Sudan university of Science and technology

College of Science

Power generation by gable Awlia Dam

A graduation project submitted as to complete the requirements of 4 years course B . S . C degree in physics science

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DEDICATION

This effort is dedicated to

Dear parents,

To brothers &sisters,

To my friends.

Deep appreciation for their moral and finacial support, aspiration for attitude.

we hope the targeted degree will make them prouder.

ACKNOWLEDGMENTS

First we thank my God for helping us to perform this research and for giving us all we need and guiding us towards the right way.

We are greatly thankful and greatly indebted to our supervisor Prof. Mohamed Osman of the Department of physic, Faculty of Science, Sudan University of science technology for suggesting the problem, keen supervision and fatherly encouragement throughout the work. we do appreciate the efforts he exerted to train us making free hand drawing using Microsoft word.

our gratitude's are extended to include Eng. Ramadan for helping us and guiding us to make our project.

Conclusion

In this research project we studied and discussed one of the methods of generating electricity that is the hydropower electric generation.

we considered GablAwlia dames a special case We found that the Dam has high efficiently which is about 94%. This high efficiency could be explained due to the fact that all measurements were taken during the rainy season.

ABSTRACT

In this research project we studied and discussed electricity generation, both by thermal and hydropower. We interested in a case study and we have taken Gabl Awlia dam as a case study . It is worthy noticed that the electricity generation efficiency being calculated is remarkably high, that is its of about 94%. This high efficiency could be explained due to the fact that the measurements were taken during the rainy season.

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SUDAN ENERGY HANDBOOK

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1.1 Introduction

1.1.1background:

Sudan is the second country in Africa with an area of 1.882 millions square kilometers. It lies between latitudes 845 and 238 N

And longitudes 2134 and 3934 Eland borders seven other countries, including Egypt, Libya, central Africa Eretria south Sudan Chad and Ethiopia.

1.1.2 Sudan Energy Balance:

Figure 1 represents Sudan energy balance of the year 2011 .It shows the flows of energy from the energy resources, through conversion, transformation, distribution and up to the end uses. In this year the total primary energy used in Sudan is about 14.986 million ton of oil equivalent .Out of this energy supply only 74% reached end users .Losses of about 3.864 million ton of oil equivalent occurred during conversion, transport and distribution.

As shown in Sudan Energy supply of the year 2011 (Fig.1) the hydropower energy contribution is 533 thousand TOES represents 3.7%. of total primary energy supply in this year . In 2008 this share was less than 1%. This increase is due to the commissioning of Merowe (1250 MW) Hydro power plant in 2009.

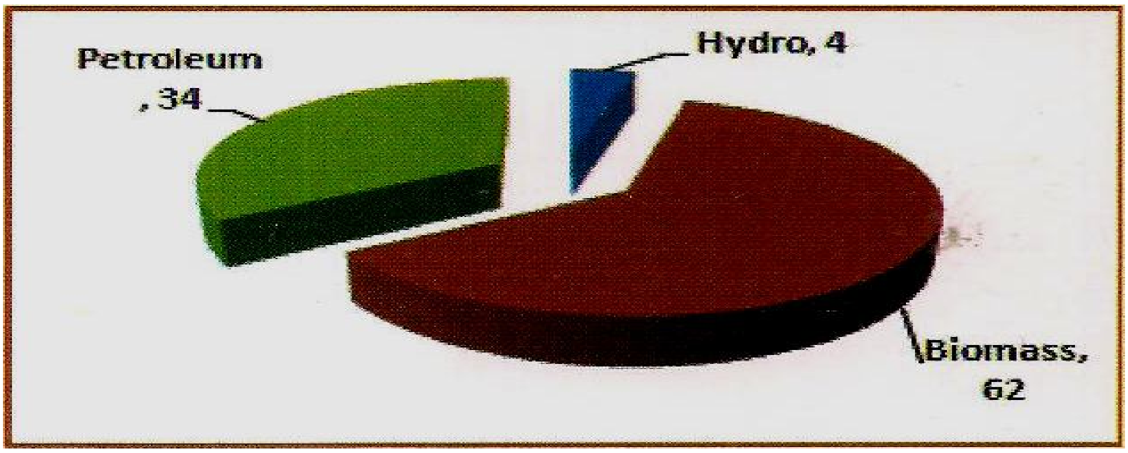


Fig.1.primary Energy 2010 by type fuel.[1]

The hydropower generation represents about 83% of the total electricity generation in the national grid in the same year. This share increased more than three times of that of 2008due to commissioning of all Merowe hydropower turbines in this year

Petroleum energy supply represents 33.9% of the total energy supply 2011 compared to about 14% in 2000. This big increase is due to utilization of country indigenous crude oil after the commissioning of Khartoum refinery (50 thousands barrel a day) in 2000.

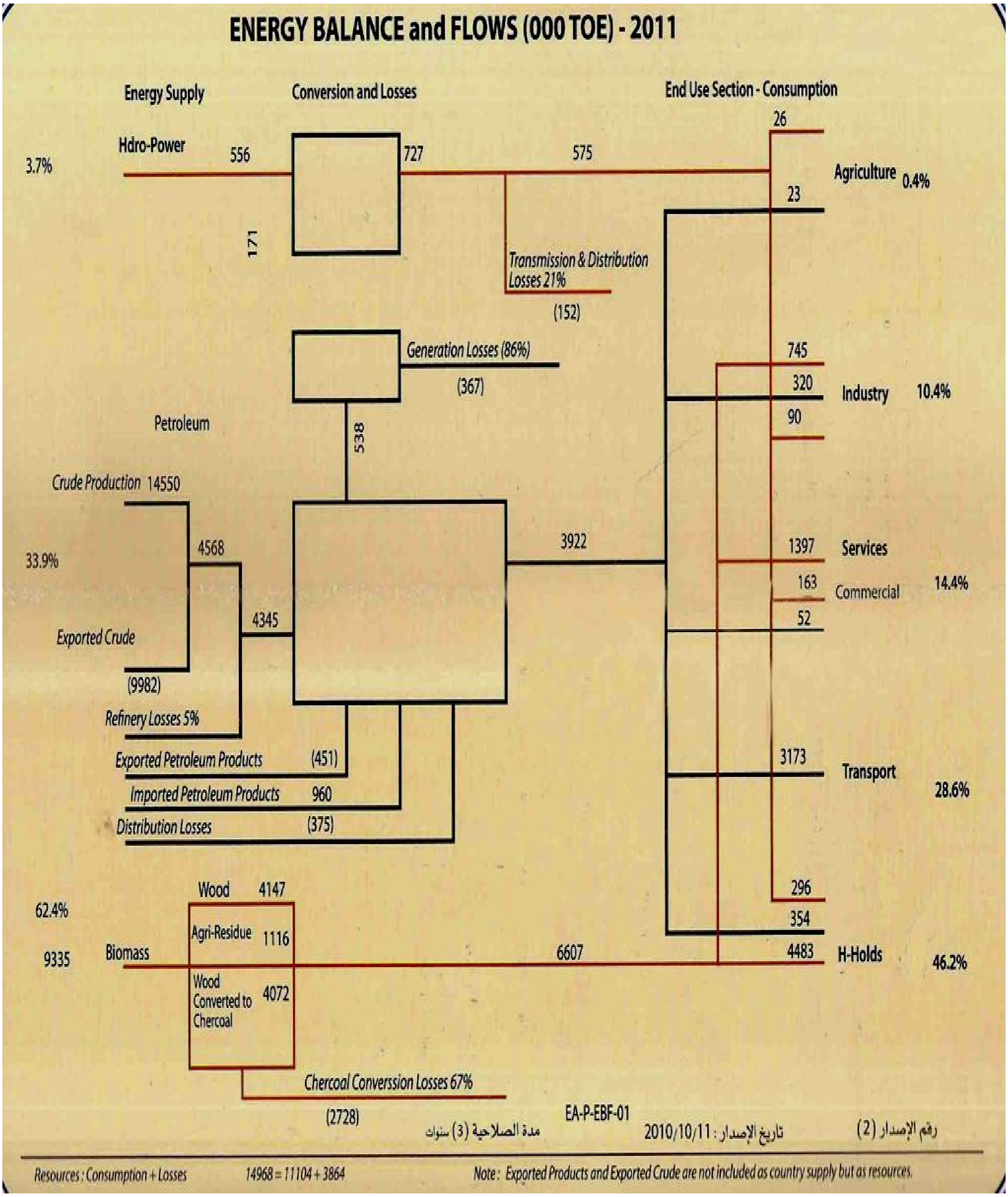
1.1.3 ENERGY CONSUMPTION:

The total final energy consumption reached to the end users was only 11,104 thousands TOE while the total losses was about 3864 thousands TOE (about 26% of the primary resources consumed) in this year. These losses are due to conversion transmission and distribution processes.

