Lecture Three- Economics of power supply

A power station is required to deliver power to a large number of consumers to meet their requirements. While designing and building a power station, efforts should be made to achieve overall economy so that the per unit cost of production is as low as possible. This will enable the electric supply company to sell electrical energy at a profit and ensure reliable service. The problem of determining the cost of production of electrical energy is highly complex and poses a challenge to power engineers. There are several factors which influence the production cost such as cost of land and equipment, depreciation of equipment, interest on capital investment etc. Therefore, a careful study has to be made to calculate the cost of production.

3. 1 Economics of Power Generation

It is the art of determining the per unit (i.e., one kWh) cost of production of electrical energy.

A consumer will use electric power only if it is supplied at reasonable rate.
Therefore, power engineers have to find convenient methods to produce electric power as cheap as possible so that consumers are tempted to use electrical methods.

(*i*) Interest.

It is *the cost of use of money.* A power station is constructed by investing a huge capital. This money is generally borrowed from banks or other financial institutions and the supply company has to pay the annual interest on this amount. Even if company has spent out of its reserve funds, the interest must be still allowed for, since this amount could have earned interest if deposited in a bank. Therefore, while calculating the cost of production of electrical energy, the interest payable on the capital investment must be included. The rate of interest depends upon market position and other factors, and may vary from 4% to 8% per annum.

(*ii*) Depreciation.

It *is the decrease in the value of the power plant equipment and building due to constant use.* If the power station equipment were to last forever, then interest on the capital investment would have been the only charge to be made. However, in actual practice, every power station has a useful life ranging from fifty to sixty years. From the time the power station is installed, its equipment steadily deteriorates due to wear and tear so that there is a gradual reduction in the

value of the plant.
This reduction in the value of plant every year is known as *annual depreciation*. Due to depreciation, the plant has to be replaced by the new one after its useful life. Therefore, suitable amount must be set aside every year so that by the time the plant retires, the collected amount by way of depreciation equals the cost of replacement. It becomes obvious that while determining the cost of production, annual depreciation charges must be included.

3.2 Cost of Electrical Energy

The total cost of electrical energy generated can be divided into three parts, namely;

i. Fixed cost;
ii. Semi-fixed cost;
iii. Running or operating cost.

(*i*) Fixed cost. *It is the cost which is independent of maximum demand and units generated.*
The fixed cost is due to the *annual cost of central organization*, *interest on capital cost of land* and *salaries of high officials*. The annual expenditure on the central organization and salaries of high officials is fixed since it has to be met whether the plant has high or low maximum demand or it generates less or more units. Further, the capital investment on the land is fixed and hence the amount of interest is also fixed.
(ii) Semi-fixed cost. *It is the cost which depends upon maximum demand but is independent of units generated.*
The semi-fixed cost is directly proportional to the maximum demand on power station and is on account of *annual interest and depreciation on capital investment of building and equipment, taxes, salaries of management and clerical staff*. The maximum demand on the power station determines its size and cost of installation. The greater the maximum demand on a power station, the greater is its size and cost of installation. Further, the taxes and clerical staff depend upon the size of the plant and hence upon maximum demand.
(iii) Running cost. *It is the cost which depends only upon the number of units generated.*
The running cost is on account of *annual cost of fuel, lubricating oil, maintenance, repairs* and *salaries of operating staff*. Since these charges depend upon the energy output, the running cost is directly proportional to the number of units generated by the station. In other words, if the power station generates more units, it will have higher running cost and *vice-versa*.

3.3 Expressions for Cost of Electrical Energy

The overall annual cost of electrical energy generated by a power station can be expressed in two forms viz three part form and two part form.

(i) Three part form. In this method, the overall annual cost of electrical energy generated is divided into three parts viz fixed cost, semi-fixed cost and running cost i.e.

Total annual cost of energy = Fixed cost + Semi-fixed cost + Running cost

= Constant + Proportional to maximum demand + Proportional to kWh generated.

= KShs (a + b kW + c kWh)

Where

a = annual fixed cost independent of maximum demand and energy output.

b = constant which when multiplied by maximum kW demand on the station gives the annual semi-fixed cost.

c = a constant which when multiplied by kWh output per annum gives the annual running cost.

(ii) Two part form. It is sometimes convenient to give the annual cost of energy in two part form. In this case, the annual cost of energy is divided into two parts viz., a fixed sum per kW of maximum demand plus a running charge per unit of energy. The expression for the annual cost of energy then becomes:

Total annual cost of energy = KShs (A kW + B kWh)

Where

A = a constant which when multiplied by maximum kW demand on the station gives the annual cost of the first part.

