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Investigation of a Trigeneration System Using Natural Gas for Tunceli University

[1]Hasan Kaan Berent and *[2]Erdem Işık
[1,2] Tunceli University, Faculty of Engineeering, Department of Mechanical Engineering, 62000 Tunceli, Turkey
erdem@tunceli.edu.tr

Abstract

Turkey is dependent to imported energy around a ratio of 75%. For this reason, the proper and efficient use of renewable and also especially non-renewable resources are extremely important. Many methods have been developed by current technology in order to be able to use the energy resources more efficiently. Some of these methods are cogeneration and trigeneration systems. Trigeneration system is the systems assemblage which is set up by adding a refrigeration system to a cogeneration system. In this system, there is only one energy input and three energy outputs electricity production, heating and refrigeration. It is significantly important to increase the number of those systems in order to reduce the energy costs for Turkey. Therefore, the installation of a trigeneration system at Tunceli University, the calculation of its cost and its payback time were determined in this study.

Keywords: Trigeneration, Energy efficiency, Cogeneration

1. Introduction

Energy is essential for Turkey as it is also in every country of our world. Everything in the universe we live in is somehow related to energy. Energy is in the basis of all futuristic 50 year plans of every developing country. Since Turkey is also among the developing countries, it is impossible for Turkey to ignore this fact. Because of this reason, energy is irreplaceable in daily life and it is the fundamental of industrialization. The energy and its conversions which are vital for providing the needs of individuals and for continuous development are used correspondingly in the specific areas of industry, residence and transportation. Being energy an necessary source for the mankind have resulted in drawbacks as well as advantages. As an example to the drawbacks, the waste heat gases occurring after the use of energy sources and which are mixed to the air may be given. Besides, the vast use of non-renewable energy resources in the world has increased the environment problems significantly. Due to this reason, it is aimed to reduce or eliminate those drawbacks by the latest studies. This situation can lead the academia to develop new methods to reuse the energy conversion equipment and to make more use of the existing and limited energy resources.

Evaluating the trigeneration system and analyzing it properly is important for energy efficiency. Some of the studies carried out around the world about the analysis of trigeneration systems are as below:

A trigeneration system design was carried out for Nevşehir Kapadokya Airport and the system feasibility was investigated. As a result, it was determined that the fuel consumption was reduced and the energy efficiency was obtained due to the large reduction of losses [1]. The ability of use of a micro-trigeneration system for Toronto and region protection facility sample houses in Northern America was investigated. In this study, it was emphasized that the

*Corresponding author: Address: Faculty of Engineering, Department of Mechanical Engineering Tunceli University, 62000, Tunceli, TURKEY. **E-mail address: erdem@tunceli.edu.tr, Phone: +904282131794**

trigeneration system using natural gas as fuel was highly efficient in cold climates after its thermo-economical analyses [2]. In another study, the data of trigeneration experiments were compared to another conventional system performance -which has another energy production needs- and thermo-economical feasibility study was carried out. The comparison was carried out by Italian prediction scenarios in order to compare primary energy production, operating costs and CO_2 equivalents [3]. The 2012-2013 energy status of Süleyman Demirel University was summarized and a natural gas trigeneration system which can satisfy the need for electricity, heating and refrigeration in university campuses was evaluated. It was emphasized that the first condition to be a self-sufficient and continuous university is to produce its own energy and to turn towards to renewable energy resources [4]. The thermo-economical analyze of a trigeneration system working with a vapor turbine was presented in another study. The aim was to perform an exergy analysis and formulize them through a calculation system. In that trigeneration system, biomass (waste wood) was used as fuel. Four different plant setup was presented and evaluated in the study [5]. In a study performed in Spain, the thermo-economical analysis of a trigeneration system which is involved in an interaction with economical environment. The aim was to determine the total cost of the energy of the internal flow in the whole system. The cost analysis of the whole cogeneration side-products are carried out with respect to avoiding unnecessary expenses principle. In order to encourage the system, it was applied to a hospital with 500 Bed capacities in Zaragoza [6]. A simulation program has been developed to calculate the annual analysis of the trigeneration system. This program was used to determine the energy demand of system regarding the system characteristics created by each of individual parts of system, system assumptions and parameters and also to evaluate the system performance [7].