The main end-use sectors of energy are categorized as household, transport, services, industry and agriculture. The shares of these sectors out of the total final energy consumption in 2011 are 46.2%, 28.6%, 14.4%, 10.4% and 0.4% respectively.

1.1.4HOUSEHOLD SECTOR:

Residential sector is biggest consumer sector it consumed about 5.133 million TOE consumption which was 46% of total final energy consumption in the country in 2011. Most of this consumption supplied by biomass (90% of total sector). The respective shares of petroleum products and electricity in the total final energy consumption of this sector were 7% and 6%. These shares increased at expense of biomass share.



ENERGY BALANCE and FLOWS (000 TOE) - 2011
Energy Supply
Conversion and Losses
End Use Section - Consumption
3.7%
Hdro-Power
556
727
575
171
26
Agriculture 0.4%
23
Transmission & Distribution Losses 21%
(152)
Generation Losses (86%)
(367)
538
Petroleum
745
320
Industry
10.4%
90
Crude Production 14550
33.9%
4568
3922
1397
Services
163
Commercial
14.4%
52
4345
Exported Crude
(9982)
Refinery Losses 5%
Exported Petroleum Products
(451)
Imported Petroleum Products
960
Distribution Losses
(375)
3173
Transport
28.6%
Wood
4147
62.4%
Agri-Residue
1116
9335
Biomass
6607
296
354
4483
H-Holds
46.2%
Wood Converted to Chercoal
4072
Chercoal Conversion Losses 67%
(2728)
EA-P-EBF-01
مدة الصلاحية (3) سنوات
تاريخ الإصدار: 2010/10/11
رقم الإصدار (2)
Resources: Consumption + Losses
14968 = 11104 + 3864
Note: Exported Products and Exported Crude are not included as country supply but as resources.

Fig.2.Energy Balance and Flows[1]

About 89%of energy consumed in this sector came from biomass resources. These resources are mainly firewood, charcoal and crop residues. The other energy resources are petroleum products (mainly LPG and kerosene)and electricity . The share of each is slightly more than 5%. These latter energy resources are expected to increase their contribution more at the expense of the former ones as a result of the substitution of biomass fuels by LPG, and also in view of the increasing electrification rate which is expected to take place as a result of implementing government strategic plans in this sector.

1.1.5 TRANSPORT SECTOR:

Transport sector which uses petroleum products only, the share of this sector in the total final energy consumption in the country in this year is 28.6%. This sector is the biggest petroleum products consumer; it consumed about 81% of the petroleum supply in 2011.

Close investigation showed that some petroleum consumed in agriculture sector appeared as transport consumption. Due to the increase in the economic activities and increase of paved roads and reduction of other transportation modes capacity this share (transportation) is expected to significantly increase in the coming years.

1.1.6 SERVICE SECTOR:

Service sector is third biggest consumer of total; final energy consumption it consumed about 14%of the total final energy consumption in Sudan in this year.

This sector mainly consumes biomass fuel about 87% of it is total consumption while petroleum products and electricity contributed by 3% and 10% respectively in this year.

1.1.7 INDUSTRY SECTOR:

Industry sector uses petroleum product, electricity and biomass fuel for its product, electricity. In 2011 its share to total final energy consumption of the country was about 10%. It respective shares of petroleum Product, electricity and biomass were 28%, 8%, 64%.

The second fuel is Petroleum which accounted for about 42% of the total sector consumption .the remaining 5% of the energy demand consumed in this sector was electricity. The share of consumption the industry out the total final energy consumption in this compared to that of the year 2000 showed no significant change this is due to the problems of production

Associated with sector

.1.1.8 Agriculture sector:

Agriculture sector is the smallest energy sector consumer. It consumes only by 0.4% of the total energy consumption.

The comparison of the consumption share of this sector in this year to that in the 2000 shows that there is a great decrease in this share due to fact that some consumption of this sector occurred as a consumption of transport.

PETROLEUM SECTOR

Petroleum Products Consumption by Fuel (KTOE)

Fuel	06	07	08	09	10	11
LPG	296.3	274.8	269.8	318.7	300.6	423.8
Aviation	0.0	0.0	0.0	0.0	0.0	0.0
Benzene	517.5	577.4	617.5	708.8	799.6	830.6
Kerosene	12.6	9.0	6.9	4.3	3.1	3.6
Jet-A1	286.7	240.0	254.5	225.2	242.4	298.2
Gas Oil	2100.3	2393.8	2393.3	2406.5	2245.1	2207.1
Diesel	48.9	44.8	46.4	36.5	26.7	22.8
Fuel Oil	460.9	441.1	510.9	501.2	569.3	537.3
Pet.Coke	0.0	0.0	0.0	266.4	344.3	213.8
Total	3723.3	3980.9	4099.2	4467.7	4531.0	4537.1

Fig.3. Petroleum Products Consumption by Fuel[1]

Petroleum Products Consumption by Sector (KTOE)

Fuel	06	07	08	09	10	11
Transport	2381.7	2534.1	2576.7	2808.1	3000.8	3172.9
Industrial	1122.4	1200.8	1276.8	1064.6	838.6	1033.8
Household	208.2	227.0	224.1	262.1	283.2	406.1
Total	3712.3	3961.9	4077.6	4134.8	4122.6	4612.8

Fig.4.petroleum products consumption by sector[1]

Imported Petroleum Products (KTOE)						
LPG	0.0	0.0	35.9	9.7	43.7	99.3
Gas Oil	510.1	401.3	783.2	368.6	467.6	692.2
Gasoline	0.0	0.0	28.6	0.0	0.0	0.0
Jet-A1	57.3	91.2	122.0	110.1	94.3	168.5
Total	567.5	492.5	969.7	488.5	605.6	960.0

Fig.5. Imported Petroleum Products[1]

Exported Petroleum Products (KTOE)						
LPG	15.5	10.0	15.5	11.8	13.4	9.8
Gas Oil	27.1	30.4	0.0	4.1	0.0	0.0
Gasoline	630.6	636.7	455.3	365.6	383.5	328.5
Naphtha	22.0	2.5	0.0	0.0	0.0	0.0
Fuel oil	17.3	85.8	33.6	42.6	20.7	38.9
Pet. Coke	41.8	44.0	68.0	9.9	0.0	90.6
Total	754.2	959.2	716.5	664.7	504.7	467.8

Fig.6.Exported petroleum products[1]

ELECTRICITY SECTOR

Electricity Generation by Type (GWH)

Sector	06	07	08	09	10	11
Hydro	1369	1457	1466	3236	6202	6467
Thermal	2841	3564	4041	3137	1297	1988
Total	**4210**	**5021**	**5506**	**6372**	**7499**	8455

Fig.7. Electricity Generation by type[1]

