K. K. Wagh Institute of Engineering Education and Research, Nashik

(An Autonomous Institute from A. Y. 202223)

End Sem Examination Winter 2025

Academic Year: 2025-26	**Semester: II**
Name of Programme: Electrical Engineering	**Pattern: 2023**
Name of Course: Power Generation Technologies	**Course Code: 2300118D**
Max. Marks: 60	**Duration: 2:30Hr.**

Paper Solution
Set A

Q. No.	Answer Details	Max. Marks
Q.1.	a) (i) Air PreHeater Working:The air preheater is placed between the economiser and the boiler furnace. It uses waste heat of flue gases leaving the boiler to preheat the air supplied to the combustion chamber. When hot flue gases pass over the metal tubes/plates, they transfer heat to the incoming fresh air. This increases the furnace temperature, improves combustion efficiency, saves fuel, and increases overall boiler efficiency. (ii) Economiser Working:The economiser is installed in the boiler flue gas path, before the air preheater. It uses residual heat of flue gases to preheat the feed water before it enters the boiler drum. Cold feed water flows through economiser coils and absorbs heat from the flue gases. By feeding warm water instead of cold water into the boiler, the economiser reduces fuel consumption, improves steaming rate, and increases boiler efficiency. (iii) Condenser Working:The condenser is located at the outlet of the steam turbine. It condenses the exhaust steam coming from the turbine by circulating cold water through tubes. Steam loses heat to the cooling water and converts back into water (condensate). This creates a low pressure region at the turbine outlet, increasing turbine efficiency (greater work output). The condensate collected is pumped back to the boiler as feed water, forming a closed cycle	6
Q.2.	1. Air Compressor: Draws atmospheric air and compresses it to high pressure. 2. Combustion Chamber (Combustor): Fuel is mixed with compressed air and burned to produce high temperature, high pressure gases. 3. Gas Turbine:Expands the hot gases to produce mechanical power that drives the compressor and the generator. 4. Alternator/Generator: Converts the mechanical power of the turbine into electrical power. 5. Starting Motor: Helps the compressor turbine set to reach the required starting speed. 6. Fuel System: Stores, filters, and supplies fuel to the combustor. 7. Lubrication System: Provides lubrication and cooling to bearings and moving parts. . Cooling System: Maintains required operating temperatures of turbine components. 9. Control and Governing System: Controls fuel flow, speed, temperature, and ensures safe operation. 10. Air Intake and Exhaust System: Ensures clean air enters the compressor and hot gases exit safely.	6
Q.3.	a) (1) Spillway – Function: A spillway is a passage provided in a dam to release excess water safely from the reservoir.	

It prevents overtopping of the dam during floods or heavy rainfall.
Ensures the dam's structural safety by allowing floodwater to discharge in a controlled manner.

(2) Surge Tank – Function: A surge tank is a small reservoir or chamber installed near the turbine end of a long penstock.
It absorbs sudden changes in water pressure due to rapid load changes on the turbine.
It prevents pressure rise by allowing water level to rise in the tank and prevents pressure drop by supplying extra water.
Helps in stabilizing flow and protects the penstock from failure.

(3) Water Hammer – Function / Meaning: Water hammer is a sudden rise or fall in pressure inside the penstock when water flow is rapidly stopped or accelerated (e.g., sudden closure of turbine gates).
It can create high pressure waves that may damage pipes, penstock, and fittings.
Surge tanks and slowclosing valves are used to reduce the effect of water hammer.

OR

b) Pelton Turbine – Working Principle
1. Water from the highhead reservoir is conveyed through a penstock to the turbine.
2. At the end of the penstock, a nozzle converts the highpressure water into a highvelocity jet.
3. This water jet strikes the buckets (spoonshaped) mounted on the runner.
4. The jet splits into two equal parts by the splitter, causing a rapid change in momentum.
5. This impulse force makes the runner rotate, converting hydraulic energy into mechanical energy.
6. The used water loses almost all its kinetic energy and falls into the tailrace.
7. The rotating runner drives a generator, producing electrical power.
. A spear/needle valve in the nozzle controls the water flow and turbine speed.

```
High Head Reservoir
        |
    Penstock
        |

   |  Nozzle   |

        |
   High Velocity Jet
        |

 |    Buckets      |
 |  (Pelton Wheel) |

        |
   Tail Race Water
```

c) Let the quantity of water be x m^3:
P.E = x 1000 9. 300
eff = OP/IP
0. 5 = 3.6 10^6x 1000 9. 300
x = 3.610^6/0. 510009. 300
x =1.44m^3

