UTBM		
Exam: R.M.A.S of energy hydrogen systems ER59	**duration:1h30**	**4 pages**
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Date: 12/ January/2022		

Exercise 1: (3 points)

The Electrolyze system is made up of 4 sub-assemblies A, B, C and D in series reliability configuration. Each sub-assembly has a constant failure rate λ_A, λ_B, λ_C, λ_D of which are:

MTBF (A) = 14500 h ; MTBF (B) = 13200 h; MTBF (C) = 16000 h; MTBF (D) : unknown

1.1- Calculate the MTBF(D) to achieve an overall failure rate of the system $\lambda_T = 2\ 10^{-4}$ /h,

1.2-Calculate the reliability of the system at t = 1500 h?

1.3-What is the probability of reaching 5000 hours without failure?

Exercise n°2 (4 points)

The "main shut off with solenoid control valve" is installed in the vicinity of the high-pressure storage hydrogen tank. The safety shutoff valve is normally closed and requires a magnetic field created by the solenoid's coil to open and remain open. The solenoids are energized ON to open valve when the vehicle is operating. The solenoid is de-energized to close valve when the vehicle is turned off or when hydrogen gas leakage occurs.

The "main shut off with solenoid control valve" has a reliability described by a Weibull distribution:

$$R(t) = \exp - \left(\frac{t-\gamma}{\eta}\right)^{\beta}$$

2.1 Give the definitions of the parameters β, η and γ

2.2 Find the expression of the failure density function

2.3 Find the expression of the failure rate function

The shut off valve follow a Weibull law with parameters:

$\beta = 2.6$; $\eta = 5$ years; $\gamma = 0$,

2.4 Calculate the reliability of the shut off valve at 1 year

2.5 Calculate the failure rate of the shut off valve at 1 year

2.6 After how long a preventive replacement must be made if we want to guarantee reliability of the shut off valve of 95%

Exercise n°3A (3 points) (choose exercise n°3A or n°3B)

Hydrogen has a very wide flammability range from 4% to 74% concentration in air and 4% to 94% in oxygen. Only 0.02 mJ of energy is required to ignite the hydrogen–air mixture.

Safe Instrumented Function SIF is used to prevent hazards of fire, explosion, asphyxiation. SIF consists of **3 identical hydrogen sensors**, one Programmable Logic Controllers (PLC), one buzzer and one shutoff valve.

In accordance with Regulation No 134 of the Economic Commission for Europe of the United Nations (UN/ECE), the alarm (buzzer) is automatically triggered **if at least 1 out of 3** (1oo3) H_2 sensors detect 3% hydrogen concentration. If the hydrogen concentration exceeds 4%, the main shut-off valve shall be closed to stop hydrogen flow and isolate the storage system.

3.1A What is the probability F(t) at 1 year that the alarm will not be triggered in the event of a hydrogen leakage? Each detector has 85% reliability of functioning correctly for 1 year

3.2A Present the Fault Tree of the hydrogen detection subsystem

3.3A find the number of minimal cut sets of (1oo3) system and their corresponding order.

Exercise °3B (3 points) (choose exercise n°3A or n°3B)

Five components 1,2, 3, 4 and 5 with the respective reliability R1(t), R2(t), R3(t) R4(t) and R5(t)

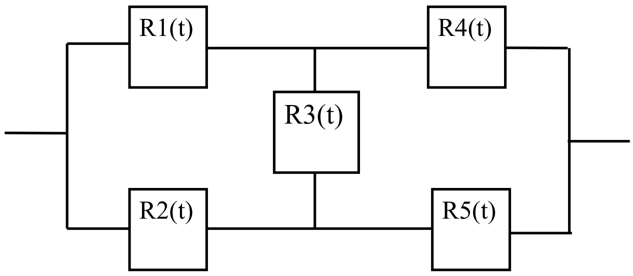

Figure 1

3.1B if R1(t) = R2(t) = R3(t) = R4(t) =R5(t)=R(t)

Demonstrate that the reliability function of the system is expressed as:

$Rs(t) = a.R^5+b.R^4+c.R^3+d.R^2$

Find a,b,c and d coefficients

Exercice 4 (10 points)

As shown by figure 2, the water management circuit allows the Proton Exchange Membrane Fuel Cell PEMFC (7) to operate within 60–80 °C.