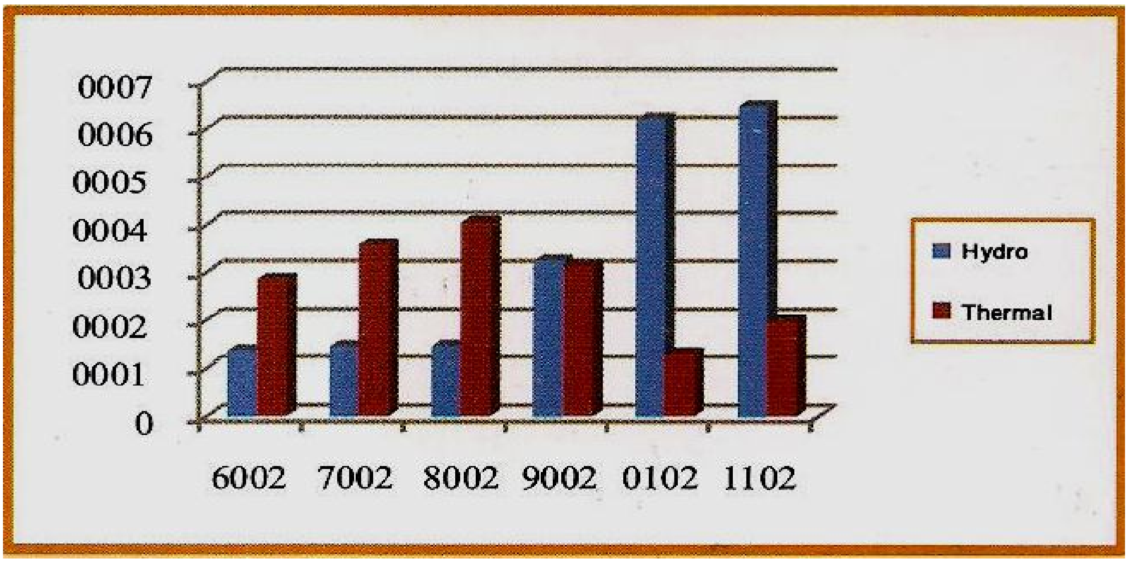


Fig.8. Electricity Generation by Type[1]

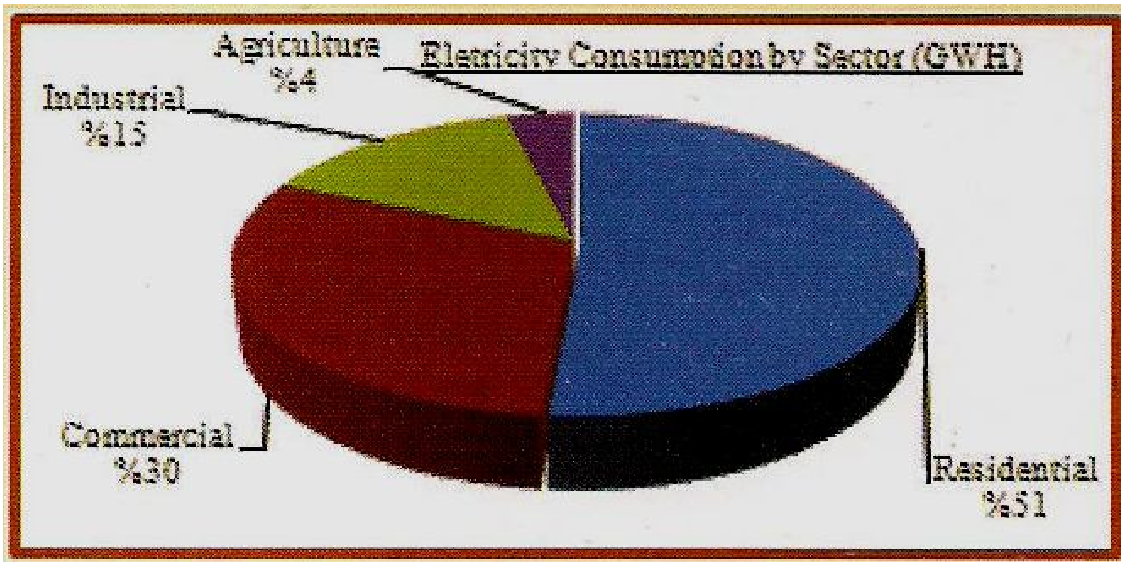


Fig.9. Electricity Consumption by Sectors[1]

CHAPTER 2

2.1Thermal power station

A **thermal power station** is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle. The greatest variation in the design of thermal power stations is due to the different fossil fuel resources generally used to heat the water. Some prefer to use the term energy center because such facilities convert forms of heat energy into electrical energy. Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally, fossil fueled thermal power plants produce a large part of man-made CO_2 emissions to the atmosphere, and efforts to reduce these are varied and widespread.

2.1.1 Types of thermal power station

Almost all coal, nuclear, geothermal, solar thermal electric and waste incineration plants, as well as many natural gas power plants are thermal. Natural has is frequently combusted in gas turbines as well as boilers. The waste heat from a gas turbine can be used to raise steam, in a combined cycle plant that improves overall efficiency. Power plants burning coal, fuel oil, or natural gas are often called fossil-fuel power plants. Some biomass-fueled thermal power plants have appeared also. Non-nuclear thermal power plants, particularly fossil-fueled plants, which do not use co-generation, are sometimes referred to as conventional power plants

Commercial electric utility power stations are usually constructed on a large scale and designed for continuous operation. Electric power plants typically use three-phase electrical generators to produce alternating current (AC) electric power at a frequency of 50 Hz or 60 Hz. Large companies or institutions may have their own power plants to supply heating or electricity to their facilities, especially if steam is created anyway for other purposes. Steam-driven power plants have been used in various large ships, but are now usually used in large naval ships. Shipboard power plants usually directly couple the turbine to the ship's propellers through gearboxes. Power plants in such ships also provide steam to smaller turbines driving electric generators to supply electricity. Shipboard steam power plants can be either fossil fuel or nuclear. Nuclear marine propulsion is, with few exceptions, used only in naval vessels. There have been perhaps about a dozen turbo-electric ships in which a steam-driven turbine drives an electric generator which powers an electric motor for propulsion.

Combined heat and power plants (CH&P plants), often called co-generation plants, produce both electric power and heat for process heat or space heating. Steam and hot water lose energy when piped over substantial distance, so carrying heat energy by steam or hot water is often only worthwhile within a local area, such as a ship, industrial plant, or district heating of nearby buildings.

2.1.2Efficiency

The energy efficiency of a conventional thermal power station, considered salable energy produced as a percent of the heating value of the fuel consumed, is typically 33% to 48%.[citation needed] As with all heat engines, their efficiency is limited, and governed by the laws of thermodynamics. By comparison, most hydropower stations in the United States are about 90 percent efficient in converting the energy of falling water into electricity.

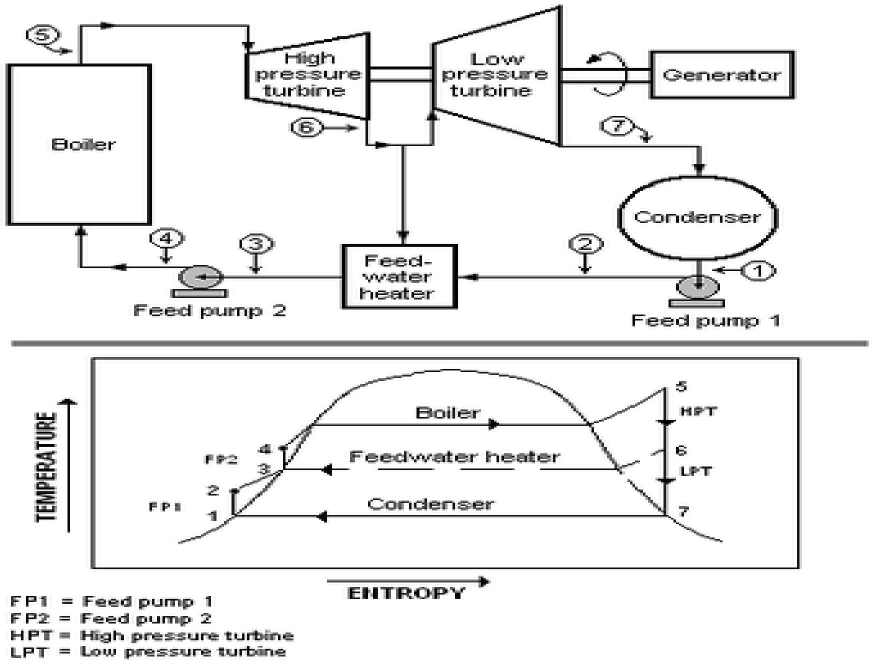


Fig.1 Cycle of a thermal power station[2]

The energy of a thermal not utilized in power production must leave the plant in the form of heat to the environment. This waste heat can go through a condenser and be disposed of with cooling water or in cooling towers. If the waste heat is instead utilized for district heating, it is called co-generation. An important class of thermal power station is associated with desalination facilities; these are typically found in desert countries with large supplies of natural gas and in these plants, freshwater production and electricity are equally important co-products.

