Lecture 4: Variable Load on Power Stations

The function of a power station is to deliver power to a large number of consumers. However, the power demands of different consumers vary in accordance with their activities. The result of this variation in demand is that load on a power station is never constant, rather it varies from time to time. Most of the complexities of modern power plant operation arise from the inherent variability of the load demanded by the users. Unfortunately, electrical power cannot be stored and, therefore, the power station must produce power as and when demanded to meet the requirements of the consumers. On one hand, the power engineer would like that the alternators in the power station should run at their rated capacity for maximum efficiency and on the other hand, the demands of the consumers have wide variations. This makes the design of a power station highly complex.

4.1 Variable Load on Power Station

The load on a power station varies from time to time due to uncertain demands of the consumers and is known as variable load on the station.

A power station is designed to meet the load requirements of the consumers. An ideal load on the station, from stand point of equipment needed and operating routine, would be one of constant magnitude and steady duration. However, such a steady load on the station is never realized in actual practice. The consumers require their small or large block of power in accordance with the demands of their activities.

Effects of variable load

(i) Need of additional equipment. The variable load on a power station necessitates to have additional equipment. In a modern power plant, there is much equipment devoted entirely to adjust the rates of supply of raw materials in accordance with the power demand made on the plant.

(ii) Increase in production cost. The variable load on the plant increases the cost of the production of electrical energy. An alternator operates at maximum efficiency near its rated capacity. If a single alternator is used, it will have poor efficiency during periods of light loads on the plant. Therefore, in actual practice, a number of alternators of different capacities are installed so that most of the alternators can be operated at nearly full load capacity.

4.2 Load Curves

The curve showing the variation of load on the power station with respect to (*w.r.t*) *time is known as a* load curve. The load on a power station is never constant; it varies from time to time. These load variations during the whole day (*i.e.,* 24 hours) are recorded half-hourly or hourly and are plotted against time on the graph. The curve thus obtained is known as *daily load curve* as it shows the variations of load *w.r.t.* time during the day.

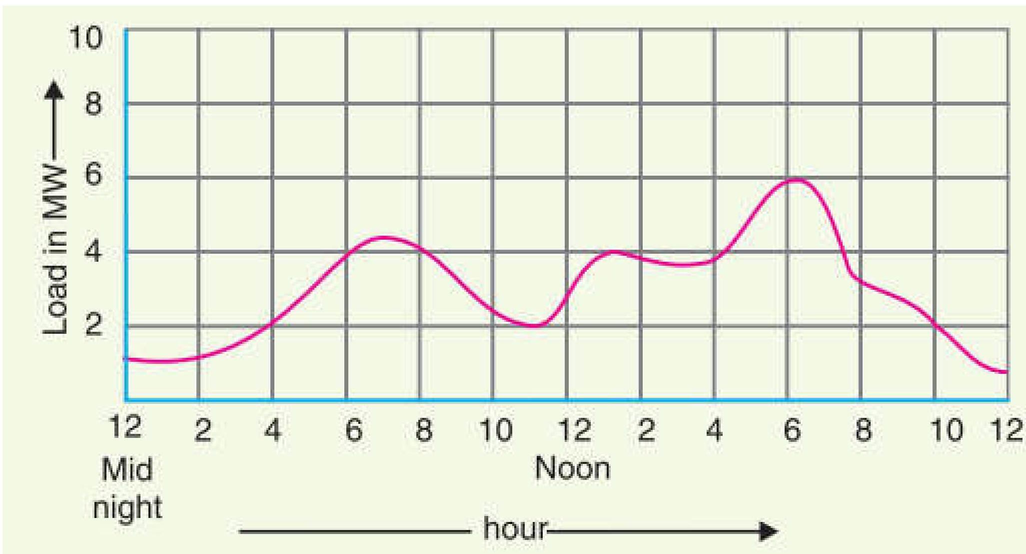

Figure 4.1

Fig. 4.1. Shows a typical daily load curve of a power station. It is clear that load on the power station is varying, being maximum at 6 P.M. in this case. It may be seen that load curve indicates at a glance the general character of the load that is being imposed on the plant.

