Lesson2-Section2

Electric Power Stations

Characteristics Influencing Generation and Transmission

There are four main characteristics of electricity supply which, however obvious, have a profound effect on the manner in which it is engineered. They are as follows:

(a) Electricity, unlike gas and water, cannot be stored and the supplier has little control over the load at any time. The control engineers endeavor to keep the output from the generators equal to the connected load at the specified voltage and frequency.

(b) There is a continuous increase in the demand for power. Although in industrialized countries the rate of increase has declined in recent years, even the modest rate entails massive additions to the existing systems. A large and continuous process of adding to the system thus exists. Networks are evolved over the years rather than planned in a clear-cut manner and then left untouched.

(c) The distribution and nature of the *fuel* available. This aspect is of great interest as coal is mined in areas not necessarily the main load centres; hydroelectric power is usually remote from the large load centres. The problem of station siting and transmission distances is an involved exercise in economics. The greater use of nuclear energy will tend to modify the existing pattern of supply.

(d) In recent years environmental considerations have assumed major importance and influence the siting, construction cost, and operation of generating plants. Planning is also affected because of delays in making a start to projects because of legal proceedings, etc. Of particular importance at the present time is the question of the environmental impact of nuclear plants, especially the proposed fast breeder reactor.

Energy Conversion Employing Steam

The combustion of coal or oil in boilers produces steam at high temperatures and pressures which is passed to steam turbines. Oil has economic advantages when it can be pumped from the refinery through pipelines direct to the boilers of the generating station. The use of energy resulting from nuclear fission is being progressively extended in electricity generation; here also the basic energy is used to produce steam for turbines. The axial-flow type of turbine is in common use with several cylinders on the same shaft.

The steam power station operates on the Rankine cycle, modified to include muted superheating, feed-waterheating, and steam reheating. Increased thermal efficiency results from the use of steam at the highest possible pressure and temperature .Also , for turbines to be economically constructed 500 MW and over a re now being used. With steam turbines of 100 MW capacity and over the efficiency is increased by reheating the steam after it has been partially expanded , by an external heater . The reheated steam is then

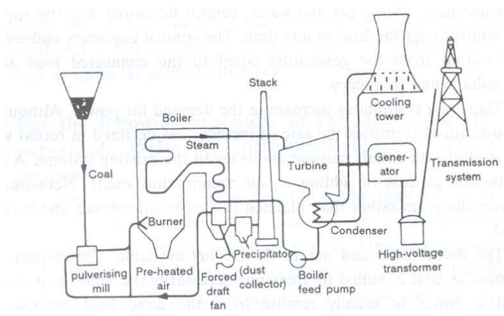

Figure 2-1. Schematic View of Coal-Fired Generating Station.

Figure returned to the turbine where it is expanded through the final stages of blading. A schematic diagram of a coal-fired station is shown in Figure 2-1. In Figure 2-2, the flow of energy in a modern steam station is shown. Despite continual advances in the design of boilers and in the development of improved materials, the nature of the steam cycle is such that efficiencies are comparatively low and vast quantities of heat are lost in the condensate. However, the great advances in design and materials in the last few years have increased the thermal efficiencies of coal stations to about 40 percent.

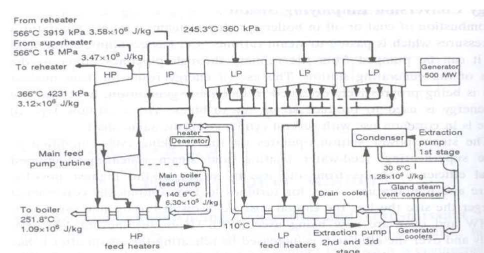

Figure 2-2. Energy Flow Diagram for a 500 MW Turbo-Generator.

In coal-fired stations, coal is conveyed to a mill and crushed into fine powder i.e., pulverised. The pulverized fuel is blown into the boiler where it mixes with a supply of air for combustion. The exhaust from the LP turbine is cooled to form condensate by the passage through the condenser of large quantities of sea- or river-water. Where this is not possible cooling towers are used.