The Carnot efficiency dictates that higher efficiencies can be attained by increasing the temperature of the steam. Sub-critical fossil fuel power plants can achieve 36–40% efficiency. Super critical designs have efficiencies in the low to mid 40% range, with new "ultra critical" designs using pressures of 4400 psi (30.3 MPa) and multiple stage reheat reaching about 48% efficiency. Above the critical point for water of 705 °F (374 °C) and 3212 psi (22.06 MPa), there is no phase transition from water to steam, but only a gradual decrease in density.

Currently most of the nuclear power plants must operate below the temperatures and pressures that coal-fired plants do, since the pressurized vessel is very large and contains the entire bundle of nuclear fuel rods. The size of the reactor limits the pressure that can be reached. This, in turn, limits their thermodynamic efficiency to 30–32%. Some advanced reactor designs being studied, such as the very high temperature reactor, advanced gas-cooled reactor and supercritical water reactor, would operate at temperatures and pressures similar to current coal plants, producing comparable thermodynamic efficiency.

2.1.3 Electricity cost

The direct cost of electric energy produced by a thermal power station is the result of cost of fuel, capital cost for the plant, operator labor, maintenance, and such factors as ash handling and disposal. Indirect, social or environmental costs such as the economic value of environmental impacts, or environmental and health effects of the complete fuel cycle and plant decommissioning, are not usually assigned to generation costs for thermal stations in utility practice, but may form part of an environmental impact assessment.

2.1.4 Boiler and steam cycle

In the nuclear plant field, steam generator refers to a specific type of large heat exchanger used in a pressurized water reactor (PWR) to thermally connect the primary (reactor plant) and secondary (steam plant) systems, which generates steam. In a nuclear reactor called a boiling water reactor (BWR), water is boiled to generate steam directly in the reactor itself and there are no units called steam generators.

In some industrial settings, there can also be steam-producing heat exchangers called heat recovery steam generators (HRSG) which utilize heat from some industrial process. The steam generating boiler has to produce steam at the high purity, pressure and temperature required for the steam turbine that drives the electrical generator.

Geothermal plants need no boiler since they use naturally occurring steam sources. Heat exchangers may be used where the geothermal steam is very corrosive or contains excessive suspended solids.

A fossil fuel steam generator includes an economizer, a steam drum, and the furnace with its steam generating tubes and superheated coils. Necessary safety valves are located at suitable points to avoid excessive boiler pressure. The air and flue gas path equipment include: forced draft (FD) fan, air preheater (AP), boiler furnace, induced draft (ID) fan, fly ash collectors (electrostatic precipitator or baghouse) and the flue gas stack

2.1.5 Feed water heating and deaeration

The boiler feedwater used in the steam boiler is a means of transferring heat energy from the burning fuel to the mechanical energy of the spinning steam turbine. The total feed water consists of recirculated condensate water and purified makeup water. Because the metallic materials it contacts are subject to corrosion at high temperatures and pressures, the makeup water is highly purified before use. A system of water softeners and ion exchange demineralizers produces water so pure that it coincidentally becomes an electrical insulator, with conductivity in the range of 0.3–1.0microsiemensper centimeter. The makeup water in a 500 MW plant amounts to perhaps 120 US gallons per minute (7.6 L/s) to replace water drawn off from the boiler drums for water purity management, and to also offset the small losses from steam leaks in the system.

The feed water cycle begins with condensate water being pumped out of the condenser after traveling through the steam turbines. The condensate flow rate at full load in a 500 MW plant is about 6,000 US gallons per minute (400 L/s).

The water is pressurized in two stages, and flows through a series of six or seven intermediate feed water heaters, heated up at each point with steam extracted from an appropriate duct on the turbines and gaining temperature at each stage. Typically, in the middle of this series of feed water heaters, and before the second stage of pressurization, the condensate plus the makeup water flows through a deaerator that removes dissolved air from the water, further purifying and reducing its corrosiveness. The water may be dosed following this point with hydrazine, a chemical that removes the remaining oxygen in the water to below 5 parts per billion (ppb).[vague] It is also dosed with pH control agents such as ammonia or morph line to keep the residual acidity low and thus non-corrosive.

2.1.6 Boiler operation

The boiler is a rectangular furnace about 50 feet (15 m) on a side and 130 feet (40 m) tall. Its walls are made of a web of high pressure steel tubes about 2.3 inches (58 mm) in diameter.

Pulverized coal is air-blown into the furnace through burners located at the four corners, or along one wall, or two opposite walls, and it is ignited to rapidly burn, forming a large fireball at the center. The thermal radiation of the fireball heats the water that circulates through the boiler tubes near the boiler perimeter. The water circulation rate in the boiler is three to four times the throughput. As the water in the boiler circulates it absorbs heat and changes into steam. It is separated from the water inside a drum at the top of the furnace. The saturated steam is introduced into superheat pendant tubes that hang in the hottest part of the combustion gases as they exit the furnace. Here the steam is superheated to 1,000 °F (540 °C) to prepare it for the turbine.

Plants designed for lignite (brown coal) are increasingly used in locations as varied as Germany, Victoria, Australia and North Dakota. Lignite is a much younger form of coal than black coal. It has a lower energy density than black coal and requires a much larger furnace for equivalent heat output. Such coals may contain up to 70% water and ash, yielding lower furnace temperatures and requiring larger induced-draft fans. The firing systems also differ from black coal and typically draw hot gas from the furnace-exit level and mix it with the incoming coal in fan-type mills that inject the pulverized coal and hot gas mixture into the boiler.

Plants that use gas turbines to heat the water for conversion into steam use boilers known as heat recovery steam generators (HRSG). The exhaust heat from the gas turbines is used to make superheated steam that is then used in a conventional water-steam generation cycle, as described in gas turbine combined-cycle plants section below.

2.1.7 Boiler furnace and steam drum

The water enters the boiler through a section in the convection pass called the economizer. From the economizer it passes to the steam drum and from there it goes through down comers to inlet headers at the bottom of the water walls. From these headers the water rises through the water walls of the furnace where some of it is turned into steam and the mixture of water and steam then re-enters the steam drum. This process may be driven purely by natural circulation (because the water is the down comer is denser than the water/steam mixture in the water walls) or assisted by pumps. In the steam drum, the water is returned to the down comers and the steam is passed through a series of steam separators and dryers that remove water droplets from the steam. The dry steam then flows into the super heater coils.

The boiler furnace auxiliary equipment includes coal feed nozzles and igniter guns, soot blowers, water lancing and observation ports (in the furnace walls) for observation of the furnace interior. Furnace explosions due to any accumulation of combustible gases after a trip-out are avoided by flushing out such gases from the combustion zone before igniting the coal.

The steam drum (as well as the super heater coils and headers) have air vents and drains needed for initial start up.

2.1.8Superheater

Fossil fuel power plants often have a super heater section in the steam generating furnace. The steam passes through drying equipment inside the steam drum on to the superheater, a set of tubes in the furnace. Here the steam picks up more energy from hot flue gases outside the tubing and its temperature is now superheated above the saturation temperature. The superheated steam is then piped through the main steam lines to the valves before the high pressure turbine.

