Cogeneration Technologies

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Abstract— Combined heat and power brings about the need of the co-generation to meet the present demand of electricity. It also bridges the gap between supply and ever increasing demand of electrical energy and becoming self-reliant in terms of captive electrical power rather depends on the state grids. It also talks about the co-generation technology, benefits, applications and potential beneficiaries for the amateurs who are keen to implement this technology to meet their needs and serves nation as a whole by reducing the load on grids and reduction of CO2 emissions to protect the environment. However, in a changing scenario where renewable sources play an important role in energy supply, new approaches to energy efficiency looking to supply side may be very helpful on achieving a big amount of energy savings that can be added to those expected from demand side. This paper intends to propose a methodology for calculation and measurement of the overall energy efficiency for biomass cogeneration or combined heat and power plants. This paper intends to propose a methodology for calculation and measurement of the overall energy efficiency for biomass cogeneration or combined heat and power plants.

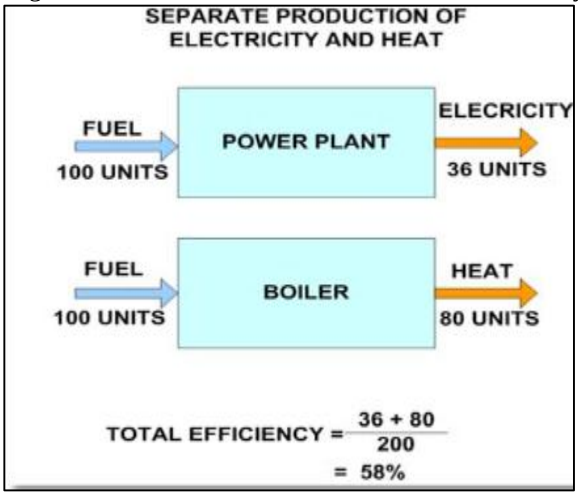
Keywords: CHP (Combined Heat and Power), CSP (Concentrating Solar Power), HRSE (Heat Recovery Steam Engine)

I. INTRODUCTION

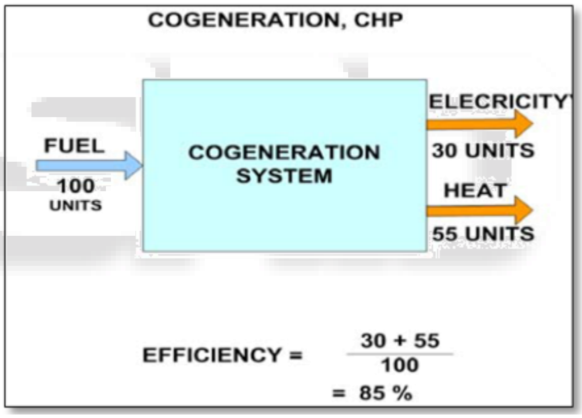
Cogeneration is the simultaneous production of power and heat, with a view to the practical application of both products. It also bridges the gap between supply and ever increasing demand of electrical energy and becoming self reliant in terms of captive electrical power rather depends on the state grids. High efficiency of cogeneration systems is one of the major factors that make them attractive for investors. The utilization of these systems is possible by using different strategies such as electrical dispatch, thermal dispatch and a combination of these two methods which is known as hybrid dispatch. In this paper, the efficiency of cogeneration systems is evaluated by some indices such as overall energy saving, thermal efficiency and Energy-Chargeable-to-Power (ECP).

Also, the amount of CO2 production has been calculated by using above operational strategies and in a case of without CHP. Then, all of the operational modes are applied to a local customer having predefined electrical and thermal loads and the results are However, in a changing scenario where renewable sources play an important role in energy supply, new approaches to energy efficiency looking to supply side may be very helpful on achieving a big amount of energy savings that can be added to those expected from demand side.

So Renewable sources can play a vital role in the cogeneration. Biogas cogeneration is the important type of renewable sources cogeneration. In Figure 1, cogeneration is compared with the separate, conventional production of electricity and heat. It shows that the separate production of heat and electricity requires more primary energy (fuel) than the cogeneration of similar amounts of heat and electricity.