The *monthly load curve* can be obtained from the daily load curves of that month. For this purpose, average* values of power over a month at different times of the day are calculated and then plotted on the graph. The monthly load curve is generally used to fix the rates of energy. The *yearly load curve* is obtained by considering the monthly load curves of that particular year. The yearly load curve is generally used to determine the annual load factor.

Note: *The daily load curves have attained a great importance in generation as they supply the following information readily:*

(i) T*he daily load curve shows the variations of load on the power station during different hours of the day.*

(ii) *The area under the daily load curve gives the number of units generated in the day.*

Units generated/day = Area (in kWh) under daily load curve.

(iii) *The highest point on the daily load curve represents the maximum demand on the station on that day.*

(iv) *The area under the daily load curve divided by the total number of hours gives the average load on the station in the day.*

$Average\ load = = \frac{Area\ (in\ kWh)\ under\ daily\ load\ curve}{24\ hours}$

(v) *The ratio of the area under the load curve to the total area of rectangle in which it is contained gives the load factor.*

$$Load\ Factor = \frac{Average\ load}{Max.demand} = \frac{Average\ load\ \times 24}{Max.demand\ \times 24}$$

$$Load\ Factor = \frac{A\text{Area (in kWh) under daily load curve}}{\text{Total area of rectangle in which the load curve is contained}}$$

(***vi***) The load curve helps in selecting the size and number of generating units.

(***vii***) The load curve helps in preparing the operation schedule of the station.

4.3 Important Terms and Factors

(*i*) Connected load. *It is the sum of continuous ratings of all the equipment connected to supply system.*

A power station supplies load to thousands of consumers. Each consumer has certain equipment installed in his premises. The sum of the continuous ratings of all the equipment in the consumer's premises is the "connected load" of the consumer.

(*ii*) Maximum demand: *It is the greatest demand of load on the power station during a given period.*

The load on the power station varies from time to time. The maximum of all the demands that have occurred during a given period (*say* a day) is the maximum demand.

(*iii*) Demand factor. *It is the ratio of maximum demand on the power station to its connected load i.e,*

$$Demand\ factor = \frac{Maximum\ demand}{Connected\ load}$$

The value of demand factor is usually less than 1. It is expected because maximum demand on the power station is generally less than the connected load. The knowledge of demand factor is vital in determining the capacity of the plant equipment.

(*iv*) Average load. *The average of loads occurring on the power station in a given period* (*day or month or year*) *is known as* **average load** *or* **average demand**

$$Daily\ average\ load = \frac{No. of\ units\ (kWh)\ generated\ in\ a\ day}{24\ hours}$$

$$Monthly\ average\ load = \frac{No. of\ units\ (kWh)\ generated\ in\ a\ month}{Number\ of\ hours\ in\ a\ month}$$

$$Yearly\ average\ load = \frac{No. of\ units\ (kWh)\ generated\ in\ a\ year}{8760\ hours}$$

(*v*) Load factor. *The ratio of average load to the maximum demand during a given period is known as load factor i.e,*

$$Load\ factor = \frac{Average\ load}{Max. demand}$$

If the plant is in operation for T hours,

$$Load\ factor = \frac{Average\ load\ \times T}{Max. demand\ \times T}$$

$$Load\ factor = \frac{Units\ generated\ in\ T\ hours}{Max. demand\ T\ hours}$$

The load factor may be daily load factor, monthly load factor or annual load factor if the time period considered is a day or month or year. Load factor is always less than 1 because average load is smaller than the maximum demand. The load factor plays key role in determining the overall cost per unit generated. Higher the load factor of the power station, lesser will be the cost per unit generated.

(vi) Diversity factor. *The ratio of the sum of individual maximum demands to the maximum demand on power station is known as diversity factor i.e*

$$Diversity\ factor = \frac{Sum\ of\ individual\ max.demands}{Max.demand\ on\ power\ station}$$

A power station supplies load to various types of consumers whose maximum demands generally do not occur at the same time. Therefore, the maximum demand on the power station is always less than the sum of individual maximum demands of the consumers. Obviously, diversity† factor will always be greater than 1. The greater the diversity factor, the lesser is the cost of generation of power.