Nuclear-powered steam plants do not have such sections but produce steam at essentially saturated conditions. Experimental nuclear plants were equipped with fossil-fired super heaters in an attempt to improve overall plant operating cost.

2.1.9 Steam condensing

The condenser condenses the steam from the exhaust of the turbine into liquid to allow it to be pumped. If the condenser can be made cooler, the pressure of the exhaust steam is reduced and efficiency of the cycle increases.

The surface condenser is a shell and tube heat exchanger in which cooling water is circulated through the tubes the exhaust steam from the low pressure turbine enters the shell where it is cooled and converted to condensate (water) by flowing over the tubes as shown in the adjacent diagram. Such condensers use steam ejectors or rotary motor-driven exhausters for continuous removal of air and gases from the steam side to maintain vacuum.

For best efficiency, the temperature in the condenser must be kept as low as practical in order to achieve the lowest possible pressure in the condensing steam. Since the condenser temperature can almost always be kept significantly below 100 °C where the vapor pressure of water is much less than atmospheric pressure, the condenser generally works under vacuum. Thus leaks of non-condensable air into the closed loop must be prevented.

Typically the cooling water causes the steam to condense at a temperature of about 35 °C (95 °F) and that creates an absolute pressure in the condenser of about 2–7 kPa (0.59–2.07 inHg), i.e. a vacuum of about −95 kPa (−28 inHg) relative to atmospheric pressure. The large decrease in volume that occurs when water vapor condenses to liquid creates the low vacuum that helps pull steam through and increase the efficiency of the turbines.

The limiting factor is the temperature of the cooling water and that, in turn, is limited by the prevailing average climatic conditions at the power plant's location (it may be possible to lower the temperature beyond the turbine limits during winter, causing excessive condensation in the turbine). Plants operating in hot climates may have to reduce output if their source of condenser cooling water becomes warmer; unfortunately this usually coincides with periods of high electrical demand for air conditioning.

The condenser generally uses either circulating cooling water from a cooling tower to reject waste heat to the atmosphere, or once-through water from a river, lake or ocean.

The heat absorbed by the circulating cooling water in the condenser tubes must also be removed to maintain the ability of the water to cool as it circulates. This is done by pumping the warm water from the condenser through either natural draft, forced draft or induced draft cooling towers (as seen in the image to the right) that reduce the temperature of the water by evaporation, by about 11 to 17 °C (20 to 30 °F)—expelling waste heat to the atmosphere. The circulation flow rate of the cooling water in a 500 MW unit is about 14.2 m^3/s (500 ft^3/s or 225,000 US gal/min) at full load.

The condenser tubes are made of brass or stainless steel to resist corrosion from either side. Nevertheless they may become internally fouled during operation by bacteria or algae in the cooling water or by mineral scaling, all of which inhibit heat transfer and reduce thermodynamic efficiency. Many plants include an automatic cleaning system that circulates sponge rubber balls through the tubes to scrub them clean without the need to take the system off-line.[citation needed]

The cooling water used to condense the steam in the condenser returns to its source without having been changed other than having been warmed. If the water returns to a local water body (rather than a circulating cooling tower), it is tempered with cool 'raw' water to prevent thermal shock when discharged into that body of water.

Another form of condensing system is the air-cooled condenser. The process is similar to that of a radiator and fan. Exhaust heat from the low pressure section of a steam turbine runs through the condensing tubes, the tubes are usually finned and ambient air is pushed through the fins with the help of a large fan. The steam condenses to water to be reused in the water-steam cycle. Air-cooled condensers typically operate at a higher temperature than water-cooled versions. While saving water, the efficiency of the cycle is reduced (resulting in more carbon dioxide per megawatt of electricity).

From the bottom of the condenser, powerful condensate pumps recycle the condensed steam (water) back to the water/steam cycle.

2.1.10 Reheater

Power plant furnaces may have a reheater section containing tubes heated by hot flue gases outside the tubes. Exhaust steam from the high pressure turbine is passed through these heated tubes to collect more energy before driving the intermediate and then low pressure turbines.

2.1.11 Air path

External fans are provided to give sufficient air for combustion. The Primary air fan takes air from the atmosphere and, first warming it in the air preheater for better combustion, injects it via the air nozzles on the furnace wall.

The induced draft fan assists the FD fan by drawing out combustible gases from the furnace, maintaining a slightly negative pressure in the furnace to avoid backfiring through any closing.

2.1.12 Steam turbine generator

The turbine generator consists of a series of steam turbines interconnected to each other and a generator on a common shaft. There is a high pressure turbine at one end, followed by an intermediate pressure turbine, two low pressure turbines, and the generator. As steam moves through the system and loses pressure and thermal energy it expands in volume, requiring increasing diameter and longer blades at each succeeding stage to extract the remaining energy. The entire rotating mass may be over 200 metric tons and 100 feet (30 m) long. It is so heavy that it must be kept turning slowly even when shut down (at 3 rpm) so that the shaft will not bow even slightly and become unbalanced. This is so important that it is one of only five functions of blackout emergency power batteries on site. Other functions are emergency lighting, communication, station alarms and turbo generator lube oil.

Superheated steam from the boiler is delivered through 14–16-inch (360–410 mm) diameter piping to the high pressure turbine where it falls in pressure to 600 psi (4.1 MPa) and to 600 °F (320 °C) in temperature through the stage. It exits via 24–26-inch (610–660 mm) diameter cold reheat lines and passes back into the boiler where the steam is reheated in special reheat pendant tubes back to 1,000 °F (540 °C). The hot reheat steam is conducted to the intermediate pressure turbine where it falls in both temperature and pressure and exits directly to the long-bladed low pressure turbines and finally exits to the condenser.

The generator, 30 feet (9 m) long and 12 feet (3.7 m) in diameter, contains a stationary stator and a spinning rotor, each containing miles of heavy copper conductor—no permanent magnets here. In operation it generates up to 21,000 amperes at 24,000 volts AC (504 MW) as it spins at either 3,000 or 3,600 rpm, synchronized to the power grid. The rotor spins in a sealed chamber cooled with hydrogen gas, selected because it has the highest known heat transfer coefficient of any gas and for its low viscosity which reduces wind age losses. This system requires special handling during startup, with air in the chamber first displaced by carbon dioxide before filling with hydrogen. This ensures that the highly explosive hydrogen–oxygen environment is not created.

The power grid frequency is 60 Hz across North America and 50 Hz in Europe, Oceania, Asia (Korea and parts of Japan are notable exceptions) and parts of Africa. The desired frequency affects the design of large turbines, since they are highly optimized for one particular speed.

The electricity flows to a distribution yard where transformers increase the voltage for transmission to its destination.

The steam turbine-driven generators have auxiliary systems enabling them to work satisfactorily and safely. The steam turbine generator being rotating equipment generally has a heavy, large diameter shaft. The shaft therefore requires not only supports but also has to be kept in position while running. To minimize the frictional resistance to the rotation, the shaft has a number of bearings. The bearing shells, in which the shaft rotates, are lined with a low friction material like Babbitt metal. Oil lubrication is provided to further reduce the friction between shaft and bearing surface and to limit the heat generated.

2.1.13 Stack gas path and cleanup

As the combustion flue gas exits the boiler it is routed through a rotating flat basket of metal mesh which picks up heat and returns it to incoming fresh air as the basket rotates, This is called the air preheater. The gas exiting the boiler is laden with fly ash, which are tiny spherical ash particles. The flue gas contains nitrogen along with combustion products carbon dioxide, sulfur dioxide, and nitrogen oxides. The fly ash is removed by fabric bag filters or electrostatic precipitators. Once removed, the fly ash byproduct can sometimes be used in the manufacturing of concrete. This cleaning up of flue gases, however, only occurs in plants that are fitted with the appropriate technology. Still, the majority of coal-fired power plants in the world do not have these facilities.[citation needed] Legislation in Europe has been efficient to reduce flue gas pollution. Japan has been using flue gas cleaning technology for over 30 years and the US has been doing the same for over 25 years. China is now beginning to grapple with the pollution caused by coal-fired power plants.