(A)



(B)

Fig. 1.1: Comparison between Efficiencies

II. NEED FOR COGENERATION

The major source of electricity in India is thermal power plant. But only third part of energy is available to the user rest of energy is lost. The major source of loss in the conversion process is the heat rejected to the surrounding water or air due to the inherent constraints of the different thermodynamic cycles employed in power generation.

The conventional method of power generation and supply to the customer is wasteful in the sense that only about a third of the primary energy fed into the power plant is actually made available to the user in the form of electricity. In conventional power plant, efficiency is only 35% and remaining 65% of energy is lost.

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10-15% are associated with the transmission and distribution of electricity in the electrical grid.

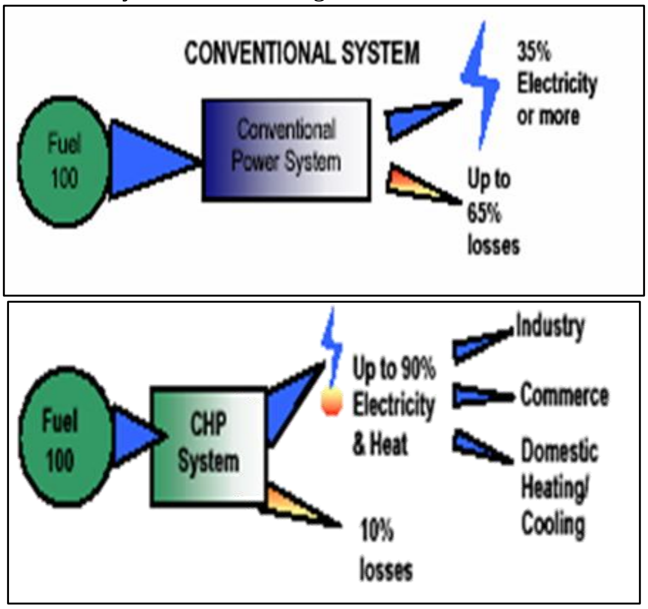

Fig. 2.1: Comparison between two Systems

Cogeneration is more efficient use of fuel because otherwise – wasted heat from electricity generation is put to some productive use. Combined heat and power (CHP) plants recover otherwise wasted thermal energy for heating This is also called combined heat and power district heating. Small CHP plants are an example of decentralized energy. By-product heat at moderate temperatures (100–180 °C, 212–356 °F) can also be used in absorption refrigerators or cooling.

The supply of high-temperature heat first drives a gas or steam turbine powered generator. The resulting low-temperature waste heat is then used for water or space heating. At smaller scales (typically below 1 MW) a gas engine or diesel engine may be used. Trigeneration differs from cogeneration in that the waste heat is used for both heating and cooling, typically in an absorption refrigerator. Combined cooling, heat and power systems can attain higher overall efficiencies than cogeneration or traditional power plants. In the United States, the application of trigeneration in buildings is called building cooling, heating and power. Heating and cooling output may operate concurrently or alternately depending on need and system construction.

Cogeneration was practiced in some of the earliest installations of electrical generation. Before central stations distributed power, industries generating their own power used exhaust steam for process heating. Large office and apartment buildings, hotels and stores commonly generated their own power and used waste steam for building heat. Due to the high cost of early purchased power, these CHP operations continued for many years after utility electricity became available.

III. Principle of Cogeneration

Cogeneration plant consists of four basic elements: Prime mover, Electricity generator, Heat recovery system and Control system. Conventional power generation, on average, is only 35% efficient – up to 65% of the energy potential is released as waste heat. More recent combined cycle generation can improve this to 55%, excluding losses for the transmission and distribution of electricity. Cogeneration reduces this loss by using the heat for industry, commerce and home heating/cooling.

Through the utilisation of the heat, the efficiency of cogeneration plant can reach 90% or more. Cogeneration therefore offers energy savings ranging between 15-40% when compared against the supply of electricity and heat from conventional power stations and boilers.

IV. How Does CHP Work?

A. *Cogeneration Plant Consists of Four Basic Elements:*

1) A prime mover.
2) An electricity generator.
3) A heat recovery system.
4) A control system.

