Individual components for combined heat and power distillation to produce electricity

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Abstract. This paper work is illustration of energy management and consumption, different types of steam turbine cogeneration system. Moreover, this research schematically illustrates the work principle of combined heat and power distillation process, which gives the best environmental effect for the reduction of carbon dioxide (CO2) gases that effects in water prices and yields pure water from the extraction process.

Combined Heat and Power (CHP - known as cogeneration) is the sequent generation of multiple forms of useful energy (thermal and mechanical) in integral system. In other words, it is a concurrent production of the electricity and useful heat in a process, which is more energy efficient than the separate generation of electricity. Moreover, that energy (heat) is a by-product of the electricity generation process. Via a boiler and power station the CHP can decrease the carbon emissions up to 30-40% related to the separate means of conventional generation. [1, 2].

Combined heat and power system consists number of different components:

A prime mover – is the main part of the cogeneration system and its can be stated as a mechanical generator that produces the electricity or mechanical power through combustion of fuels. The prime mover can be in 5 types of engines:

Steam turbine cogeneration system produces the steam energy from waste or boiler heat into shaft power, therefore, this process has the highest fuel utilization efficiency than others. The boiler can be flamed with different types of fuel such as: coal, oil or wood. Hence, with fuel consumption this turbine can produce the mechanical energy, which carried further into an electric generator and steam engine processes a high-pressure steam that can be extended through the turbine. There are two different types of steam turbines: extraction (condensing, figure 1) and the backpressure (figure 2).

Extraction steam turbine (figure 1) is the steam system that is loaded thermally and obtained by extraction from one or more stage at the appropriate pressure and temperature. The system proceeds at very low pressure approximately 0.05 bar with a condensing temperature of around 330°C [9]. It is very important to have a low temperature heat to find the right application, so it is environmentally not accepted, as it needs lots of energy to heat the system up to that temperature.
Figure 1. Extraction Condensing Stream Turbine [3].

Back-pressure steam turbine (figure 2) is the easiest configuration that exist the turbine at a higher pressure or equal to the atmospheric pressure. Due to this reason, the term of back-pressure is more used than steam turbine condenser. Moreover, the back-pressure turbine has the possibility to extract steam from intermediate stages of the steam turbines at appropriate temperature and pressure to the thermal load. Further, the steam is entering to the load and releases the heat as well.

Figure 2. Back-pressure system [3].

Additionally, if to compare, the extraction steam turbine to the back-pressure system, then it has lower total efficiency and higher capital cost, however it can control the electrical power non-dependently to the thermal load by suitable regulation of the steam flow rate.

Steam turbine cogeneration system (also known as Brayton cycle, figure 3) is made from a single or multiple turbines and waste heat recovery unit, so it uses the heat to move turbine twisty to produce electricity. The engine is fuelled by light petroleum product, so the hot products of combustion energy turbines to generate the mechanical heat that can be used to electricity with a generator. The typical range of gas turbine varies 1 megawatt (MW) to 100 MW. In recent years, gas turbine cogeneration is possibly the most rapid progress in the technology, cause of the larger availability of natural gas,
significant instillation price reduction and better environmental performance. Gas turbines provide the flexibility and short start-up time of discontinuous operations. However, more heat can be regenerated at greater temperature even though they have low energy to conversion efficiency. For gas turbine cogeneration it is possible to have supplementary natural gas burning to increase the thermal output more proficiently [4].

![Thermodynamic cycle – Brayton cycle.](image)

**Figure 3.** Thermodynamic cycle – Brayton cycle.

The Brayton cycle efficiency can be determined by:

$$\eta = 1 - \frac{1 Pu}{Pr}^{\frac{1-k}{k}}$$

Where is defined as:

$$r_P = \frac{P_2}{P_1} = \frac{P_3}{P_4}$$

In gas turbine CHP possible to have either closed (figure 4) or opened figure 6 cycle turbines and the differences between them are:

In a closed cycle system, the operating fluid (mostly He or O2) flows from the generator in a closed circuit. Before entering to the turbine the fluid is heated up to 100°C in a heat exchanger and after leaving the turbine the fluid is cooled down within releasing the advantageous heat (figure 4). Therefore, the operating fluid stays clean and it does not cause the corrosion on the equipment.

![Close cycle gas turbine combined heat and power (CHP).](image)

**Figure 4.** Close cycle gas turbine combined heat and power (CHP) [3].

Open cycle gas turbine combined heat and power (figure 5) and it is the most available gas turbine system for nowadays, where the compressor sucks in air from the atmosphere and delivers its in higher pressure to the combustor. The temperature of air is also increased cause of compressor. Further, an air is derived across a diffuser to a constant pressure combustion chamber, where fuel is injected and burned. This process reduces the air velocity in the combustor, where the pressure decreases.
The gas leaves the combustor at high temperature and within the concentration of oxygen up to 16%. At this point the highest point of temperature in open cycle gas turbine is appears where the higher temperature is, the higher efficiency of the cycle is. Nowadays, the maximum temperature that can handle this type of turbine is around 1700°C [5].

The gas combustor produces better mechanical work with higher pressure entrance of gases to the turbine. The gas leaves the turbine at 500°C - 600°C, so this helps to make high temperature heat recovery. The produced steam can have higher temperature and pressure that can make the steam more suitable not just for thermal processes, but also additionally, for driving steam turbine as well, therefore, more power is producing [3].

Reciprocating internal combustion (IC) engines works on wide range of gaseous and liquid fuels but not in solid fuels. The IC engine shaft power can produce electricity through drive loads directly to the generator. The conversion efficiency from heat to electricity of IC engine is the highest, however the fuel utilization is the lowest. The overall plant capacity can be increased with multiple reciprocating engine units. Besides, in size comparison the reciprocating internal combustion has higher electrical efficiency than gas turbine, which means it also has the fuel – related operating cost lower as well.

Fuel cells engine – from chemical reaction between hydrogen (H) and oxygen (O2) produces the heat and an electric current, so it does not produce anything from combustion. The fuel cells require clean methanol with different restrictions on the impurities [7].

Stirling engines – can operate on any type of fuel and also produces either electricity through a generator or drive loads directly.

Only Steam turbine cogeneration system and reciprocating internal combustion (IC) engines are the cogeneration systems, consequently, these two cogeneration systems are classified as bottoming or topping cycle. Where in topping cycle produces the energy that supplied with fuel first, whereas in the bottoming cycle the fuel produces in within high temperature through recovery boiler and heat is rejected from the process that used to generate the power. So, for this reason the topping cycle is more advantageous in plants than bottoming cycle plants. [8]

The selection prime mover depends mostly on the time of operation, in other words, hours of operation, cause most of the CHP plants are designed for continuous flow processes. Besides, the choice is also must be dependent on maintenances, fuel required in a plant and for the capacity limits as well.

**Figure 5.** Open cycle gas turbine combined heat and power (CHP) [3].
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