CO-GENERATION

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Summary

Co-generation is defined as the combined generation of electric (or mechanical) and thermal energy from the same initial energy source. The conventional way of meeting power and heat loads of one or more consumer(s) is purchasing power from the national

network and burning fuel (in a boiler or furnace) to generate heat. However, the total fuel consumption is significantly reduced when “co-generation” or “combined heat and power” (CHP) is applied. Apart from the advantages of co-generation use that are given in this chapter, its disadvantages are also described while the wide application as well as the operational codes are analyzed in detail.

1. General Aspects

Thermal energy may be used for heating as well as for cooling or air conditioning purposes. Cooling or air-conditioning is achieved by heat absorption machinery operating on steam or hot water.

During the operation of a conventional thermal power station, large amounts of heat are rejected to the environment either through the cooling circuits (steam condensers, cooling towers, diesel engine radiators etc.) or through the exhaust gases (gas turbines, diesel engines, Otto engines etc.). The largest portion of this heat may be recovered and utilized. In particular, conventional power stations have an efficiency of 30-45% whereas co-generation systems have an efficiency of 80-85%.

Co-generation was initially introduced in Europe and the USA around 1890. During the first decades of the 20th century, most industries had their own power generation units with a steam furnace-turbine, operating on coal. Many of those units were co-generation units. It is worth mentioning that a good 58% of power generated by various industries in the USA was actually generated by co-generation units. Later, a period of decline followed. Industrial co-generation dropped to 15% of the total power generation potential until 1950 and, after that, continued its descending course to as low as 5% in 1974. This course has now been reversed not only in the USA but also in Europe, Japan etc., mainly due to the abrupt rise of fuel prices since 1973, and the energy policy motives provided at a National level.

The decrease in the need for co-generation plants may be attributed to two major reasons:

- The development of power transfer and distribution networks which provided inexpensive and reliable power, and
- The availability of liquid fuels and natural gas which rendered furnace operation feasible.

2. The Present and the Future of Co-generation

On June 4, 1993, ministers from all twenty three member states in the International Energy Committee of the Organization for Economic Cooperation and Development (OECD) met in Paris. In an attempt to create the conditions in which the energy sectors would be able to contribute as much as possible to a financial development and prosperity of the nations, protecting the environment at the same time, they put the following common objectives:

- diversity, efficiency and flexibility in the energy sector, these being the basic conditions for a long term energy safety

- capability for a timely and flexible response in case of emergency energy needs
- environmentally accepted (viable) disposal and usage of energy
- encouragement and development of more environmentally acceptable energy sources
- improvement of energy efficiency, contributing to environmental protection and energy safety in a more efficient manner
- continuous research, development and marketing of new and improved energy technologies
- energy prices enabling market to function in a more efficient manner
- free and open commerce and a safe framework for investments contributing to the energy efficiency and safety
- co-operation of all members of the energy market aiming to improve communication and understanding and to encourage the development of efficient, more environmentally acceptable and flexible energy systems and markets.

It is worth noting that the spread of co-generation in the countries of Organization for Economic Cooperation and Development is not only compatible but also contributes to the achievement of all the above objectives. Therefore, the majority of the countries have taken measures to encourage co-generation, even if such measures differ from one country to another regarding the efficiency.

The spread of co-generation in countries outside the Organization for Economic Cooperation and Development is also significant, especially in Central and Eastern Europe, but the prerequisites for energy and financial efficiency are not always ensured.

2.1 Contribution of Co-generation to the Power Generation and District Heating

The average portion of power generated at co-generation plants in all 12 countries of the European Union in 1985 was 8.13% with tendency for a small increase in the recent years. This percentage is rather low and allows significant room for development. It is worth reporting certain particularly interesting cases in detail, because they present either high percentages of co-generated energy forms or exhibit acute growth rates.

In Spain, the contribution of co-generation in power generation increased by 56% during 1987-1989 (from 2.0% to 3.12%). In the late 1994, when the ongoing works were completed, co-generated power reached 6.1%.

In UK, in 1993, 700 co-generation units with a total capacity of 3,000MW_e generated approx. 3-4% of the total public power (compared to 2% in 1990).

In Denmark, in 1985, a good 40% of the heating needs of the country were covered by district heating. A 50% portion of the heat consumed in district heating was generated at co-generation plants. During 1990-1991, these figures increased to 63% and 60% respectively, while 29% of the total public power was generated at co-generation plants.

In Germany during 1986-1987, 3.9% of the annually generated power was generated at co-generation plants leading to an annual saving of 2.5 billion liters of liquid fuel (IEA, 1988). In 1990, this figure increased to 9.5 %. During 1986-1990, the annual contribution of co-generation to district heating ranged between 67 and 75%. There are 500 district heating networks throughout the country, 80% of which belong to the power corporations.

In Finland, 30% of the total power and 45% of the total heat are generated at co-generation plants. A good 71% of the heat consumed in district heating was generated at co-generation plants. In Helsinki, 90% of the buildings are heated by a district heating network.