Fluidized-Bed Boilers. For typical coals, combustion gases contain 0.2-0.3 percent sulphur dioxide by volume. If the gas flow-rate through the granular bed of a great-type boiler is increased the gravity pull is balanced by the upward gas force and the fuel-bed lakes on the character of a fluid. In a travelling grate this increases the heat output and temperature. The ash formed conglomerates and sinks into the grate and is carried to the ash pit. The bed is limited to the ash-sintering temperature of 1050-1200°C. Secondary combustion occurs above the bed where CO burns to CO_2 and H_2S to SO_2. This type of boiler is undergoing extensive development and is attractive because of the lower pollutant level and better efficiency.

Energy Conversion Using Water

Perhaps the oldest form of energy conversion is by the use of water power. In the hydroelectric station the energy is obtained free of cost. This attractive feature has always been somewhat offset by the very high capital cost of construction, especially of the civil engineering works. Today, however, the capital cost per kilowatt of hydroelectric stations is becoming comparable with that of steam stations. Unfortunately, the geographical conditions necessary for hydro-generation are not commonly found. In most highly developed countries hydroelectric resources are used to the utmost.

An alternative to the conventional use of water energy, pumped storage, enables water to be used in situations which would not be amenable to conventional schemes. The utilization of the energy in tidal flows in channels has long been the subject of speculation. The technical and economic difficulties are very great and few locations exist where such a scheme would be feasible. An installation using tidal flow has been constructed on the La Rance estuary in northern France where the tidal height range is 9.2 m (30 ft) and the tidal flow is estimated at 18,000 m^3/s.

Before discussing the types of turbine used, a brief comment on the general modes of operation of hydroelectric stations will be given. The vertical difference between the upper reservoir and the level of the turbines is known head. The water falling through this head gains kinetic energy which it then imparts to the turbine blades. There are three main types of installation as follows:

(a) *High. Head* or *Stored*-the storage area or reservoir normally fills in over 400 h;

(b) *Medium Head* or Pondage-storage Tills in 200-400 h;

(c) *Run of River-storage* fills in less than 2 h and has 3-15 m head.

A schematic diagram for type (c) is shown in Figure 2-3.

Associated with these various heights or heads of water level above the turbines are particular types of turbine. These are:

(a) *Pelton.* This is used for heads of 184-1840 m (600-6000 it) and consists of a bucket wheel rotor with adjustable How nozzles.

(b) *Francis.* Used for heads of 37-490 m (120-1600 ft) and is of the mixed flow type.

(c) *Kaplan.* Used for run of river and pondage stations with heads of up to 61 m (200 ft). This type has an axial-flow rotor with variable-pitch blades.

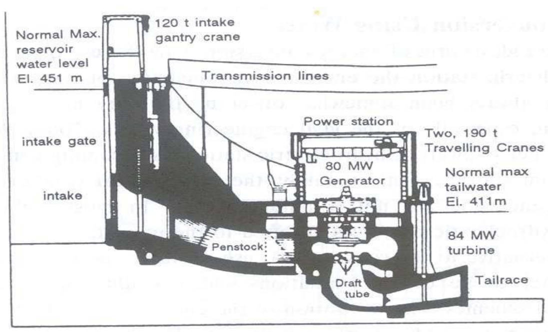

Figure 2-3. Hydroelectric Scheme —Kainji, Nigeria. Section through the intake dam and power house. The scheme comprises an initial four 80 MW Kaplan turbine sets with the later installation of eight more sets. Running speed 115.4 rev/min. This is a large-flow scheme with penstocks 9 m in diameter. *(Permission of Engineering.)*

Typical efficiency curves for each type of turbine are shown in Figure 2-4. As the efficiency depends upon the head of water which is continually fluctuating, often water consumption in cubic meters per kilowatt-hour is used and is related to the head of water. Hydroelectric plant has the ability to start UP quickly and the advantage that no losses are incurred when at a standstill. It has great advantages, therefore, for generation to meet peak loads at minimum cost, working in conjunction with thermal station. By using remote control of the hydro sets, the time from the instruction to start up to the actual connexion to the power network can be as short as 2 min

