ELG3336: Celebrating the Confederation Line (O-Train), 2019

History: The first electric passenger train was presented by Werner von Siemens at Berlin in 1879. The locomotive was driven by a 2.2 kW, series DC motor, and the train consisting of the locomotive and three cars, reached a speed of 13 km/h.

Case: The train uses two electric locomotive DC motors (1500 V, 1 MW, each) powered by electricity from overhead DC lines. Assume 10 locomotives operating in the line at the same time for 20 hours per day.

\[
\Delta I = V_o(V_s-V_o)/fLV_s; \Delta V_c = \Delta I/8fC; D = V_o/V_s \\
\Delta I = V_sDT/L; \Delta V_c = I_oD/fC; D = 1-V_s/V_o \\
\eta = P_o/P_{in}
\]

Question 1: Design a solar farm and a storage facility that provides enough energy to the entire overhead power line of the train system. Use solar panels (V, W, per unit). Feel free to use suitable converters. Estimate the harvested power in kW and kWh.
**Question 2:** Design a suitable DC to DC converter to supply $i_o = ?$ A to the locomotive DC series motor from the overhead power line (1500 V). Assume: $E_a = ?$ V, $R_a = ?$ Ohm, $f_s = ?$ Hz. Assume $\%$ ripple current, $10\%$ ripple voltage, and efficiency of $\%$. 
**Question 3:** Consider the following step-down and step-up chopper (two quadrant chopper). The circuit can provide both motoring forward operation ($S_1$ and $D_1$) and regenerating braking operation ($S_2$ and $D_2$).

For the motoring mode (I), chopper circuit ($S_1$ and $D_1$), determine the duty cycle and turn-on time in the motoring mode if $n = \, ? \, r/min$, and $i_o = \, ? \, A$. Assume $V_s = 1500 \, V$, $E_a = \, ? \, n$, $R_a = \, ? \, \Omega$, $f_s = \, ? \, Hz$. Calculate the absorbed power in the motor armature winding and the power delivered by the voltage supply. What is the role of the diode ($D_1$)? Draw the voltage waveform first with $D_1$ and second without $D_1$. 
**Question 4:** Consider the following step-down and step-up chopper (two quadrant chopper). The circuit can provide both motoring forward operation ($S_1$ and $D_1$) and regenerating braking operation ($S_2$ and $D_2$).

![Chopper Circuit Diagram]

For the forward breaking mode (IV), chopper circuit ($S_2$ and $D_2$), determine the duty cycle and turn-on time in the motoring mode if $n = ?$ r/min, and $i_o = -$ A. Assume $V_s = ?$ V, $E_a = ?$ V, $R_a = ?$ Ohm, $f_s = ?$ Hz. Calculate the absorbed power in the motor armature winding and the power delivered by the voltage supply. What is the role of the diode ($D_2$)? Draw the voltage waveform first with $D_2$ and second without $D_2$. 