OR

d) Reservoir capacity

V = 5 10^ m^3

Mass of water

m = V 1000 = 5 10^ 1000 = 5 10^11 kg

Potential energy

PE = m g h = 5 10^11 9. 200

PE = 9.   10^14 J

Convert J → kWh

1 kWh = 3.6 10^6 J = 2.72 10^ kWh

For 70% efficiency (Plant A)

eff = 0.70

O/P = 0.70 2.72 10^

O/P = 1.904 10^ kWh

For 0% efficiency (Plant B):

eff = 0. 0

O/P = 0. 0 2.72 10^

O/P = 2.176 10^ kWh

Q.4. a) Types of Wind Turbine Electrical Generators

1. Synchronous Generator (SG): (a) Permanent Magnet Synchronous Generator (PMSG): Uses permanent magnets on the rotor.
No need for external excitation.
High efficiency and suitable for directdrive (gearless) wind turbines.
Widely used in modern large turbines.

(b) Electrically Excited Synchronous Generator (EESG): Rotor has a DC field winding supplied by slip rings.
Output frequency depends on speed, usually requires a power electronic converter.
Used in variablespeed wind turbines.

2. Induction Generator (Asynchronous Generator): (a) Squirrel Cage Induction Generator (SCIG): Simple, robust, and lowcost.
Operates at nearconstant speed.
Used in fixedspeed wind turbines with gearbox.
Requires reactive power from grid or capacitor bank.

(b) Wound Rotor Induction Generator (WRIG): Rotor has slip rings and external resistances or converters.
Allows limited speed control.
Used in older variablespeed turbines.

OR

b) Biomass energy conversion is the process of converting organic materials (wood, agricultural waste, animal waste, municipal waste, crop residues, etc.) into useful energy such as heat, electricity, or biofuels. The conversion occurs through three main methods:
1. Thermo Chemical Conversion: Uses heat to convert biomass into energy.
(a) Combustion: Biomass is burned in presence of oxygen.
Produces heat energy used for steam generation → runs steam turbine → produces electricity.
(b) Gasification: Biomass is heated with limited oxygen.
Produces producer gas/syngas (CO, H, CH_4).
Syngas is used in gas engines, turbines, or for making chemicals.
(c) Pyrolysis: Biomass is heated in absence of oxygen.
Produces bio oil, syngas, and charcoal.
Bio oil can be used as fuel in boilers or can be upgraded to transportation fuel.

2. Biological Conversion: Uses microorganisms to break down biomass.
(a) Anaerobic Digestion: Organic waste decomposes in absence of oxygen.
Produces biogas (CH_4 + CO_2).
Biogas is used for cooking, heating, or electricity generation.
(b) Fermentation: Biomass rich in sugars/starches is fermented using enzymes.
Produces ethanol (biofuel) used in engines or blending with petrol.
(c) Composting: Biological breakdown in presence of oxygen.

Produces manure (not for energy generation but useful byproduct).

3. Mechanical Extraction: Mainly used for oilrich biomass (like seeds).
Examples:Extraction of vegetable oils from seeds (jatropha, soybean, etc.).
These oils are transesterified to produce biodiesel, which can be used in diesel engines.

c) Given
Rotor diameter (=40 m) ⇒ radius (R=20 m)
Power produced (Pout=600 kW=600,000 W)
Wind speed (V=14 m/s)
Air density (rho=1.225 kg/m^3)
Tip speed ratio (lambda=4.0)
Generator speed (Ng=1 00 rpm)
(a) Rotor speed (rpm): Tip speed of blade:
Vtip=lambda V=4.014=56 m/s
Angular speed: omega=Vtip/R=56/20=2. rad/s
Convert to rpm: Nr=omega60/2pi =2. 60/2pi =16 /2pi = 26.74 rpm
(b) Tip speed of the rotor: Vtip = 56 m/s
(c) Gear ratio (generator : rotor): Gear ratio=Ng/Nr=1 00/26.73 0 = 67.32:1
(d) Efficiency of complete system: Swept area:A=pi R^2=pi(20)^2 = 1256.637 m^2
Power available in wind: Pwind=1/2rho A V^3
= 0.51.2251256.63714^3 = 2112.03 kW
Overall efficiency: =Pout/Pwind=600/2112.03 = 0.2 409 = 2 .41%

