Course 31778 – Assignment 1 – Cell modeling and control
SOLUTION

3) 3.1. In the narrative document, discuss and plot v_{cell} in order to discharge the 20 W for 10 minutes. Is the value constant? If not, why? Plot the joule losses during the 15 minutes of simulation and assess the total amount of energy lost during the period of time.

Answer:

The V_{cell} is derived as follows:

$$V_{cell} = \frac{V_{oc}}{2} + \frac{sqrt(V_{oc}^2 - 4 * R_{cell} * P)}{2}$$

As shown in Figure 1 V_{cell} is not constant as it is function of the V_{oc}, which is varying depending on the SOC.

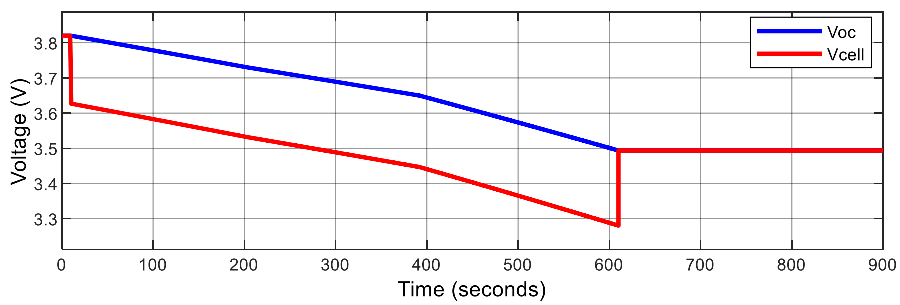

Figure 1: Voc and Vcell during the 15 minutes of simulation.

The joule losses during the 15 minutes of simulations can be seen in Figure 2:

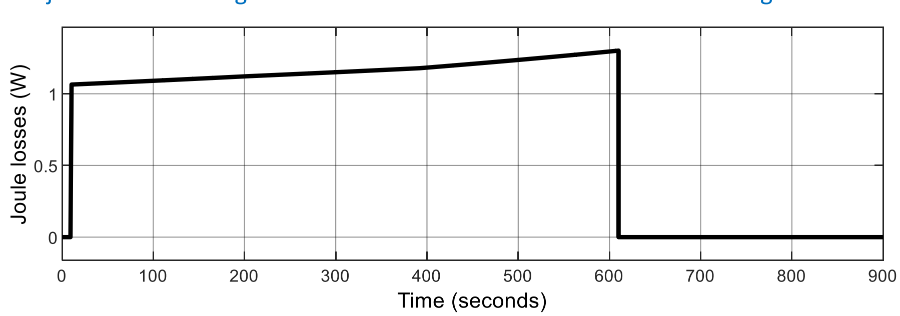

Figure 2: Joule losses during the 15 minutes of simulation.

The total amount of energy lost during the period of time is equal to 698 Ws, and it is derived in Simulink as the integral of the joule losses.

3.2 In the narrative document, report and shortly discuss the temperature behavior during the 15 minutes of simulation. Calculate the thermal time constant and comment the value and its meaning.

Answer:

Figure 3 provides the outside temperature (T_{out}) and the cell temperature (T_{cell}) during the 15 minutes of simulation.

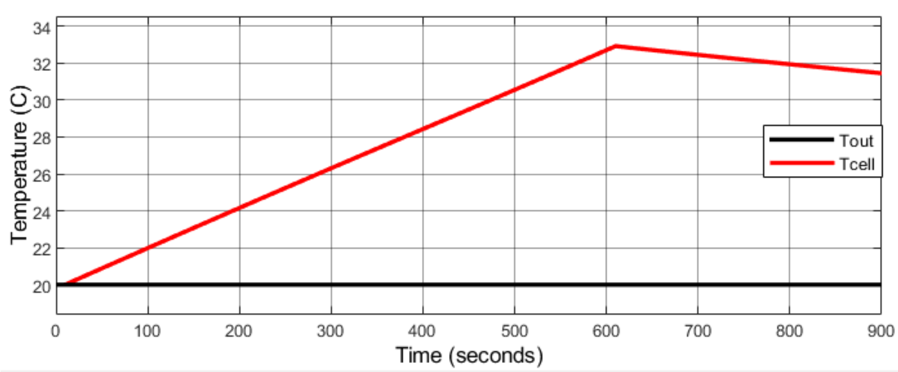

Figure 3: Outside and cell temperature during the 15 minutes of simulation.

The outside temperature is constant, nevertheless when the cell is discharged, from 10 to 610 seconds, the cell temperature increases due to the joule losses. At 610 sec, when the current flow is stopped, the temperature of the cell decreases, going back to the outside temperature.

The thermal time constant is:

$\tau = R_{th} * C_{th}$ = 2400 s and therefore 3τ is 7200s (= 2 h).

This value tells the time required to get the cell temperature back inside the following band:

$$T_{cell_{end}} \pm 0.05 * \left|T_{cell_{end}} - T_{cell_{in}}\right| = 20 + 0.05 * |20 - 32.92| = 20.65\ deg$$

$T_{cell_{in}}$ is the initial temperature of the cell, in the present case equal to 32.92 deg, $T_{cell_{end}}$ is the final temperature of the battery, equal to the outside temperature of 20 deg. Since the discharging process is stopped after 610 sec, this temperature should be reached after 610 sec plus 2 hours, meaning 7810 sec. As shown in Figure 4, the cell temperature at 7810 sec is equal to 20.64 deg.

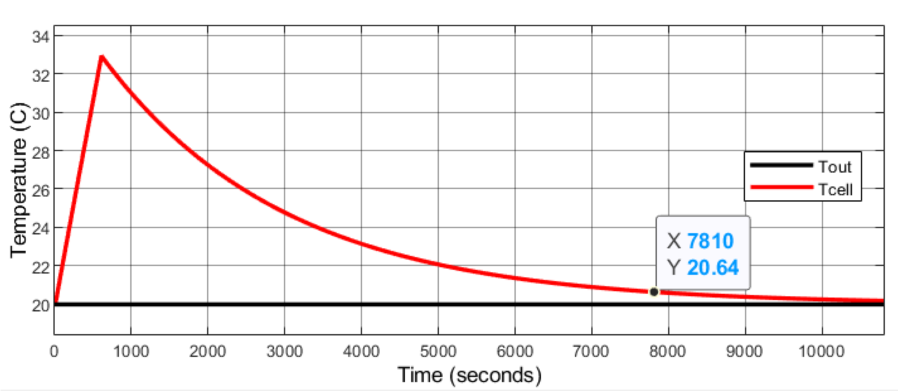

Figure 4: Outside and cell temperature during the 15 minutes of simulation.

4) Based on the same previous conditions and assuming a measurement delay of cell power equal 0.1 s, create a second model (in the same Simulink file) where the cell voltage is controlled by a PI controller instead of the explicit calculation. PI parameters have to be chosen so that the response is stable and is settling within 3 seconds. In the narrative document, describe how the PI parameters have been derived in few lines.

Answer:

The procedure consists in setting initially to zero the gains. Then the proportional gain is increased until it reaches the critical gain, which in the present case is equal to 0.029. Ku=0.029, and Tu is approximately 0.2 s, which is the period of the oscillation with the Ku.

Applying Ziegler-Nichols method: Kp=0.45*Ku=0.013 and Ki=0.54*Ku/Tu=0.08.