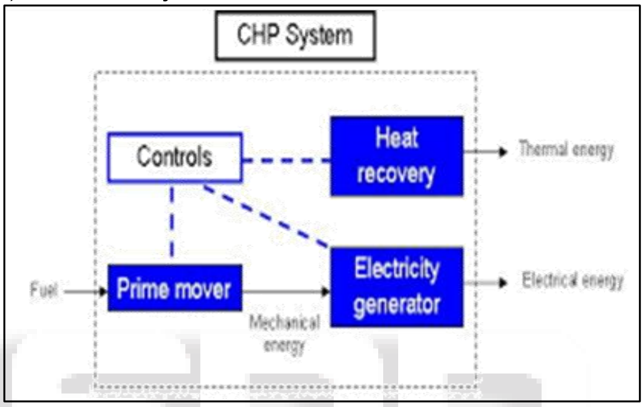

Fig. 4.1: Basic Elements of CHP

Prime Mover is an engine used to make the generator run.

B. *Fuel System*

The Generator is used to generate electricity from the power distribution system into the building's

Heat Recovery System is used to pick up utilizable heat from the locomotive (engine).

Cooling System for dissipating heat which is rejected from the locomotive that cannot be improved Combustion & Ventilation Air Systems for supplying clean air and to carry waste gases left from the engine, Control System is used for maintaining secure & proficient operation.

The Enclosure is used for achieving the protection for the engine as well as machinists, and also for reducing noise.

A conventional power plant makes electricity by a fairly inefficient process. A fossil fuel such as oil, coal, or natural gas is burned in a giant furnace to release heat energy. The heat is used to boil water and make steam, the steam drives a turbine, the turbine drives a generator, and the generator makes electricity.

The trouble with this is that energy is wasted in every step of the process—sometimes quite spectacularly. For example, the water that's boiled into steam to drive the steam turbines has to be cooled back down using giant cooling towers in the open air, wasting huge amounts of energy—much of which literally disappears into thin air! Now a fuel-driven power plant has to work by heating and cooling—that's what the laws of physics say—but surely we don't have to waste quite so much energy in the process?

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Instead of letting heat escape uselessly up cooling towers, why not simply pipe it as hot water to homes and offices instead? That's essentially the idea behind CHP: to capture the heat that would normally be wasted in electricity generation and supply it to local buildings as well. Where a conventional power plant makes electricity and wastes the heat it makes as a byproduct, a CHP power plant makes both electricity and hot water and supplies both to consumers. Cogeneration (the alternative name for CHP) simply means that the electricity and heat are made at the same time.

V. COGENERATION TECHNOLOGY

There are three main technologies of cogeneration(CHP) systems are :

A. *Topping Cycle*

There are two main kinds of cogeneration cycle: a topping cycle and a bottoming cycle.

The topping cycle really is the only economic cycle of the two. The main heat source generates high-enthalpy steam and electricity. Low-enthalpy steam is taken from an intermediate turbine stage or the turbine exhaust for process requirements. If the steam is taken from the turbine exhaust, this is called a back-pressure turbine.

The range of pressures for process steam varies and generally is on the order of 0.5 bar to 40 bar.

In topping cycle cogeneration plant, the power is produced prior to the recovery of useful residual heat. The plants that generate mechanical power may produce electricity for their own use and then sell any excess power if available to a utility.

There are four types of topping cycle cogeneration systems are:

1) Steam turbine topping cycle
2) Gas turbine topping cycle
3) Reciprocating engine topping cycle
4) Combined cycle topping cycle

In steam turbine topping cycle, the fossil fuels is burnt in the boiler and produce steam which is dumped into the steam turbine to drive the alternator and generate the electricity. The steam is extracted from the steam turbine and utilized for the process heat duties.

In Gas turbine topping cycle or reciprocating topping cycle plant, the premium fuel is burnt in combustion chamber and expand in gas turbine or diesel engine to produce mechanical power or otherwise electricity. The engine cooling and exhaust provides heat which goes to a heat recovery boiler to generate steam to drive a secondary steam turbine. This is a combined cycle power plant. Usually, the topping cycle plant is used where the electrical power requirement is more that heat demands.

B. *Bottoming Cycle*

In bottoming cycle cogeneration plant, heat is produced first and utilized for various industrial heat process and than waste heat is recaptured from heating process to power a turbine. Bottoming cycle plants relatively uncommon but does specifically used in heavy industries such as glass or metals manufacturing, where there is a considerable heat of reactions. Since the fuel is burnt first in the boiler, no extra fuel is generally required to produce electricity.