OR

d) Given
Wind speed V = 18 m/s
Pressure (p = 4bar = 4.0 10^ 5 Pa)
Temperature (T = 600 K)
Gas constant (R = 287 N·m/(kg·K)
Turbine efficiencies: 50% = 0.50 and 60% = 0.60
Compute per 1 m² of rotor swept area.
Air density:
Ideal gas law: rho= p/ R,T = 4.0 10^ 5 / 287 600
rho = 400000 /172200 = 2.32288 kg/m ^3 = rho = 2.32 kg/m ^3
Power available in wind (per m²)
Formula: Pwind =18/ 2 rhoV^ 3
Compute (V^3 = 18^3 = 5832).
P wind = 0.5 2.322 5832
Pwind = 6773.519 W/m ^2
Convert to kW/m²: P wind = 6.773 kW/m ^2
Actual power recovered:
For 0.50:
P0.50 = 0.50 6773.519 = 3386.759 W/m ^2
For 0.60:
P0.60 = 0.60 6773.519 = 4064.11 W/m ^2

Q.5.

a) Components of Solar Radiation
(i) Direct Radiation (Beam Radiation): Direct radiation is the sunlight that reaches the Earth's surface without being scattered by the atmosphere.
It travels in a straight line from the sun to the surface.
It casts shadows and is used effectively in concentrating solar collectors (like parabolic dishes or troughs).
Maximum on clear, cloudfree days.
(ii) Diffuse Radiation: Diffuse radiation is the sunlight that reaches the Earth after being scattered by molecules, dust, clouds, and water vapour in the atmosphere.
It comes from all directions in the sky.
Does not cast sharp shadows.
Present even on cloudy or hazy days and cannot be concentrated using mirrors or lenses.
(iii) Global Radiation (Total Solar Radiation): Global radiation is the sum of direct radiation and diffuse radiation received on a horizontal surface.
Global Radiation = Direct Radiation + Diffuse Radiation
Represents the total solar energy available for solar PV and thermal systems.

OR

b) Effect of irradiation on Isc and Voc:

Isc (short-circuit current) is directly proportional to irradiation. This means if irradiation doubles, Isc roughly doubles.

Example: At 200 W/m² → Isc = 2 A, at 400 W/m² → Isc = 4 A, and so on.

Voc (open-circuit voltage) is slightly dependent on irradiation; it is more influenced by temperature. At constant temperature, Voc remains almost the same (~50V here).

Effect of temperature on Voc:

Voc decreases with increase in temperature (negative temperature coefficient).

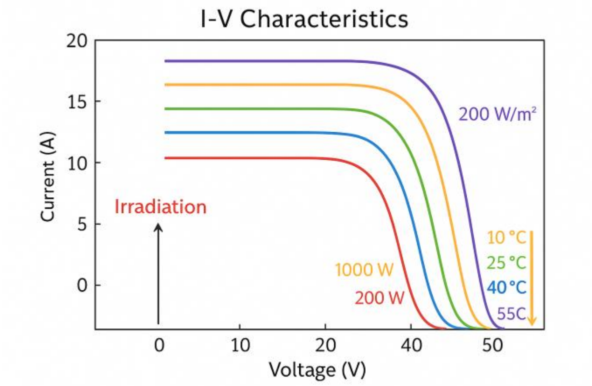
Example: Voc = 55 V at 10°C → Voc = 45 V at 55°C.

Isc slightly increases with temperature, but this effect is much smaller than Voc change. Here we take Isc constant ~14A for simplicity.

Draw two sets of I-V curves:

Irradiation curves: Plot multiple curves at 200, 400, 600, 800, 1000, 1200 W/m² at constant 25°C.

Temperature curves: Plot multiple curves at 10, 25, 40, 55°C at constant 1000 W/m².



c) Modules arranged: 7 in series × 3 strings in parallel → total modules = 7 × 3 = 21.

Open-circuit voltage of one string: (V_oc,string) = 48 7 = 336 V.

Short-circuit current of the array: (I_sc,array)= 11   3 = 33 A.

Using the image's method: Power = (V_oc,string I_sc,array) = 336   33 = 11088 W.

OR

d) Given: (V_oc=35 V, I_sc=10 A)

(i) 4 modules connected in series ⇒ total (V_oc =35 4=140 V.)

(I–V curve: short-circuit current = 10 A (same as one module), open-circuit at 140 V.)

(ii) 5 modules connected in parallel ⇒ total (I_sc,array=10 5=50 A.)

(I–V curve: open-circuit voltage = 35 V (same as one module), short-circuit at 50 A.)

(iii) Using the image method: Power=V_oc,string I_sc,array=140 50=7,000 W.