THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

FIRST SEMESTER EXAMINATION (2021)

EE453 RENEWABLE ENERGY SYSTEMS

ELECTRICAL ENGINEERING - YEAR 4 (POWER)

TIME ALLOWED: 3 HOURS

INFORMATION FOR STUDENTS

1. You have **TEN (10)** minutes to read the paper.
You must **NOT** begin writing during this time.

2. All answers must be written in the **ANSWER BOOK** supplied.
COMPLETE THE DETAILS REQUIRED ON THE FRONT COVER OF YOUR ANSWER BOOK - DO THIS NOW.

3. Drawing instruments and calculators are permitted.

4. Mobile phones and headphones are **NOT** permitted

4. Answer **ALL FIVE (5)** questions.

5. Marks are allocated to each part of each question.

6. If you are found cheating in the Examination, the penalties specified by the University shall apply.

QUESTION ONE **Solar Energy (Photovoltaic (PV)).**

Connections of photovoltaic (PV) modules. Two dissimilar PV modules are subjected to the same irradiances and temperature.

- The short-circuit current output of the first module, $I_1 = 4$ A, and the open-circuit voltage output, $V_1 = 30$ V.
- The short-circuit current output of the second module, $I_2 = 3$ A, and the open-circuit voltage output, $V_2 = 15$V.

(a) The two PV modules are connected in series, as in Fig. 1.1. Calculate;

(i) The combined short-circuit current output, I. *(2)*
(ii) The combined open-circuit voltage across both, V . *(2)*

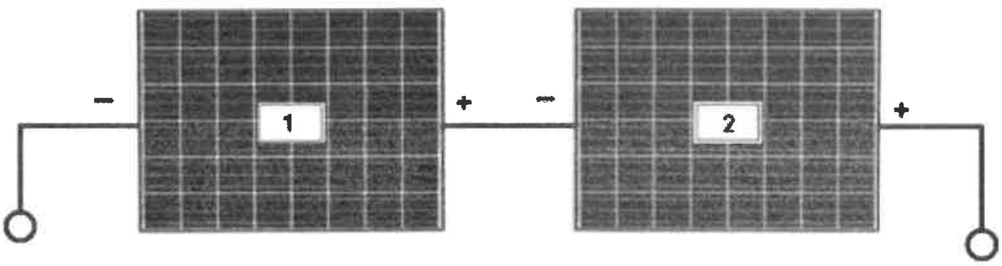

Fig. 1.1: Two dissimilar PV modules connected in series.

(b) The two PV modules are connected in parallel, as in Fig. 1.2. Calculate;

(i) The combined short-circuit current output, I. *(3)*
(ii) The combined open-circuit voltage across both, V . *(3)*

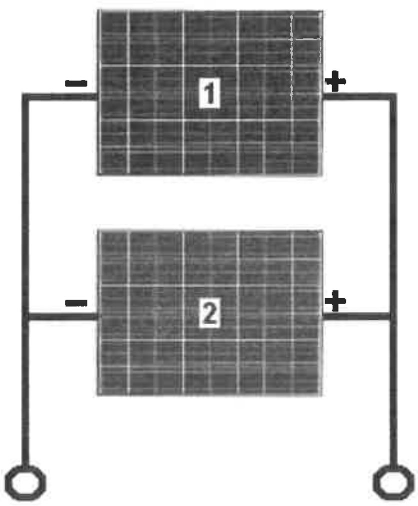

Fig. 1.2: Two dissimilar PV modules connected in parallel.

QUESTION TWO Wind Energy.

Wind energy conversion systems (WECS) are designed to convert the energy of wind movement into mechanical power.

(a) A wind energy conversion system has the following parameters: ***(5)***

- Swept area by the blades of the turbine: $A = 6570\ m^2$
- Wind turbine maximum power coefficient: $C_{po} = 0.382$
- Cut-in wind speed: $V_{wi} = 6.3$ m/sec,
- Rated wind speed: $V_{wr} = 10$ m/sec,
- Cutt-off wind speed: $V_{wo} = 20.5$ m/sec,
- Air density: $\varrho = 1.225\ kg/m^3$
- Synchronous generator rated power output, P_o =1550 kW

(i) Calculate the available power in the wind at rated wind speed.

(ii) If the wind turbine operates at maximum power coefficient at rated wind speed, then calculate the mechanical power extracted from the wind at rated wind speed, P_m,

(iii) Calculate the combined gear generator efficiency, η.

(iv) Calculate the generator capacity factor CF, if the average power output of the generator is $P_{av} = 500$ kW

(b) A three-phase, 20 kVA squirrel-cage induction generator is driven by a fixed pitch–angle wind turbine. The generator delivers its rated output at a wind speed of 14 m/sec. The generator is connected to an infinite bus (i.e., a power system where frequency and voltage are held constant); the line-to-line voltage at the infinite bus is 215 V. The generator is driven at a rated wind speed, delivering its output at a lagging power factor of 0.8. Calculate; ***(5)***

(i) The active power output, P_{o1}

(ii) The generator output current, I_o. The phase voltage is $V = 120$ volts

(iii) The reactive power the generator needs, Q

(iv) The wind speed was reduced to 10 m/sec, the generator efficiency stayed the same but the aerodynamic coefficient became 80% of what it was. Calculate the power output of the generator, P_{o2}.

QUESTION THREE **Hydropower Energy.**

The most useful source of electrical energy generation in the world is hydroelectric plant, in which the movement of water results in power production by driving a hydro turbine.

(a) Consider a Pelton turbine with a jet velocity of V and vane angle equal to φ. Obtain the relationship between bucket speed and jet velocity at the maximum efficiency of the turbine. Additionally, provide a calculation formaul for the maximum efficeiency of the Pelton turbine. ***(5)***

(b) A Pelton turbine is considered for power production equal to 100 kW, being installed in a head of 150 m. The runner is spinning at 600 rpm, and the speed ratio and velocity coefficient are 0.48 and 0.98, respectively. Design this turbine for an overall efficiency equal to 80% ***(5)***

QUESTION FOUR **Wave Energy.**

The energy from ocean waves come in irregular and oscillating form at all times of the day and night and can be harnessed to provide electricity supply.

(a) Discuss the performance and limitations of sea wave energy conversion plants. ***(3)***

(b) State the expression for energy and power in ocean waves ***(2)***

(c) Discuss limitations of ocean wave energy ***(3)***

(d) State main criteria for deciding the location of ocean wave plants ***(2)***

QUESTION FIVE **Tidal Energy.**

Tides are periodic rises and falls of large bodies of water in the ocean. Gravity is one major force that creates tides and hence tidal energy on the oceans of the earth.

(a) A tidal power plant of single-basin type has a pool area 80×104 m^2. The tidal has a range of 8 m. However, the turbine stops operating when head on it falls below 2 m. Calculate the energy generated in one filling process in kW-h, if the turbine–generator efficiency is 90%. *(3)*

(b) Derive an expression for tidal energy per tidal cycle for a simple single-pool single effect tidal scheme. *(2)*

(c) State the types of tidal energy conversion schemes. *(2)*

(d) Discuss the relative merits and limitations of tidal power. *(3)*