C. *Combined Cycle*

A combined cycle cogeneration plants combines the Rankine cycle (of steam turbine) and Brayton cycle (of gas turbine) for raising the overall efficiency.

Usually, natural gas or naptha burns in the gas engine/turbine to produce electricity. The exhaust of gas turbine have very high temperature around 500-600 C. This hot exhaust gas from gas turbine utilized in heat recovery steam generator(HRSG),which produced high pressure steam for the steam turbine to generate the electricity.

VI. TECHNICAL OPTIONS FOR COGENERATION

Cogeneration technologies that have been widely commercialized include extraction/back pressure steam turbines, gas turbine with heat recovery boiler (with or without bottoming steam turbine) and reciprocating engines with heat recovery boiler. The options by which cogeneration is technically feasible are named as:-

1) Steam turbine cogeneration systems
2) Combined Cycle Technology
3) Gas turbine cogeneration systems
4) Reciprocating engine cogeneration systems
5) Fuel cell

PRIME MOVER	FUEL	SIZE RANGE (MWe)	OVERALL EFFICIENCY(%)
COMBINED CYCLE	GAS	3->300	73 -90
GAS TURBINE	GAS	0.3->50	65-87
DIESEL ENGINE	GAS OIL	0.2-20	65 -90
GAS ENGINE	GAS,BIOGAS	0.003 - 6	70 -92
FUEL CELL	HYDROGEN, NATURAL GAS	0.001 - 100	90

Table 6.1: Comparison of Prime Mover Technologies

VII. RENEWABLE CO-GENERATION TECHNOLOGIES

Several renewable primary energy sources generate electricity via prior thermal generation. These technologies can, therefore, enjoy a double low-carbon benefit. First, the use of renewables bears obvious low-carbon credentials. Second, by operating in co-generation mode, these technologies enjoy the benefits of energy efficiency.

A. *Biomass*

Biomass co-generation is a prime example of how renewable and cogeneration can be combined. Biomass co-generation refers to the use of biological material as feedstock for co-generation plants. The biomass resource can take a variety of forms and shapes. It can be in solid form such as agricultural residues, wood wastes from forestry and industry, residues

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from food and paper industries, green municipal solid waste (MSW), dedicated energy crops and reclaimed wood. Biomass can be in gas form including in the form of landfill gas, manure biogas and wastewater treatment biogas. Alternatively, it can also be fed indirectly to generating plants through gasification of solid biomass or production of liquid biofuel.

Biomass is one the most significant renewable energy sources. Using it has many benefits, such as a generally lower impact of the technology on environment, and utilization of idle agricultural land that is not fit or needed for food production. There are multitude ways to use biomass to produce heat and power, starting with esterification of oils via generation and use of biogas up to thermal processes such as pyrolysis, combustion, and gasification.

B. Geothermal

Geothermal power plants use heat energy from below the Earth's surface to produce electricity. The heat energy is in the form of steam that results from the decompression of geothermal fluid as it travels from reservoirs (located at several hundred to a few thousand meters underground) to the surface of the Earth. There are three types of geothermal power plants, each one differing because of the composition of the geothermal resource and the temperature level of the resource: steam only, steam in combination with water and water only. Today, examples of geothermal co-generation where heat is delivered to district heating grids can be found in Iceland, Italy, Germany and Turkey.

C. Concentrating Solar Power

Concentrating solar power (CSP) converts solar energy into thermal energy which is then converted into electricity. The second process is achieved most often through a steam turbine as in most conventional power plants that are on the steam cycle to drive an electric generator.

