MACHAKOS UNIVERSITY

University Examinations for 2020/2021

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 501 RENEWABLE ENERGY TECHNOLOGIES

DATE: 11/8/2021 **TIME: 8:30 – 10:30 AM**

Instructions

- *This paper consists of Five Questions*
- *Question* ***One is Compulsory***
- *Attempt Any other Two Questions*

Some Useful Constants

- Plank's Constant:$h = 6.63x10^{-34}Js$
- Speed of Light in a Vacuum :$c = 3.0x10^{8}m/s$
- Stefan Boltzmann's Constant :$\sigma = \frac{5.67x10^{-8}W}{m^2}/k^4$
- Gravitational Acceleration :$g = 9.81N/Kg$
- Kinematic viscosity of water at $20℃$ is $10^{-6}\mathrm{m/s}$

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Show that the annual average power generated by a wind turbine as a proportion of the rated power cannot be evaluated until the dependence of the fractional wind speed decrease at the turbine with respect to the wind speed is established. Explain all the symbols used. (4 marks)

b) Beginning from a diagram, explain the operating regions and power performance of a typical wind turbine. Define the three key speeds clearly. (5 marks)

c) Show that for the *Rayleigh Distribution* of Wind Speed

i) $\Phi_{u>u'} = exp\left[-\frac{\pi}{4}\left(\frac{u'}{u}\right)^2\right]$ (2 marks)

ii) $\left(\overline{u^3}\right)^{1/3} = 1.24\bar{u}$ (1.5 marks)

iii) $P_O \cong A\rho(\bar{u})^3$ (1 mark)

iv) $\Phi_{u(max)}$ occurs at $u = \left(\frac{2}{\pi}\right)^{1/2}\bar{u}$. Determine $\Phi_{u(max)}$ (1.5 marks)

d) The turbine gearbox and electricity generation losses are estimated at *1.2 kW*. At which wind speed will the turbine start generating power. Consider the turbine to operate at the optimal tip speed ratio for wind speeds below *13 m/s* (3 marks)

e) If the average wind speed at the site is *7 m/s* and the wind speed displays a *Rayleigh distribution*, determine:

i) The total shut-down period of the turbine in hours per year (3 marks)

ii) The total period of operation at rated power output in hours per year (3 marks)

iii) The average output power of the turbine. Assume the turbine cut-off wind speed to be 20 m/s (6 marks)

QUESTION TWO (20 MARKS)

a) From first principles, show that the power extracted by any wind turbine is proportional to the cube of the wind speed and the efficiency factor. (3 marks)

b) Show that the power coefficient for any wind turbine can be expressed as (9 marks)

$$C_P = ax(1 + ay + a^2) = z\lambda$$

Hence define a and z and state the values of $x, y \; and \; z$

A three-bladed horizontal axis turbine is being considered for electricity generation at a site. The variation of the coefficient of performance, C_p of this turbine with the tip speed ratio,λ, is given by

$$C_p = 46.6 \times 10^{-3}\,\lambda^2 - 6 \times 10^{-3}\,\lambda^3$$

c) At which tip speed ratio will the conversion efficiency of the turbine be a maximum? Call this the optimal tip-speed ratio, λ_{opt} (3 marks)

d) What is the value of this maximum energy conversion efficiency? (2 marks)

e) Estimate the radius of the rotor in *m* that will enable *100 kW* to be generated by the turbine at a wind speed of *12 m/s* and at the optimal tip speed ratio. Consider the air density to be $1.225\ kg/m^3$ (3 marks)

QUESTION THREE (20 MARKS)

a) Define Renewable Energy Penetration. (4 marks)

b) Smith lives in Miami, Florida (with yearly average of 4.7 peak sun-hours per day), and is considering placing a PV array on his south-facing roof. The roof is unshaded and has a size of 8m by 13.5m. The electric power produced is to be converted to ac and used in his home. Any excess power produced will be back into the local utility company's grid system. Analyze the system configuration and determine how much energy Smith can expect to get from the solar installation (9 marks)

c) Discuss the Technical Challenges facing the Integration of Solar PV by smith to the grid and their possible solutions. (7 marks)

