, oxygen anion proceeds to anode where reacts with hydrogen and releases two electrons at the same time. Anode and cathode are connected by electric conductor, two free electrons by this process, water is created at the end and by-product is thermal power.

Types of fuel cells are different of material of electrodes, used electrolyte, working temperature and chemical reactions on the electrodes. The fuel cells are divided into six groups and these groups are divided into three main categories by working temperature.

- AFC - Alkaline Fuel Cell
 - PEMFC - Polymer Electrolyte Membrane Fuel Cell
 - DMFC - Direct Methanol Fuel Cell
- Fuel cell with middle temperature (160-200°C)
- PAFC - Phosphoric Acid Fuel Cell
- Fuel cell with high working temperature (600-1000°C)
- MCFC - Molten Carbonate Fuel Cell
 - SOFC - Solid Oxide Fuel Cell

Fuels for fuel cells are generally pure hydrogen or natural gas. Natural gas using is best in fuel cell in home; however natural gas have to be without sulfur. For natural gas using in fuel cell it is necessary applying process called reforming. Natural gas reforming is process how to produce hydrogen from natural gas molecule CH_4 . This process can be steam external reforming or internal reforming. The base of steam reforming is reaction of methane with water. The reaction is endothermic and heat balance is compensated with combustion of a part of methane. Internal reforming can be divided to direct and indirect process. During indirect internal reforming, methane comes to catalytic converter which is in direct contact with fuel cells bundle. During direct internal reforming, reforming reaction is into fuel cell anode.

CHP units with fuel cells

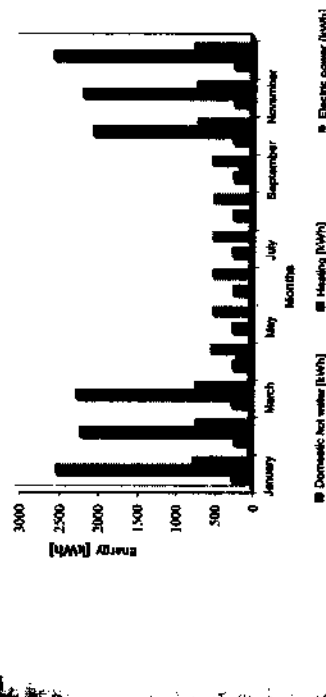
Table specifies main technical parameters of chosen micro-CHP units with fuel cells, which are or will be on the market in the near future. Operating costs were compared with boiler. Main operating cost was fuel price.

	BlueGen	ClearEdge ⁵	GenSys E-60	Panasonic Enefarm	Tropical RLN-1000	Condensing boiler
Nominal [kW]	1.5	5.0	4.6	0.75	1.2	
Range [kW]	0.5 - 1.5	0.5 - 5.0	0.3 - 4.6	0.2 - 0.75	0.25 - 1.2	
Efficiency [%]	60	60	33	39	30	
Maximal [kW]	0.54	6.0	9.0	0.6	2.2	14.5
Efficiency [%]	25	25	55	56	50	98
Price [€]	85	85	88	95	80	98

Technical parameters of micro-CHP units

for calculation

For calculation we choose single family house which is situated in village near Žilina. Heat loss of house is 7,8 kW, its total annual consumption of heat for heating and domestic hot water production is 63,05 GJ/yr. All electric power production is consumed in house; it is not sold into grid. The price of electric power was set by SSE, a.s. price list for tariff D2, without subsidy for cogeneration. The price of consumed natural gas was set by SPP, a.s. price list for tariff D2. Consumption curve of heat and electric power have been made for chosen house. Data for consumption curve were obtained by reading of gauges in periodic interval. Consumption curve is shown in the figure 2. Electric power consumption is practically constant during the year, low consumption is in summer-time what is caused by shorter time of lighting. Heat for domestic hot water production is constant during the year too. The biggest variations are in heat demand value. It is caused by house does not have swimming pool or alternative way how consume heat power during heating period. House uses thermal energy for heating only during heating period. This fact decreases number of operating hours, lengthen pay-back period and electric power has to be buy in this



Consumption curve of power

results

Table 2 contains results of operating costs calculating for chosen micro-CHP units with fuel cells. We assumed that micro-CHP units with lower performance don't cover requirement of heat. Remaining heat power is covered by condensing boiler. Main operating cost was price of

fuel, we didn't make provision for maintenance and service costs. The profit was from consumed electric power which we made and consumed in the house and we didn't have to buy from electric power distributor.

	BlueGen	ClearEdge5	GenSys E-60	Panasonic EneFarm	Tropical RLN-1000	Condensing boiler
Covering of heat demand [%]	7	77	100	7,7	28,21	100
Covering of total annual heat consumption [GJ/yr]	4,37	48,5	63,05	4,85	17,78	63,05
Amount of operation hours [hr/yr]	2245,5	2245,5	1946,02	2245,5	2245,5	1207,9
Produced electric power [kWh/yr]	3368,1	11117,03	8951,7	1684,05	2694,5	-
Annual fuel consumption - FC [m ³ /yr]	509,8	5664,3	3347,1	252,87	1038,5	-
Annual fuel consumption - FC [kWh/yr]	5206,2	57846,34	34182,0	2582,5	10605,2	-
Fuel price - FC [€]	251,10	2788,20	1647,60	124,50	511,20	-
Lump sum expenses [€]	59,76	59,76	59,76	59,76	59,76	-
Total price of fuel - FC [€]	310,86	2847,96	1707,20	184,46	570,96	-
Price of produced electric power [€]	216,50	721,67	575,41	108,25	173,20	-
Heat from alternative heat source [GJ/yr]	58,69	14,55	0,00	58,20	45,27	63,05
Annual fuel consumption - AHS [m ³ /yr]	1748,5	433,5	0,00	1734,0	1348,7	1878,5
Annual fuel consumption - AHS [kWh/yr]	17855,7	4427,1	0,00	17,708,1	13773	19183,8
Fuel price - AHS [€]	860,64	213,38	0,00	853,53	663,86	924,66
Total fuel price - FC+AHS [€]	1171,34	3061,34	1707,33	1037,76	1234,78	984,42
Difference between total fuel price and price of produced electric power [€/yr]	954,84	2339,66	1131,91	929,51	1061,58	984,42

Tab.2 Results of calculation (FC - fuel cell, AHS - alternative heat source)

6. Conclusion

The results of calculation show that difference between total fuel price and profit from produced electric power is not important. The profit is too low in compare with traditional ways of heating, fuel consumption is higher. The cost of acquisition is incomparably higher than condensing boiler. Even though technology of micro-CHP units with fuel cells is perspective and in the future they expand and their prices drop down.

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