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# MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

*(A constituent unit of MAHE, Manipal)*

## II SEMESTER M.TECH

## (ENERGY SYSTEMS & MANAGEMENT / POWER ELECTRONICS & DRIVES)

## END SEMESTER EXAMINATIONS, APRIL/ MAY 2019

## SUBJECT: ENERGY STORAGE DEVICES [ELE 5237]

REVISED CREDIT SYSTEM

**Time: 3 Hours** **Date: 2 May 2019** **Max. Marks: 50**

**Instructions to Candidates:**

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

**1A.** Define SOC (state of charge), DOD (depth of discharge), Energy density and C-rate for a battery. ***(02)***

**1B.** What are the different methods to estimate SOC of a battery and explain any two methods? Also mention the limitations of those methods. ***(04)***

**1C.** A battery has 96 cells in series per string with two parallel strings. Each cell has a no-load voltage of 4.18 V and an internal resistance of 2.8 mΩ.

i) Determine the pack current and voltage under a 80 kW discharge if the battery is fully charged.

ii) Determine the discharge efficiency of the battery. ***(02)***

**1D.** Define SOH (state of health) for a battery and explain the procedure to determine it. ***(02)***

**2A.** A 24 kWh battery pack can be fast charged from 0% to 60% SOC in 30 min. Determine the approximate charge current and power in order to achieve this charge time. Assume that the battery pack voltage is 360V. ***(02)***

**2B.** Determine the battery pack sizing for the given load conditions. DC load energy consumption is 1000Wh/day, AC load energy consumption 10kWh/day and the DC bus voltage requirement is 48V. Given that the battery specifications are 12V, 50Ah. $\eta_{DC-DC} = 90\%$, $\eta_{Inverter} = 80\%$, Temperature correction=1, Days of Autonomy=2, Design Margin=1.25, Depth of Discharge=80%. ***(04)***

**2C.** What are the different voltage losses occur in Fuel Cell and explain it by using the V-J( $mA/cm^2$ ) characteristics? ***(02)***

**2D.** What are the different control techniques associated with the Fuel Cell to regulate the output power and explain it with a proper block diagram? ***(02)***

**3A.** Explain about the working principle of Flywheel based energy storage technology through a block diagram and mention its applications in power system. Also mention its advantages and disadvantages. ***(04)***

**3B.** Explain about super conducting magnetic energy storage and mention its merits and demerits? ***(03)***

**3C.** Explain about the working principle of compressed air energy storage (CAES)? Also mention its advantages and disadvantages. ***(03)***

**4A.** Explain about Ultra capacitor as an energy storage device and mention its applications. ***(02)***

**4B.** What is the importance of energy storage devices and explain the criteria for choosing a particular energy storage device. ***(04)***

**4C.** Determine the beginning-of-life kilowatt-hour storage required in a BEV battery pack based on the following requirements: 6 years of operation, an average of 80 km of driving per day $S_{day}$ over the 365 days of the year, daily charging, and an average battery output energy per kilometer $E_{km}$=200 Wh/km. Assume battery pack cycle lifetime index L = 3 and number of charge/discharge cycles for 100% depth of discharge $N_{100\%}$=1000. Assume two parallel battery strings with 96 Li-ion cells per string, with a total number of cells $N_{cell}$=192, and a nominal voltage of 3.75 V per cell. Assume that the capacity of the battery pack will reduces to 80% at the end of life.

i. Determine the ampere-hours per cell.
ii. What are the vehicle ranges at beginning of life (BOL) and end of life (EOL)? ***(04)***

**5A.** The 2015 Nissan Leaf is traveling down a −8° slope at 120 km/h. The vehicle parameters of the Nissan leaf 2015 model are A=133.3 N, B=0.7094 $N/ms^{-1}$, C=0.491 $N/(ms)^{-2}$. Assuming calm conditions, how much regenerative power is available to brake the vehicle while maintaining a constant speed? ***(02)***

**5B.** An electric vehicle has the following attributes: drag coefficient $C_D = 0.25$, vehicle cross Section $A=2.5m^2$, and available propulsion energy of $E_b$=20kWh. Let the density of air $\rho_{air}=1.2kg/m^3$. Instantaneously at a vehicle speed of 120 km/h, calculate the aerodynamic drag force, power, and range, while driving in

i. calm conditions with no wind and
ii. Windy conditions with a 12 km/h tailwind. ***(03)***

**5C.** A fully loaded bus has the following parameters: mass m = 20,000 kg, drag coefficient $C_D = 0.7$, vehicle cross section $A=10m^2$, and coefficient of rolling resistance $C_R=0.008$. The nominal efficiency of the powertrain and transmission $\eta_{pt}=85\%$, and the auxiliary load is 2 kW. Let the density of air $\rho_{air}=1.2kg/m^3$. The overall mass of the fuel cell system (including the fuel cell, balance of plant, storage tanks, and mechanical bracketing) is 400 kg plus 80 kg per 5 kg of stored hydrogen.

i. Determine the hydrogen mass, and the overall mass of the fuel cell system if the vehicle is to travel at a constant speed of 64 km/h for two work shifts of 16 h total, or 1024 km. The fuel cell plant efficiency is 50% for this operating condition.
ii. Determine the mass of battery which would be required if the specific energy is 0.15 kWh/kg.
iii. What is the range of the vehicle without passengers if the weight drops by 1/3? The fuel cell plant efficiency is 53% for this operating condition. ***(05)***