QUESTION FOUR (20 MARKS)

a) Using diagrams Only, explain the fact that *"Renewable Energy Integration provides a virtual storage while Electrical Energy Storage (EES) provides a reasonable gain in the feedback path"* (4 marks)

b) Explain the reasons behind the use of Electrical Energy Storage (EES) in Renewable Energy (RE) generation (4 marks)

c) Giving time scale and examples, discuss the *Grid-Side Benefits* of electrical energy storage (EES) in Renewable Energy Integration (REI). (8 marks)

d) Discuss the need for EES planning and decision tool now and in future. (4 marks)

QUESTION FIVE (20 MARKS)

a) Using diagrams ONLY explain the following statements.

i) Renewable Energy Systems are *Feedback Control Systems* while Conventional Energy Sources (CES) are Open Loop Systems (4 marks)

ii) *Negative Feedback Control* is not beneficial in RE utilization (3 marks)

iii) *Positive feed forward control* is the most efficient way to utilize RE (2 marks)

b) Figure Q 5b) shows a flexible experimental hybrid system of a mixed type. It is paramount to note that the elements marked by dashed line will be accomplished in the future.

i) Using Diagrams Only, distinguish between *Serial, Switched* and *Parallel Hybrid* systems (3 marks)

ii) Explain the *Future Challenges* in implementing Hybrid Systems with Renewable Energy Sources (HSRES) (3 marks)

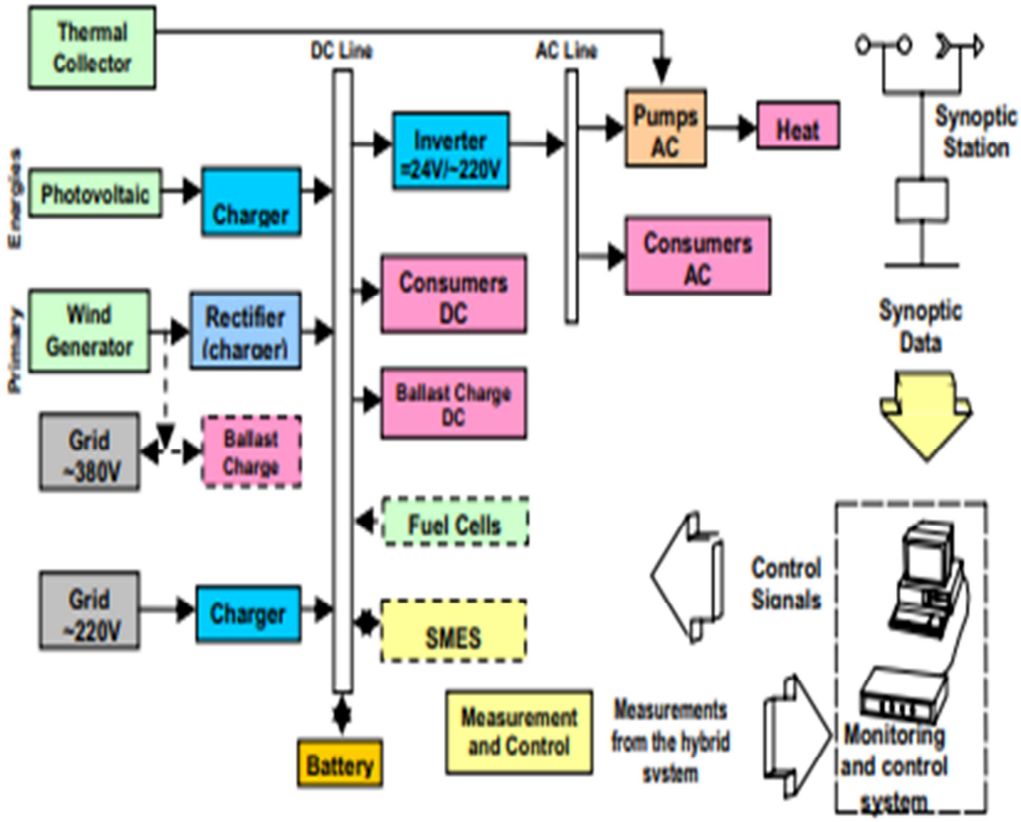

Figure Q 5b) Flexible Hybrid System