At the present time, the continuity of institutions is the most specific indicator of development. In order to provide continuity, energy is an indispensable tool. For this reason, a trigeneration system which uses natural gas as fuel and which goes beyond the conventional systems and can satisfies the electricity, heating and refrigeration needs of existing plants by increasing the efficiency by taking advantages of conventional systems was studied.

2. Thermodynamic Methodology

2.1. Cogeneration

Cogeneration is, in short, described as the production of both electricity and heat together from one energy source or those heat pumps are taking advantage of the waste heat which they have to give to environment. This togetherness gives more economical results than those two energy outputs are produced in separated locations. A gas turbine or engine which is working in simple cycle which means that it is producing only electricity can convert only 30-40% of its input energy to electricity. However, in case of this system is used with a cogeneration system, the total energy input can be converted to beneficial energy output up to 70-90% by using the waste heat which is meant to send to environment. This technique is called "Combined Heat-Power Systems" (CHP) or just "cogeneration" in short [8]. Cogeneration system has numerous advantages. These are:

- Since the energy is produced in a cheaper way, it can provide to industry or even to residents cheaper electricity and heat energy.
- Because of building in smaller scales, it can be operated by relatively smaller and local companies.

- Air pollution and global climate defects can be reduced by reducing the CO_2 emissions.
- Due to the result that the energy production is in the same location with its consumed location, the losses occurring in the transmission and distribution lines are disappeared, the efficiency is increased, uninterrupted and qualitative electricity is provided without affected by grid. In addition to that, the investment and maintenance costs of central production, transmission and distribution systems are reduced significantly [9].

The main usage area of cogeneration systems in Turkey in the name of industrial use regarding the year 2013 is shown in the schematic below.

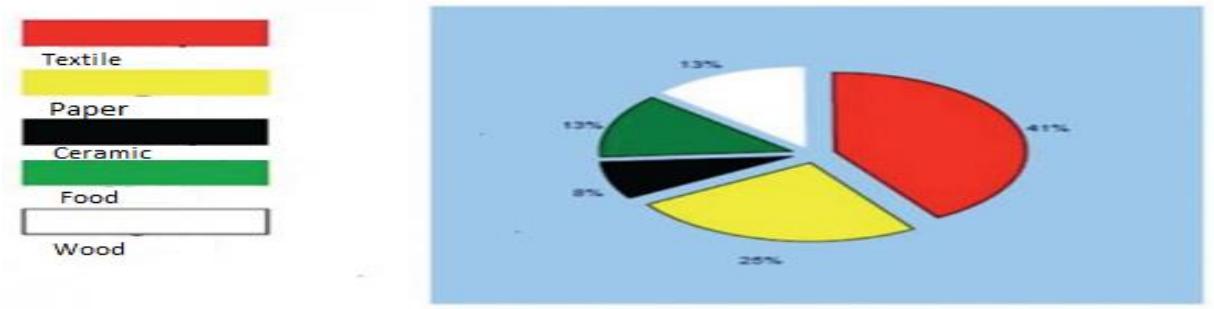

Figure 1. The distribution of cogeneration systems with respect to sector in the name of industry in Turkey [10].

2.2. Trigeneration

Trigeneration is a system method which produces power (electricity), heating and refrigeration energies simultaneously by using only one energy input. Institutions are meeting their whole electricity requirements as well as they get their hot water, water vapor and refrigeration systems in a more convenient way thanks to this sort of a power plant. This technique is called "Combined Cooling Heat-Power Systems" (CCHP) or just "trigeneration" in short.