Where required by law, the sulfur and nitrogen oxide pollutants are removed by stack gas scrubbers which use a pulverized limestone or other alkaline wet slurry to remove those pollutants from the exit stack gas. Other devices use catalysts to remove Nitrous Oxide compounds from the flue gas stream. The gas travelling up the flue gas stack may by this time have dropped to about 50 °C (120 °F). A typical flue gas stack may be 150–180 meters (490–590 ft) tall to disperse the remaining flue gas components in the atmosphere. The tallest flue gas stack in the world is 419.7 meters (1,377 ft) tall at the GRES-2 power plant in Ekibastuz, Kazakhstan.

In the United States and a number of other countries, atmospheric dispersion modeling studies are required to determine the flue gas stack height needed to comply with the local air pollution regulations. The United States also requires the height of a flue gas stack to comply with what is known as the "Good Engineering Practice (GEP)" stack height. In the case of existing flue gas stacks that exceed the GEP stack height, any air pollution dispersion modeling studies for such stacks must use the GEP stack height rather than the actual stack height.

2.1.14 Fly ash collection

Fly ash is captured and removed from the flue gas by electrostatic precipitators or fabric bag filters (or sometimes both) located at the outlet of the furnace and before the induced draft fan. The fly ash is periodically removed from the collection hoppers below the precipitators or bag filters. Generally, the fly ash is pneumatically transported to storage silos for subsequent transport by trucks or railroad cars.

2.1.15 Bottom ash collection and disposal

At the bottom of the furnace, there is a hopper for collection of bottom ash. This hopper is always filled with water to quench the ash and clinkers falling down from the furnace. Some arrangement is included to crush the clinkers and for conveying the crushed clinkers and bottom ash to a storage site. Ash extractor is used to discharge ash from Municipal solid waste–fired boilers.

2.1.16 Auxiliary systems

Boiler make-up water treatment plant and storage

Since there is continuous withdrawal of steam and continuous return of condensate to the boiler, losses due to bolwdown and leakages have to be made up to maintain a desired water level in the boiler steam drum. For this, continuous make-up water is added to the boiler water system. Impurities in the raw water input to the plant generally consist of calcium and magnesium salts which impart hardness to the water. Hardness in the make-up water to the boiler will form

deposits on the tube water surfaces which will lead to overheating and failure of the tubes. Thus, the salts have to be removed from the water, and that is done by water demineralising treatment plant (DM). A DM plant generally consists of cat ion, anion, and mixed bed exchangers. Any ions in the final water from this process consist essentially of hydrogen ions and hydroxide ions, which recombine to form pure water. Very pure DM water becomes highly corrosive once it absorbs oxygen from the atmosphere because of its very high affinity for oxygen.

The capacity of the DM plant is dictated by the type and quantity of salts in the raw water input. However, some storage is essential as the DM plant may be down for maintenance. For this purpose, a storage tank is installed from which DM water is continuously withdrawn for boiler make-up. The storage tank for DM water is made from materials not affected by corrosive water, such as PVC. The piping and valves are generally of stainless steel. Sometimes, a steam blanketing arrangement or stainless steel doughnut float is provided on top of the water in the tank to avoid contact with air. DM water make-up is generally added at the steam space of the surface condenser (i.e., the vacuum side). This arrangement not only sprays the water but also DM water gets desecrated, with the dissolved gases being removed by a de-aerator through an ejector attached to the condenser.

2.1.17 Fuel preparation system

In coal-fired power stations, the raw feed coal from the coal storage area is first crushed into small pieces and then conveyed to the coal feed hoppers at the boilers. The coal is next pulverized into a very fine powder. The pulverizes may be ball mills, rotating drum grinders, or other types of grinders.

Some power stations burn fuel oil rather than coal. The oil must kept warm (above its pour point) in the fuel oil storage tanks to prevent the oil from congealing and becoming unpumpable. The oil is usually heated to about 100 °C before being pumped through the furnace fuel oil spray nozzles.

Boilers in some power stations use processed natural gas as their main fuel. Other power stations may use processed natural gas as auxiliary fuel in the event that their main fuel supply (coal or oil) is interrupted. In such cases, separate gas burners are provided on the boiler furnaces.

2.1.18 Barring gear

Barring gear (or "turning gear") is the mechanism provided to rotate the turbine generator shaft at a very low speed after unit stoppages. Once the unit is "tripped" (i.e., the steam inlet valve is closed), the turbine coasts down towards standstill. When it stops completely, there is a tendency for the turbine shaft to deflect or bend if allowed to remain in one position too long. This is because the heat inside the turbine casing tends to concentrate in the top half of the casing, making the top half portion of the shaft hotter than the bottom half. The shaft therefore could wrap or bend by millionths of inches.

This small shaft deflection, only detectable by eccentricity meters, would be enough to cause damaging vibrations to the entire steam turbine generator unit when it is restarted. The shaft is therefore automatically turned at low speed (about one percent rated speed) by the barring gear until it has cooled sufficiently to permit a complete stop.

2.1.19 Oil system

An auxiliary oil system pump is used to supply oil at the start-up of the steam turbine generator. It supplies the hydraulic oil system required for steam turbines main inlet steam stop valve, the governing control valves, the bearing and seal oil systems, the relevant hydraulic relays and other mechanisms.

At a preset speed of the turbine during start-ups, a pump driven by the turbine main shaft takes over the functions of the auxiliary system.

2.1.20 Generator cooling

While small generators may be cooled by air drawn through filters at the inlet, larger units generally require special cooling arrangements. Hydrogen gas cooling, in an oil-sealed casing, is used because it has the highest known heat transfer coefficient of any gas and for its low viscosity which reduces wind age losses. This system requires special handling during start-up, with air in the generator enclosure first displaced by carbon dioxide before filling with hydrogen. This ensures that the highly flammable hydrogen does not mix with oxygen in the air.

The hydrogen pressure inside the casing is maintained slightly higher than atmospheric pressure to avoid outside air ingress. The hydrogen must be sealed against outward leakage where the shaft emerges from the casing. Mechanical seals around the shaft are installed with a very small annular gap to avoid rubbing between the shaft and the seals. Seal oil is used to prevent the hydrogen gas leakage to atmosphere.

The generator also uses water cooling. Since the generator coils are at a potential of about 22 KV, an insulating barrier such as Teflon is used to interconnect the water line and the generator high-voltage windings. Dematerialized water of low conductivity is used.

2.1.21 Generator high-voltage system

The generator voltage for modern utility-connected generators ranges from 11 kV in smaller units to 22 kV in larger units. The generator high-voltage leads are normally large aluminum channels because of their high current as compared to the cables used in smaller machines. They are enclosed in well-grounded aluminum bus ducts and are supported on suitable insulators. The generator high-voltage leads are connected to step-up transformers for connecting to a high-voltage electrical substation (usually in the range of 115 kV to 765 kV) for further transmission by the local power grid.

The necessary protection and metering devices are included for the high-voltage leads. Thus, the steam turbine generator and the transformer form one unit. Smaller units may share a common generator step-up transformer with individual circuit breakers to connect the generators to a common bus.

2.1.22 Monitoring and alarm system

Most of the power plant operational controls are automatic. However, at times, manual intervention may be required. Thus, the plant is provided with monitors and alarm systems that alert the plant operators when certain operating parameters are seriously deviating from their normal range.

2.1.23 Battery-supplied emergency lighting and communication

A central battery system consisting of lead acid cell units is provided to supply emergency electric power, when needed, to essential items such as the power plant's control systems, communication systems, turbine lube oil pumps, and emergency lighting. This is essential for a safe, damage-free shutdown of the units in an emergency situation.