B = a constant which when multiplied by the annual kWh generated gives the annual running cost.

3.4 Importance of High Load Factor*

The load factor plays a vital role in determining the cost of energy. Some important advantages of high load factor are listed below :

(*i*) ***Reduces cost per unit generated:*** A high load factor reduces the overall cost per unit generated. The higher the load factor, the lower is the generation cost. It is because higher load factor means that for a given maximum demand, the number of units generated is more. This reduces the cost of generation.

(*ii*) ***Reduces variable load problems:*** A high load factor reduces the variable load problems on the power station. A higher load factor means comparatively less variations in the load demands at various times. This avoids the frequent use of regulating devices installed to meet the variable load on the station.

* **Electrical Load factor** *is a measure of the utilization rate, or efficiency of electrical energy usage. It is the ratio of total energy (KWh) used in the billing period divided by the possible total energy used within the period, if used at the peak demand (KW) during the entire period. If your load factor ratio is above 0.75 your electrical usage is reasonably efficient. If the load factor is below 0.5, you have periods of very high usage (demand) and a low utilization rate. Low load factor customers would benefit from a peak demand control system or from a Battery Energy Storage System to distribute electrical usage out over longer intervals of time and smooth the peaks.*

$$Load\ Factor = \frac{Average\ Load}{Maximum\ load\ in\ gievn\ time\ period}$$

Example 3.2

A generating station has a maximum demand of 50,000 kW. Calculate the cost per unit generated from the following data:

Capital cost = KSh.95 × 10^6 ; Annual load factor = 40%

Annual cost of fuel and oil = KSh.9 × 10^6 ; Taxes, wages and salaries etc. = KSh. 7·5 × 10^6

Interest and depreciation = 12%

Solution:

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

$= (50{,}000) \times (0{\cdot}4) \times (8760)$ kWh $= 17{\cdot}52 \times 10^7$ kWh

Annual fixed charges

Annual interest and depreciation = 12% of capital cost

$= \text{KSh.}0{\cdot}12 \times 95 \times 10^6 = \text{KSh.}11{\cdot}4 \times 10^6$

Annual Running Charges

Total annual running charges = Annual cost of fuel and oil + Taxes, wages etc.

$= \text{KHs.}(9 \times 106 + 7{\cdot}5 \times 10^6) = \text{KSh.}16{\cdot}5 \times 10^6$

Total annual charges = KSh. $(11{\cdot}4 \times 10^6 + 16{\cdot}5 \times 10^6) = \text{KSh.}27{\cdot}9 \times 10^6$

$$\therefore\ Cost\ per\ unit = KSh.\frac{27.9 \times 10^6}{17.52 \times 10^7} = Ksh.0.16 = 16 cents.$$

Example 3.2

A generating station has an installed capacity of 50,000 kW and delivers 220 ×10^6 units per annum. If the annual fixed charges are KSh.160 per kW installed capacity and running charges are 4 cents per kWh, determine the cost per unit generated.

Solution:

Annual fixed charges = 160 × Plant capacity

$= \text{KSh.}160 \times 50{,}000 = \text{KSh.}80 \times 10^5$

Annual running charges $= \text{KSh.}0{\cdot}04 \times 220 \times 10^6 = \text{KSh.}88 \times 10^5$

Total annual charges =KSh. $(80 \times 10^5 + 88 \times 10^5) = \text{KSh.}168 \times 10^5$

$$Cost\ per\ unit = KSh\frac{168 \times 10^5}{220 \times 10^6} = KSh.0.0764 = 7.64\ cents$$

Example 3.3

A generating plant has a maximum capacity of 100 kW and costs KSh.160, 000.

The annual fixed charges are 12% consisting of 5% interest, 5% depreciation and 2% taxes.

Find the fixed charges per kWh if the load factor is (i) 100% and (ii) 50%.

Solution:

Maximum demand = 100 kW

Annual fixed charges $= \text{KSh.}0{\cdot}12 \times 160{,}000 = \text{KSh.}19{,}\ 200$

(***i***) *When load factor is 100%*

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

= 100 × 1 × 8760 = 876,000 kWh

Fixed Charges/kWh=$KSh\frac{19,200}{876,000} = KSh.0.0219 = 2.19\ cents$

(***ii***) *When load factor is 50%*

Units generated/annum = 100 × 0·5 × 8760 = 438,000 kWh

Fixed charges/kWh=$KSh.\frac{19,200}{438,000} = KSh.0.0438 = 4.38\ cents$

It is interesting to note that by decreasing the load factor from 100% to 50%, the fixed charges/kWh have increased two-fold. Incidentally, this illustrates the utility of high load factor.