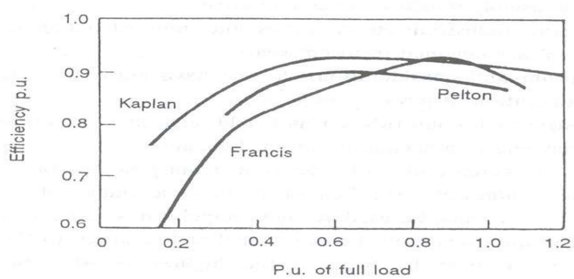

Figure 2-4. Typical Efficiency Curves of Hydraulic Turbines.

Gas Turbines

The use of the gas turbine as a prime mover has certain advantages over steam plant, although with normal running it is less economical to operate. The main advantage lies in the ability to start and take up load quickly. Hence the gas turbine is coming into use as a method for dealing with the peaks of the system load. A further use for this type of machine is as a synchronous compensator to assist with maintaining voltage levels. Even on economic grounds it is probably advantageous to meet peak loads by starting up gas turbines from cold in the order of 2 min rather than running spare steam plant continuously.

Comprehension Exercises

Choose a, b, c, or d which best completes each item.

1. We may deduce from the text that ....
   a. since electricity cannot be stored, enough electricity must be generated at all times to meet the variations in demand

b. since the supplier does not have control over the load, variations in demand have to be limited to certain degrees

c. gas, water, and electricity can be stored to satisfy the unexpected increases in demand

d. gas, water, and power systems are not amenable to ordinary energy requirements

2. It is true that ....

a. coal is usually mined in accessible areas

b. in many industrialized countries the rate of increase in power demand has declined in recent years

c. environmental considerations do not have any effect on the siting and operation of power plants

d. industrialized countries do not add any new networks to their systems due to a decline in power demand

3. In order to increase the efficiency of a steam power station, ...

a. steam turbines of 100 MW capacity must be employed

b. coal and oil must be used at high temperatures and pressures

c. the reheated steam must be expanded and returned to the turbine

d. the steam must be used at the highest possible pressure and temperature

4. It is true that ....

a. the advances in the design of boilers have not affected the efficiency of coal stations

b. coal stations have low efficiencies because of the heat lost in the steam cycle

c. systems operating on the steam cycle have high efficiencies

d. the MW capacity of all the steam turbines used today is over 500

5. In fluidized-bed boilers …..... .

a. the upward gas force causes the fuel-bed to take the character of a fluid

b. the fluid characteristic of the fuel-bed increases the heat output

c. CO burns to CO2 and H_2S to SO_2.

d. all of the above

6. The use of energy in tidal flows ....

a. has greatly replaced the conventional use of water energy

b. has enabled man to make use of water energy wherever he likes

c. may be an alternative to the conventional use of water energy

d. is a common way of using water energy without any difficulties

7. The last paragraph mainly discusses ....
    a. how the gas turbine deals with the peaks of the system load
    b. how the gas turbine is used as a synchronous machine
    c. the advantages of the gas turbine
    d. the mechanism of the gas turbine

B Write the answers to the following questions.

1 What are the four main characteristics of electricity supply?
2. What are coal and nuclear energy used for?
3. What **is** the function of an external heater?
4. What process does the coal go through in coal-fired stations?
5. When are cooling towers used in coal-fired systems?
6. Why are fluidized-bed boilers called so?
7. What are the advantages of fluidized-bed boilers?
8. What is the most prominent feature of hydroelectric power stations?
9. What are the initial requirements for hydro-generation?
10. How does water obtain the energy required to impart to the turbine blades?
11. What are the three types of installation?
12. What is the head of water?
13. How is Kaplan turbine different from Francis and Pelton turbines?

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