2.1.24 Transport of coal fuel to site and to storage

Most thermal stations use coal as the main fuel. Raw coal is transported from coal mines to a power station site by trucks, barges, bulk cargo ships or railway cars. Generally, when shipped

Shipped by railways, the coal cars are sent as a full train of cars. The coal received at site may be of different sizes. The railway cars are unloaded at site by rotary dumpers or side tilt dumpers to tip over onto conveyor belts below. The coal is generally conveyed to crushers which crush the coal to about ¾ inch (19 mm) size. The crushed coal is then sent by belt conveyors to a storage pile. Normally, the crushed coal is compacted by bulldozers, as compacting of highly volatile coal avoids spontaneous ignition.

The crushed coal is conveyed from the storage pile to silos or hoppers at the boilers by another belt conveyor system.

CHAPTER 3

3.0 Hydroelectricity

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation – 3,427 terawatt-hours of electricity production in 2010, and is expected to increase about 3.1% each year for the next 25 years.

Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. There are now four hydroelectricity stations larger than 10 GW: the Three Gorges Dam and XiluoduDam in China, Itapúa Dam across the Brazil/Paraguay border, and Guru Dam in Venezuela.

The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. The average cost of electricity from a hydro station larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour. It is also a flexible source of electricity since the amount produced by the station can be changed up or down very quickly to adapt to changing energy demands. However, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide ($CO2$) than fossil fuel powered energy plants.

3.1 Generating methods

Conventional (dams)

Hydroelectric power stations

Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head. The amount of potential energy in water is proportional to the head. A large pipe (the "penstock") delivers water to the turbine.

3.1.1 Pumped-storage

This method produces electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low electrical demand, excess generation capacity is used to pump water into the higher reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine. Pumped-storage schemes currently provide the most commercially important means of large-scale grid energy storage and improve the daily capacity factor of the generation system. Pumped storage is not an energy source, and appears as a negative number in listings.

3.1.2 Run of the river

Run of the river hydroelectric stations are those with small or no reservoir capacity, so that the water coming from upstream must be used for generation at that moment, or must be allowed to bypass the dam. In the United States, run of the river hydropower could potentially provide 60,000 MW (about 13.7% of total use in 2011 if continuously available).

3.1.3 Large facilities

Although no official definition exists for the capacity range of large hydroelectric power stations, facilities from over a few hundred megawattsto more than 10 GW are generally considered large hydroelectric facilities. Currently, only three facilities over 10 GW (10,000 MW) are in operation worldwide; Three Gorges Dam at 22.5 GW, Itaipu Dam at 14 GW, and Guri Dam at 10.2 GW. Large-scale hydroelectric power stations are more commonly seen as the largest power producing facilities in the world, with some hydroelectric facilities capable of generating

3.1.4 Small

Small hydro is the development of hydroelectric power on a scale serving a small community or industrial plant. The definition of a small hydro project varies but a generating capacity of up to 10 megawatts (MW) is generally accepted as the upper limit of what can be termed small hydro. This may be stretched to 25 MW and 30 MW in Canada and the Unite. Small-scale hydroelectricity production grew by 28% during 2008 from 2005, raising the total world small-hydro capacity to 85 GW. Over 70% of this was Chan in (65 GW), followed by Japan (3.5 GW), the United States (3 GW), and India (2 GW).

Small hydro stations may be connected to conventional electrical distribution networks as a source of low-cost renewable energy. Alternatively, small hydro projects may be built in isolated areas that would be uneconomic to serve from a network, or in areas where there is no national electrical distribution network. Since small hydro projects usually have minimal reservoirs and civil construction work, they are seen as having a relatively low environmental impact compared to large hydro. This decreased environmental impact depends strongly on the balance between stream flow and power production.

3.1.5 Micro

Micro hydro is a term used for hydroelectric power installations that typically produce up to 100 KW of power. These installations can provide power to an isolated home or small community, or are sometimes connected to electric power networks. There are many of these installations around the world, particularly in developing nations as they can provide an economical source of energy without purchase of fuel. Micro hydro systems complement photovoltai solar energy systems because in many areas, water flow, and thus available hydro power, is highest in the winter when solar energy is at a minimum.

3.1.6 Pico

Pico hydro is a term used for hydroelectric power generation of under 5 KW. It is useful in small, remote communities that require only a small amount of electricity. For example, to power one or two fluorescent light bulbs and a TV or radio for a few homes. Even smaller turbines of 200-300W may power a single home in a developing country with a drop of only 1 m (3 ft). A Pico-hydro setup is typically run-of-the-river, meaning that dams are not used, but rather pipes divert some of the flow, drop this down a gradient, and through the turbine before returning it to the stream.

3.1.7 Calculating available power

A simple formula for approximating electric power production at a hydroelectric station is:, where

$p = \rho \ h \ q \ g \ \eta$ …………..{3.1}

- p is Power in watts,
- ρ is the density of water (~1000 kg/m^3),
- h is height in meters,
- q is flow rate in cubic meters per second,
- g is acceleration due to gravity of 9.8 m/s^2,
- η is a coefficient of efficiency ranging from 0 to 1. Efficiency is often higher (that is, closer to 1) with larger and more modern turbines.

Annual electric energy production depends on the available water supply. In some installations, the water flow rate can vary by a factor of 10:1 over the course of a year.

3.1.8 Advantages and disadvantages

Advantages

Flexibility

Hydro is a flexible source of electricity since stations can be ramped up and down very quickly to adapt to changing energy demands. Hydro turbines have a start-up time of the order of a few minutes. It takes around 60 to 90 seconds to bring a unit from cold start-up to full load; this is much shorter than for gas turbines or steam plants. Power generation can also be decreased quickly when there is a surplus power generation. Hence the limited capacity of hydropower units is not generally used to produce base power except for vacating the flood pool or meeting downstream needs. Instead, it serves as backup for non-hydro generators.

3.1.9 Low power costs

The major advantage of hydroelectricity is elimination of the cost of fuel. The cost of operating a hydroelectric station is nearly immune to increases in the cost of fossil fuels such as oil, natural gas or coal, and no imports are needed. The average cost of electricity from a hydro station larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour.

Hydroelectric stations have long economic lives, with some plants still in service after 50–100 years. Operating labor cost is also usually low, as plants are automated and have few personnel on site during normal operation.

Where a dam serves multiple purposes, a hydroelectric station may be added with relatively low construction cost, providing a useful revenue stream to offset the costs of dam operation. It has been calculated that the sale of electricity from the Three Gorges Dam will cover the construction costs after 5 to 8 years of full generation. Additionally, some data shows that in most countries large hydropower dams will be too costly and take too long to build to deliver a positive risk adjusted return, unless appropriate risk management measures are put in place.

3.1.10 Suitability for industrial applications

While many hydroelectric projects supply public electricity networks, some are created to serve specific industrial enterprises. Dedicated hydroelectric projects are often built to provide the substantial amounts of electricity needed for aluminium electrolytic plants, for example. The Grand Coulee Dam switched to support Alcoa aluminum in Bellingham, Washington, United States for American World War II airplanes before it was allowed to provide irrigation and power to citizens (in addition to aluminum power) after the war. In Suriname, the Brokopondo Reservoir was constructed to provide electricity for the Alocaaluminium industry. New Zealand's Manipuri Power Station was constructed to supply electricity to the aluminium smelter at Tiwai Point.

3.1.11 Reduced CO_2 emissions

Since hydroelectric dams do not burn fossil fuels, they do not directly produce carbon dioxide. While some carbon dioxide is produced during manufacture and construction of the project, this is a tiny fraction of the operating emissions of equivalent fossil-fuel electricity generation. One measurement of greenhouse gas related and other externality comparison between energy sources can be found in the Extreme project by the Paul ScherrerInstitut and the University of Stuttgart which was funded by the Europen Commission. According to that study, hydroelectricity produces the least amount of greenhouse gases and externality of any energy source. Coming in second place was wind, third was nuclear energy, and fourth was solar photovoltaic. The low greenhouse gas impact of hydroelectricity is found especially in temperate climates. The above study was for local energy in Europe; presumably similar conditions prevail in North America and Northern Asia, which all see a regular, natural freeze/thaw cycle (with associated seasonal plant decay and regret). Greater greenhouse gas emission impacts are found in the tropical regions because the reservoirs of power stations in tropical regions produce a larger amount of methane than those in temperate areas.

