ERGU Tutorial Week No: 7 – Electrical Energy Systems

Q.1
75 tonnes of coal having an energy content of 30 MJ/kg are fed to a steam turbine boiler every hour. What is the input power in kW?

Q.2
With the aid of a sketch, draw a simplified power system diagram?

Q.3
Briefly detail what load forecasting entails as applied to electrical power systems?

Q,4
The combustion of 1 tonne of coal releases 2.9 tonnes of carbon dioxide (CO2) and produces 30 GJ of heat.

(a) Calculate the CO2 emissions in kg per GJ of heat.

(b) If the electrical energy reaching the consumer is 36 per cent of the energy in the coal burned in the power station, calculate the CO2 emissions in kg per kW h of electricity used in the home

Q.5
Briefly, describe the following types of industrial plants;

(a) CCGT
(b) CHP
(c) PWR

Q.6
The Dinorwig pumped storage station in Wales has a water capacity of 7×10^6 m^3 which can be released for generating electricity to meet peak demand over a period of up to 5 hours. If the effective head H is 500 m and the generator efficiency is 90 per cent, calculate:

(a) the average power output;
(b) the total electrical energy produced in 5 hours.

It takes 6.5 hours to refill the reservoir. Because of frictional drag, the effective head when pumping is 530 m. For pumps having an efficiency of 90 per cent, calculate:

(c) the input power to the pumps;
(d) the total electrical energy required for pumping;
(e) the overall energy efficiency of the pumped storage plant.

Q.7
Briefly describe the advantages and disadvantages of hydroelectricity

Q.8
Briefly, explain the main components of a wind turbine system

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Q.9
What is the theoretical maximum power that can be extracted from a 20 km/h wind, to power a wind generator?

Q.10
Sketch the Wind speed/power curve for a typical 2 MW generator.

Q.11
Explain the term "capacity factor"?

Q.12
Briefly, describe the advantages and disadvantages of wind generation

Q.13
The average power density in regions off the island of Lewis is about 50 kW per metre of wavefront. If 60 TW h per year (UK total demand = 350 TW h) were to be generated from wave power machines, what total length of wave power plant having 20 per cent conversion efficiency would be necessary?

Q.14
State the expression of power in a wave explaining each term and how is wave size determined.

Q.15
Briefly describe the advantages and disadvantages of wave power

Q.16
Briefly describe the main concepts of a wave energy convertor (WEC)

Q.17
The Islay OWC wave power plant is rated at 500 kW. Assuming a capacity factor of 40 per cent, calculate how many homes consuming 4000 kW h/year each can be supplied.

Q.18
The La Rance Barrage in Brittany, France, was completed in 1966. It has 24, 10 MW bulb turbines, each over 5 m in diameter. For an energy conversion factor of 33 per cent, a tidal range of 9 m and a trapped area of 22 km^2, calculate the annual output in GW h.

Q.19
Briefly describe the advantages and disadvantages of tidal barrages.

Q.20
Briefly describe the advantages and disadvantages of tidal turbines.

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Q.21
Calculate the energy associated with photons of wavelength 550 nm (mean value of visible sunlight), where the energy associated with a photon is E = hf (h is Planck's constant = 6.63 x 10^{-34} J s; f is the frequency of the incident electromagnetic radiation – sunlight; c is the speed of light = 3 x 10^{8} m/s.

Q.22
Compare and contrast the following components within Solar PV panels; Cells, modules, arrays.

Q.23

A PV cell has a working area of 250 x 160 mm and has a conversion efficiency of 12 per cent. It receives a total solar radiation of:

150 kW h/m^2 in July;
30 kW h/m^2 in January;
1000 kW h/m^2 per annum.

(a) Calculate the electrical energy produced by such a cell for each of the above.
(b) Calculate the number of cells required to produce 1200 kW h of 'essential' electricity each year.
(c) What is the main problem of this supply method?

Q.24
With the aid of a diagram, describe a grid-connected domestic solar PV system explaining the function of all components.

Q.25
Domestic waste releases 9 GJ/tonne when burned in electricity from waste plant having a conversion efficiency of 25 per cent. A community of 15,000 households produces 12,000 tonnes of combustible waste annually.

(a) What is the annual electricity output? (Note 1 kW h = 3600 kJ)
(b) For plant load factor of 80 per cent, what generator rating is appropriate?
(c) What fraction of the total community demand can be supplied if the annual demand per household is 4000 kW h?

Q.26
There are some 24 million households in the UK. If every household replaces a single 100 W tungsten filament lamp with a low-energy bulb of 20 W,

(a) Calculate the reduction in annual demand if the bulbs are switched on for 3 hours per day.
(b) What are the CO2 emissions savings at 1 kg/kW h?
(c) Compare the energy savings with the annual output of a 1000 MW power station having an 80 per cent capacity factor.
(d) What conclusions might be drawn from this for a national energy policy?

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Q.27
Briefly explain the following terms:

- Cogeneration
- Nuclear fission
- Pumped storage
- Sustainable energy
- Distributed generation
- Demand management

Q.28
The annual consumption of energy in a particular house is: gas 30 000 kW h, electricity: 3000 kW h.

a) What is the average power used throughout the year?
b) What is the total household energy consumption in GJ?

Q.29
If the annual electricity consumption of the household in Q.8 is supplied from a coal-fired power station having an energy efficiency of 40 per cent, and assuming electricity transmission and distribution losses of 8 per cent:

(a) Calculate the energy input to the power station.

(b) How many tonnes of coal with an energy content of 30 MJ/kg are used per year?

Q.30
The average annual consumption of electricity per household is 4000 kW h. How many households can be supplied by a power station of 1320 MW having an 80 per cent annual load (capacity) factor?

Q.31
(a) The average effective head of water stored at the Three Gorges Dam in China will be 170 m. Calculate the total flow rate through the hydro- generators to produce 18 200 MW with an overall efficiency of 90 per cent.

(b) The surface area of the 'reservoir' – the dammed Yangtse river – is 2100 km^2. Assuming that there is no flow of water into the reservoir, and that an output of 18,200 MW was maintained for 24 hours, by how much would the water level fall in that time?

Q.32
The upper reservoir of the Cruachan pumped storage plant lies 370 m above Loch Awe. Calculate the volume of water raised in 1 hour by the four 100 MW pumps having an efficiency of 90 per cent.

Q.33
What is the energy in kW h stored in a basin of area 50 km^2 where there is a tidal range of 5 m?

Q.34
A theoretically possible Severn Estuary barrage is predicted to deliver some 17 TW h per annum. For 706 tides in a year, what is the average energy per tide? The total proposed generating capacity is 216, 40 MW generators. Calculate the load factor (the percentage of the time that generation is occurring).

Q.35
Worldwide electricity generation is 19 000 TW h per annum (8760 h). How many 1 MW wind turbines would be required to supply the whole of this capacity, assuming an annual capacity factor of 33 per cent?

Q.36
For a wind turbine rotor diameter of 126 m, what is the theoretical power in the rated wind stream of 13 m/s? (The density of air p = 1.225 kg/m^3). If this turbine has a nominal rating of 5 MW, calculate the efficiency. Estimate the annual output of this 5 MW turbine for a capacity factor of 39 per cent and an availability of 95 per cent. Compare this output with an estimated output when v_m = 7.5 m/s. (Note: approximate annual output = 3.2 v_m^3 A kW h). How many households with an electricity consumption of 4000 kW h per year can be supplied?