Trigeneration system is actually obtained by adding a refrigeration system to a cogeneration system which is a sub-model of trigeneration systems. Absorption refrigeration system is used for the refrigeration action. The supplier companies describe the trigeneration system as meeting the refrigeration needs by using the produced heat in the absorption refrigeration system and obtaining cold water and cold air [11]. Trigeneration system is schematically shown below:

Figure 2. Schematic diagram of trigeneration system

3. Energy Status of Tunceli University

The electricity and fuel (fuel-oil-4) costs was determined in the basically done energy analysis of Tunceli University. The theoretical and experimental calculation of fuel-oil-4, which was used as fuel, was shown below. There is one boiler with a capacity of 750 kg/h mass flow rate located in Tunceli University heating center.

3.1. Fuel Status

3.1.1. Theoretical Calculation

Q_{boiler}= 750 kg/h

Daily Approximate combustion time ≈ 10 h/day

Daily Approximate consumption ≈ 0.75 ton/day×10h/day ≈ 7.50 ton/day

Monthly Approximate consumption ≈ 7.50 ton/day×30day/month ≈ 225 ton/month

Approximate consumption of 6 months ≈ 225 ton/month×6months ≈ 1350 ton

In the boiler combustion season of 2015-2016 (November 15th 2016-May 15th 2016), it is predicted that 1350 tons of fuel-oil would be consumed. At the same time, 250 tons of extra fuel-oil is in stock regarding the weather conditions.

3.1.2. Experimental Calculation

The consumed fuel-oil in the heating center is approximately 125 tons of fuel-oil between the dates 19.11.2015-05.12.2015 (17 Days).

Daily Approximate consumption ≈ 125 ton / 17 day ≈ 7.352 ton/day

Monthly Approximate consumption ≈ 7.352 ton/day × 30 day/month ≈ 220.56 ton/month

Approximate consumption of 6 months ≈ 220.56 ton/month × 6 month ≈ 1323.36 ton

3.2. Electric Status

In the university that takes its energy from the grid, it is 22 kW power-grid that it takes its energy. The annual working time of the university was determined as 8766 hours. The total annual electric consumption data taken from the Tunceli University Energy Central is 95069.21 €/Year. The cost of electricity taken from the grid is 0.1324 €/kWh in the season of 2015-2016.

3.3. Trigeneration System of Tunceli University

The ambient conditions for Trigeneration System were given in the Table-1 below.

Table 1. The ambient conditions for Trigeneration System

Weighted average mean temperature	12.8 °C
Altitude	914m
Mean relative humidity ratio	58 %
The natural gas pressure in the region	3.9 bar
Unit price of natural gas (Fons included)	0.3556 €

İts planned to use a gas engine which uses natural gas as fuel. The reason is that natural gas is a more environment-friendly fuel in compare to other fuels considering the greenhouse effect. The performance value taken from the catalogue of producer firm is shown below in the Table 2.

Table 2. Performance values of the system (Jenbacher, 2005) [12]

Electricity Production	1063	kW
Ambient Temperature	30	˚C
Natural Gas Consumption	275	Nm^3/h
Producible Cold Water	880	kW/h
Produced Hot Water	1205	kW/h

Operation expenses and economic returns of Trigeneration System were given in the Table 3-4 below.

Table 3. Operating Expenses of Trigeneration System

Total Cost of Heating	1012664.41 €
Cost of Electricity Supplied from the Grid	95069.21 €
Total Cost	1107733.62 €

Table 4. Economic Returns of Trigeneration System

Returns from Produced Electricty	1327673.72 €
Returns From Produced Cooling	146488.45 €
Total Returns	1474162.17 €

4. Conclusion

The total annual earnings after the installation of the system were determined as 366428.55 € by subtracting total costs from total earning. The investment cost for the system is found as 780000 € which is 2555982 TL. According to this result, the system can amortize itself in 2.13 years (which is approximately 25.5 months) in the case of comparing the investment costs of trigeneration system and the total annual earnings.

Because of the reasons such as the growing costs of energy, the simultaneous need for electricity and heating, the significant increase in greenhouse effect due to the use of conventional systems from past to present, it is very important that the university produces its own energy, In the context, this kind of a system which can amortize itself in a short time period like 25.5 months, and having a long life cycle, will provide great contributes to the universities sustainability.

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