(*vii*) Plant capacity factor. *It is the ratio of actual energy produced to the maximum possible energy that could have been produced during a given period i.e.*

$$\boldsymbol{Plant\ cap\ acityfactor} = \frac{Actual\ energy\ produced}{Max.energy\ that\ could\ have\ been\ produced}$$

$$= \frac{Average\ demand \times T}{Plant\ capacity \times T}$$

$$= \frac{Average\ demand}{Plant\ capacity}$$

Thus if the considered period is one year,

$$\boldsymbol{Plant\ cap\ acityfactor} = \frac{Annual\ kWh\ output}{Plant\ capacity\ \times 8760}$$

4.4 Units Generated per Annum

It is often required to find the kWh generated per annum from maximum demand and load factor. The procedure is as follows:

$$Load\ factor = \frac{Average\ load}{Max.demand}$$

Average load = Max. demand × L.F

Units generated/annum = Average load (in kW) × Hours in a year

= Max. demand (in kW) × L.F. × 8760

4.5 Types of Loads

A device which taps electrical energy from the electric power system is called a load on the system.

The load may be resistive (e.g., electric lamp), inductive (e.g., induction motor), capacitive or some combination of them. The various types of loads on the power system are :

(i) Domestic load. Domestic load consists of lights, fans, refrigerators, heaters, television, small motors for pumping water etc. Most of the residential load occurs only for some hours during the day (i.e., 24 hours) e.g., lighting load occurs during night time and domestic appliance load occurs for only a few hours. For this reason, the load factor is low (10% to 12%).

(ii) Commercial load. Commercial load consists of lighting for shops, fans and electric appliances used in restaurants etc. This class of load occurs for more hours during the day as compared to the domestic load. The commercial load has seasonal variations due to the extensive use of air conditioners and space heaters.

(iii) Industrial load. Industrial load consists of load demand by industries. The magnitude of industrial load depends upon the type of industry. Thus small scale industry requires load up to 25 kW, medium scale industry between 25kW and 100 kW and large-scale industry requires load above 500 kW. Industrial loads are generally not weather dependent.

(iv) Municipal load. Municipal load consists of street lighting, power required for water supply and drainage purposes. Street lighting load is practically constant throughout the hours of the night. For water supply, water is pumped to overhead tanks by pumps driven by electric motors. Pumping is carried out during the off-peak period, usually occurring during the night. This helps to improve the load factor of the power system.

(v) Traction load. This type of load includes tram cars, trolley buses, railways etc. This class of load has wide variation. During the morning hour, it reaches peak value because people have to go to their work place. After morning hours, the load starts decreasing and again rises during evening since the people start coming to their homes.

Example 4.1

The maximum demand on a power station is 100 MW. If the annual load factor is 40%, calculate the total energy generated in a year.

Solution.

Energy generated/year = Max. demand × L.F. × Hours in a year

$= (100 \times 10^3) \times (0{\cdot}4) \times (24 \times 365)$ kWh

$= 3504 \times 10^5$ kWh

Example 4.2

A generating station has a connected load of 43MW and a maximum demand of 20 MW; the units generated being 61·5 × 106 per annum. Calculate (*i*) *the demand factor and* (*ii*) *load factor*

Solution

$$Demand\ factor = \frac{Max.demand}{Connected\ load} = \frac{20}{43} = 0.465$$

$$Average\ demand = \frac{Units\ generated\ /\ annum}{Hours\ in\ a\ year} = \frac{61.5 \times 10^6}{8760} = 7020kW$$

$$Load\ factor = \frac{Average\ load}{Max.demand} = \frac{7020}{20 \times 10^3} = 0.351\ or\ 35.1\%$$

Example 4.3

A 100 MW power station delivers 100 MW for 2 hours, 50 MW for 6 hours and is shut down for the rest of each day. It is also shut down for maintenance for 45 days each year. Calculate its annual load factor.

Solution:

Energy supplied for each working day

= (100 × 2) + (50 × 6) = 500 MWh

Station operates for = 365 - 45 = 320 days in a year

∴ Energy supplied/year = 500 × 320 = 160,000 MWh

$$Annual\ Load\ factor = \frac{MWh\ supplied\ per\ annum}{Max.demand\ in\ MW\ \times Working\ hours} \times 100$$

$$Annual\ Load\ factor = \frac{160{,}000}{(100) \times (\ 320 \times\ 24)} \times 100 = 20.8\%$$