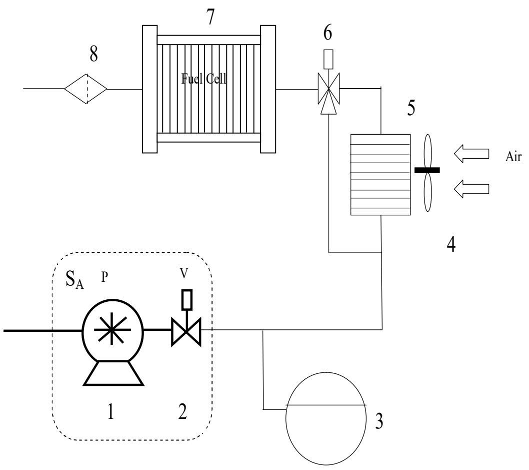

Figure 2: Configuration A of fuel Cell cooling loop

The coolant loop is composed by deionizing filter (8), by-pass solenoid valve (6), heat exchanger water/Air (5), fun (4), expansion tank (3), pump (1) and flow regulation valve (2). The expansion tank has 2 levels: 1 minimum level and 1 maximum level, these levels allow the volume of the coolant to vary with increasing temperature.

To prevent current leakage and maintain low electrical conductivity of coolant < 5 µS/cm, the stack coolant can either pure de-ionized water, or a mixture of 50% pure de-ionized water with 50% pure ethylene glycol.

Questions:

The sub-system S_A is composed by a circulation pump P and flow regulation valve V, with respective constant failure rate λ_p, λ_v

4.1 Express the reliability function $R_A(t)$ of the sub-system S_A as a function of constant failure rates λ_p, λ_v

4.2 Express the $MTBF_A = \int_0^\infty R_A(t)dt$ of the sub-system S_A

4.3 Present the Fault Tree of the sub-system S_A and find the number of minimal cut sets and their corresponding order.

To improve the reliability of cooling system, the above sub-system S_A is replaced by sub-system S_B constituted by two redundant assemblies S_{B1} and S_{B2} as proposed by figure 3.

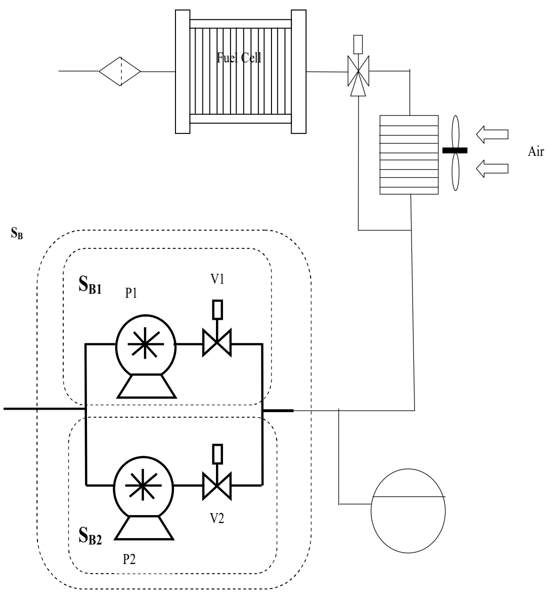

Figure 3: Configuration B of fuel Cell cooling loop

4.4 Express the reliability function $R_B(t)$ of the sub-system S_B as a function of the constant failure rates λ_{p1}, λ_{p2}, λ_{v1} and λ_{v2}

4.5 Express the $MTBF_B = \int_0^\infty R_B(t)dt$ of the sub-system S_B

4.6 Present the Fault Tree of the sub-system S_B and find the number of minimal cut sets and their corresponding order

Figure 4 presents a second version of a redundant sub-system S_C constituted by two redundant assemblies S_{C1} and S_{C2}.

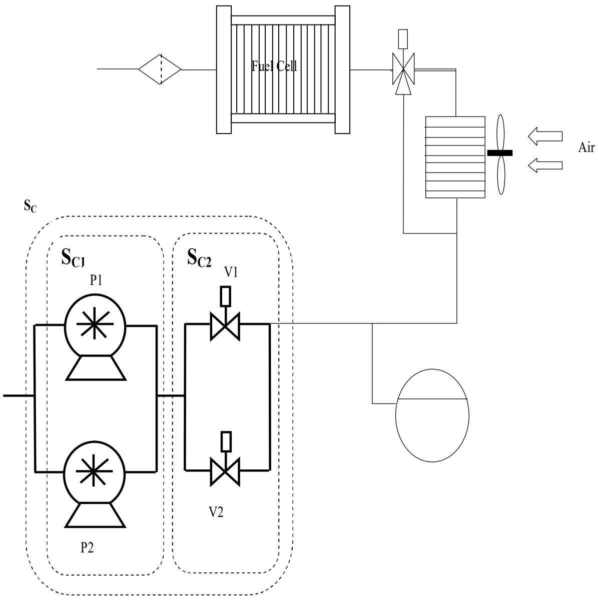

Figure 4: Configuration C of fuel Cell cooling loop

4.7 Express the reliability function $R_C(t)$ of the sub-system S_C as a function of the constant failure rates λ_{p1}, λ_{p2} , λ_{v1} and λ_{v2}

4.8 Express the $MTBF_C = \int_0^{\infty} R_C(t)dt$ of the sub-system S_C

4.9 Present the Fault Tree of the sub-system S_C and find the number of minimal cut sets and their corresponding order