3.1.12 other uses of the reservoir

Reservoirs created by hydroelectric schemes often provide facilities for water sports, and become tourist attractions themselves. In some countries, aquaculture in reservoirs is common. Multi-use dams installed for irrigation support agriculture with a relatively constant water supply. Large hydro dams can control floods, which would otherwise affect people living downstream of the project.

3.1.13 Disadvantages

Ecosystem damage and loss of land

Large reservoirs required for the operation of hydroelectric power stations result in submersion of extensive areas upstream of the dams, destroying biologically rich and productive lowland and riverine valley forests, marshland and grasslands. The loss of land is often exacerbated by habitat fragmentation of surrounding areas caused by the reservoir.

Hydroelectric projects can be disruptive to surrounding aquatic ecosystems both upstream and downstream of the plant site. Generation of hydroelectric power changes the downstream river environment. Water exiting a turbine usually contains very little suspended sediment, which can lead to scouring of river beds and loss of riverbanks. Since turbine gates are often opened intermittently, rapid or even daily fluctuations in river flow are observed.

3.1.14 Siltation and flow shortage

When water flows it has the ability to transport particles heavier than itself downstream. This has a negative effect on dams and subsequently their power stations, particularly those on rivers or within catchment areas with high siltation. Siltation can fill a reservoir and reduce its capacity to control floods along with causing additional horizontal pressure on the upstream portion of the dam. Eventually, some reservoirs can become full of sediment and useless or over-top during a flood and fail.

Changes in the amount of river flow will correlate with the amount of energy produced by a dam. Lower river flows will reduce the amount of live storage in a reservoir therefore reducing the amount of water that can be used for hydroelectricity. The result of diminished river flow can be power shortages in areas that depend heavily on hydroelectric power. The risk of flow shortage may increase as a result of climate change. One study from the Colorado River in the United States suggest that modest climate changes, such as an increase in temperature in 2 degree Celsius resulting in a 10% decline in precipitation, might reduce river run-off by up to 40%. Brazil in particular is vulnerable due to its heaving reliance on hydroelectricity, as increasing temperatures, lower water flow and alterations in the rainfall regime, could reduce total energy production by 7% annually by the end of the century.

3.1.15 Methane emissions (from reservoirs)

Lower positive impacts are found in the tropical regions, as it has been noted that the reservoirs of power plants in tropical regions produce substantial amounts of methane. This is due to plant material in flooded areas decaying in an anaerobic environment, and forming methane, a greenhouse gas. According to the World Commission on Dams report, where the reservoir is large compared to the generating capacity (less than 100 watts per square metre of surface area) and no clearing of the forests in the area was undertaken prior to impoundment of the reservoir, greenhouse gas emissions from the reservoir may be higher than those of a conventional oil-fired thermal generation plant.

In boreal reservoirs of Canada and Northern Europe, however, greenhouse gas emissions are typically only 2% to 8% of any kind of conventional fossil-fuel thermal generation. A new class of underwater logging operation that targets drowned forests can mitigate the effect of forest decay.

3.1.16 Relocation

Another disadvantage of hydroelectric dams is the need to relocate the people living where the reservoirs are planned. In 2000, the World Commission on Dams estimated that dams had physically displaced 40-80 million people worldwide.

3.1.17 Failure risks

Because large conventional dammed-hydro facilities hold back large volumes of water, a failure due to poor construction, natural disasters or sabotage can be catastrophic to downriver settlements and infrastructure. Dam failures have been some of the largest man-made disasters in history.

The Banqiao Dam failure in Southern China directly resulted in the deaths of 26,000 people, and another 145,000 from epidemics. Millions were left homeless. Also, the creation of a dam in a geologically inappropriate location may cause disasters such as 1963 disaster at Vajont Dam in Italy, where almost 2,000 people died.

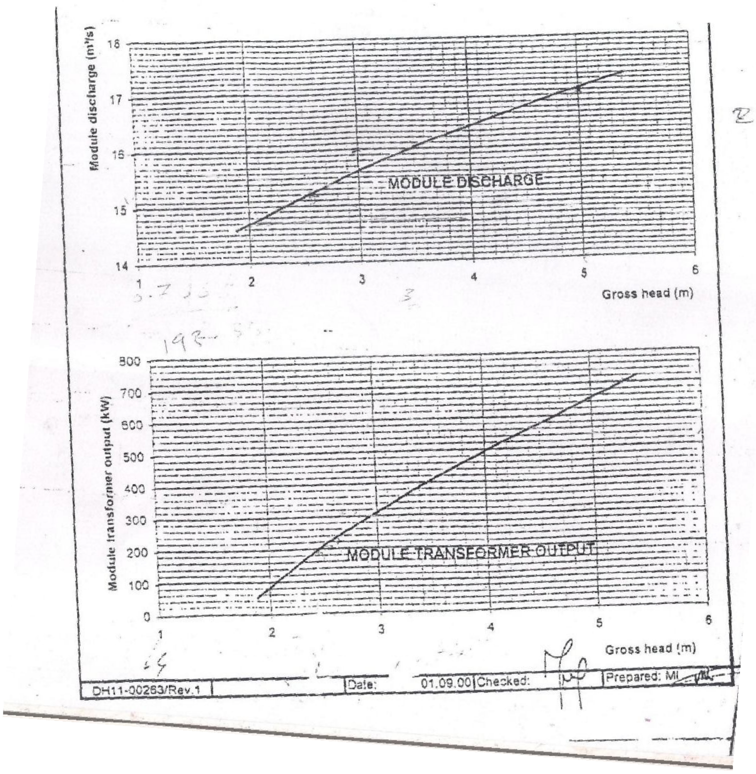
Smaller dams and micro hydro facilities create less risk, but can form continuing hazards even after being decommissioned. For example, the small Kelly Barnes Dam failed in 1967, causing 39 deaths with the Toccoa Flood, ten years after its power station was decommissioned.

3.1.18 Comparison with other methods of power generation

Hydroelectricity eliminates the flue gas emissions from fossil fuel combustion, including pollutants such as sulfur dioxide, nitric oxide, carbon monoxide, dust, and mercury in the coal. Hydroelectricity also avoids the hazards of coal mining and the indirect health effects of coal emissions. Compared to nuclear power, hydroelectricity generates no nuclear waste, has none of the dangers associated with uranium mining, nor nuclear leaks.

Compared to wind farms, hydroelectricity power stations have a more predictable load factor. If the project has a storage reservoir, it can generate power when needed. Hydroelectric stations can be easily regulated to follow variations in power demand.

CHAPTER 4
RESULTS



Refering to equation (3.1) we can carry out the efficiency

$\eta = (\Delta p/\Delta h)/g\rho(n\Delta Q/\Delta h+Q)$

Slope = $\Delta Q/\Delta H$ =1.4/2=0.7

Slope = $\Delta P/\Delta h$ =340/2=170

Q1 =17.3

Q2 =14.6

Q =(Q1+Q2)/2

Q=(17.3 +14.6)/2 =15.95

H1 =5.4

H2 =1.8

H =(h1 +h2)/2

H =(5.4+1.8)/2 =3.6

η=(170*1000)/(1000*9.8(3.6*0.7+15.95)) =94%

Conclusion

In this research project we studied and discussed on of the method of generating electricity that’s hydropower electric generation.

 we considered GablAwlia dam as aspecial case We found that the Dam has high efficiently which is about 94%. This high efficiency could be exptained due to that all fact the measurements were taken during the rainy season.

Reference

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