In Holland, co-generation contributes by 15% to the annual public power generation and by 90% in the heat consumed in district heating. In addition to other applications, the spread of co-generation in greenhouses is also significant. In the early 1990, the electric capacity of such systems reached 250MW. During 1990-1991, several systems with electric capacities of 200MW were installed.

In Greece, unlike the above mentioned countries, co-generated power is a mere 2.5-3.0% and has been maintained constant during the last years.

2.2 Co-generation Perspectives

Nowadays, co-generation is considered as one of the most important techniques for achieving a more efficient usage of fuels, natural and financial resources savings and environmental protection. Many countries make efforts to overcome obstacles and to facilitate its spreading. The motivations implemented include the relatively high cost of purchase of surplus power from the power corporations as well as the subsidy of investments. Other measures include communication, energy recording and analyses, research and development support etc.

Certain assessments for the status of co-generation in the year 2000 have already been made. Among new projects, large stations with capacities above $100MW_e$ are included, many of which will be operating on natural gas. In certain countries, the installed power co-generation capacity has increased by more than 100% in the period between 1990 and 2000.

The picture is completed by the following information known for certain countries:

- *Austria*: District heating has exhibited an annual growth rate of 9% since 1970. The amount of heat consumed in district heating is anticipated to increase by 56% before the year 2000. A good 65% of the loads of the new networks will be covered by co-generation.
- *Denmark*: It is anticipated that, by the end of this century, 50% of the thermal needs will be covered by district heating, to which co-generation will contribute at a percentage of 70% (IEA, 1988). The contribution of co-generation to district heating increased from 50% in 1985 to 60% in 1990; this means that the objective of an increase of 70% before the year 2000 is achievable.
- *Switzerland*: The spreading potential for small co-generation units (of medium capacities of the order of 150kW) is estimated to be around 100 units per year.

- *Italy*: This country exhibits the highest co-generation potential among all EU countries: 44% of the total potential.
- *UK*: The government aims both to install new units with capacities of 5000MW as well as to achieve a co-generated power percentage of 25% before the year 2000.
- *Holland*: Remarkable as it may sound, the power percentage generated at the installed co-generation systems with respect to the total power generated has been increased from 13.8% in 1990 to 17% in 1992. Furthermore, it is anticipated that it will reach 31.8% in the year 2000, i.e. a figure much higher than any other country. It is worth mentioning that the objective of 17% for 1995 was already achieved by the year of 1992.
- *Finland*: An increase of district heating is anticipated, with an annual growth rate of approx. 2%. For the year 2000, it is anticipated that 31.6% of the public power needs will be covered by co-generation systems.

According to assessments made for the industrial sector of EU countries, there is a possibility to install co-generation systems with capacities of 9,000-22,000MW during the next 10 years, corresponding to approx. 5% of the installed power generation systems in these countries.

In the commercial-building sector, where typically there is no permanently employed technical personnel, the spreading of co-generation requires good technical support by collaborating groups for regular maintenance operations and repairs (or even prevention) of emergency unit break-downs. This problem seems to be successfully dealt with in UK and other countries through the following method.

Specialized companies undertake the maintenance and repair operations of co-generation units, where they install instruments and devices for the continuous measurement of critical operational parameters. Locally installed microprocessors collect the measurement data, perform an initial data processing and then send the results to the central computer of the company via an exclusive telephone line. The central computer completes the analysis of the measurements, which points out oncoming faults. In such case, the engineering team is immediately informed on a 24-hour basis and the necessary maintenance and repair operations are performed, even before the outbreak of the fault. Consumer service is not interrupted during the performance of such operations, since the installation is connected to the regional public power network and the backup heat source in the building. Each company of this kind may support tens or hundreds of co-generation units.

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Bibliography

Haywood R.W. 1991. *Analysis of Engineering Cycles.* Fourth edition. Pergamon Press, Oxford, UK. [This book analyses a great variety of thermodynamic cycles used in engineering processes].

Marecki J. 1988. *Combined Heat and Power.* IEE Energy Series 3, Short Run Press Ltd., Peter Peregrinus Ltd., London, UK. [The central theme of this report is to give specific information on co-generation processes].

Culp A. 1991. *Principles of Energy Conversion. Second Edition. McGraw Hill, USA.*[The main aspect of this book is to analyze the energy conversion processes].

Fragopoulos C. 1988. *Combined Heat and Power.* Elkepa. Athens. Greece. [This is a student's edition book about the main processes of co-generation systems].

Biographical Sketch

Mrs. Irene Koronaki is an associate of the Department of Building Applications. She is a Mechanical Engineer and obtained her PhD in the Thermal Section of the Mechanical Engineering department of the National Technical University of Athens. She has experience in the field of Energy Efficiency in the building sector, regarding both building shell and services. She has participated in several research EC programmes (THERMIE, JOULE, SAVE, CRAFT) during her collaboration with the University of Athens, Department of Physics, as also as a collaborator of CRES. She is a member of ASHRAE and a registered engineer (Technical Chamber of Greece).