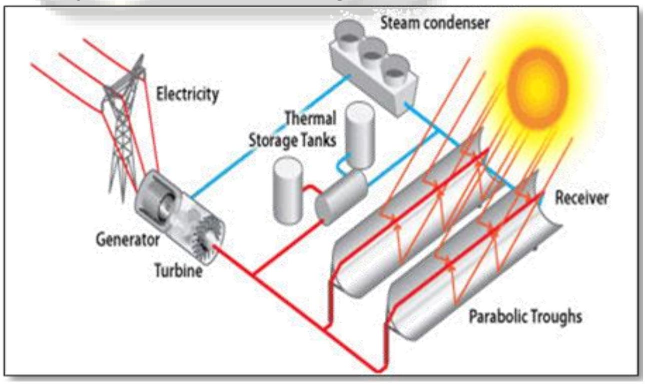

Fig. 7.1: Tower concentrating solar power (CSP) technology

D. Main parts of CSP Technology

1) Generator Steam drum,
2) Receiver,
3) Heliostats ,
4) Electricity ,
5) Turbine
6) Steam condenser

As with any technology that generates power through prior heat generation, CSP has scope for the application of co-generation. Isolated locations receiving large amounts of direct sunshine such as deserts are particularly suitable for solar CSP plants, but located far from energy demand and must deal with transmission issues. Other regions such as the Middle East and North Africa (MENA), southwestern United States and the Mediterranean, which have the best potential for solar CSP, are relatively close to inhabited and/or industrial areas. Some large metropolitan areas in diverse parts of the world including Athens, Cairo, Houston, Istanbul, Jaipur, Johannesburg, Lima, Riyadh and Sydney are likely to benefit from CSP by 2020 .With proper planning, heat derived from CSP can be used gainfully to dramatically increase the overall efficiency of a CSP system. While CSP has been reliably operating for at least 15 years in some countries such as the United States,it is still an emerging technology when considering the amount of electricity currently generated.

VIII. ADVANTAGES OF CHP

CHP provide a potentially cost-effective way of servicing the both heating & electrical demands of industrial & commercial processes.

Cogeneration can significantly reduce carbon emissions and energy costs.

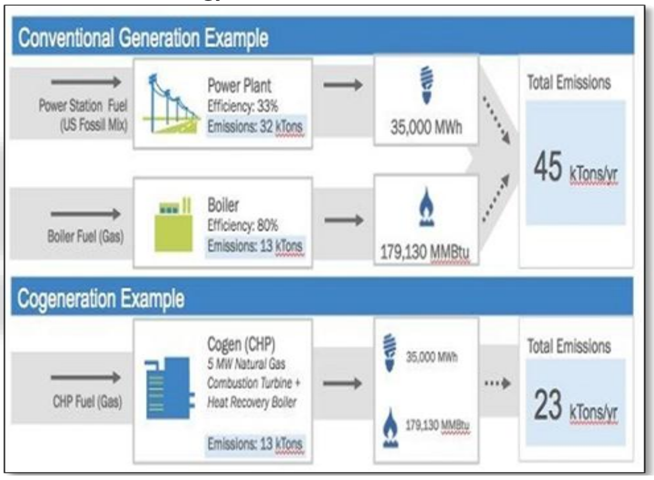

Fig. 8.1: Total emission between two systems

And while typical combustion systems have an efficiency of about 40-50 percent, cogeneration systems that combine the power and heat generation processes can be up to 80 percent efficient.

When combined with a renewable fuel supply, such as biomass or biogas, cogeneration is an environmentally responsible source of reliable, base load generation. These benefits have attracted the attention of many large-scale facilities.

The major advantages of using CHP system are:-

1) Raise efficiency & reduce fuel consumption.
2) Reduce energy costs.
3) Reduce carbon emission.
4) Reduce or differed cost for HV transmission lines because it is a decentralized plant.
5) Enhanced energy security
6) Conservation of valuable fossile fuels.
7) Elimination of T & D losses.
8) Lower CO2, NOX, & SOX, dust, ash pollutants. Enhancing operational efficiency to lower overhead costs

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9) Reducing energy waste, thereby increasing energy efficiency
10) Offering greater energy independence by moving a portion of the load off the grid
11) Allowing companies to replace aging infrastructure

IX. APPLICATIONS

1) Infrastructure projects
2) Shopping malls
3) Airports
4) Industrial plants
5) Greenhouses
6) Mines
7) Power producers, IPPs
8) Oil and gas industry, drilling rig systems, flare gas
9) Steel and chemical industry, synthesis gas, coke
10) oven gas
11) Sewage treatment plants
12) Landfills
13) Nawaro biogas
14) Natural gas

X. CONCLUSION

CHP provide a potentially cost-effective way of servicing the both heating & electrical demands of industrial & commercial processes.

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