**Assignment 2: Modeling and Simulating A Solar Panel with a DC-DC Buck Converter**

**Introduction:** In wind power applications there is a DC link between the rectifier and the inverter which is used as input for the inverter it charges energy storage element such as battery for backup operation and electrical braking of the wind turbine in special circumstances. Also, in solar panel applications and battery-operated portable communication devices such as cellular phones, PDAs, GPSs, etc., load conditions usually change drastically from low to high power levels, such as from stand-by mode to talking mode. Improving light-load efficiency of DC/DC converter is important for extending battery life, since these devices operate at light mode for most of the time. The control of DC-DC buck converter helps to minimise the settling time and steady-state error of the output voltage and keeps its operation stability. Understanding the mathematical model of the converter will be the first step to design a good controller. MATLAB/SIMULINK is a promising simulation tool for this purpose.

**Aim:** The purpose of this activity is to demonstrate how to model the solar panel, the DC-DC buck converter circuit and the battery. Also, how to predict the response of this charging system would be investigated with reference to open loop, closed loop and the implementation of controllers.

**Objectives:**

1. Understanding the mathematical equations describing the operation of the solar panel, the DC-DC buck converter and the battery.
2. Building a SIMULINK model from the derived mathematical equations.
3. Simulating the operation of the system and showing the responses of currents and voltages of the different elements of the circuit.
4. Design a PID controller that can achieve specific design criterion.

**System Components**

**Solar Panel:**

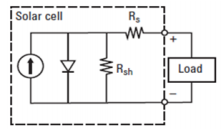
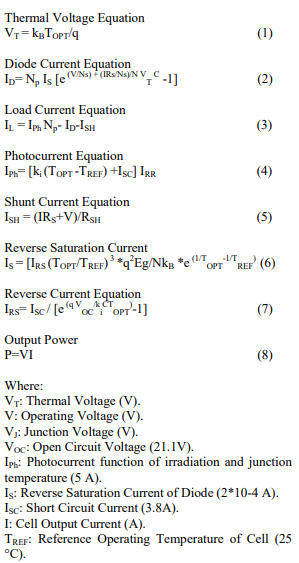
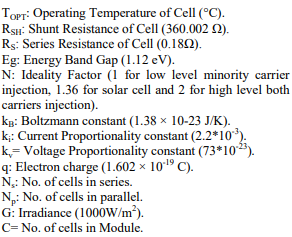


Figure 1 Solar Panel Equivalent circuit

For solar panel modelling follow this link: <https://uk.mathworks.com/help/physmod/sps/ref/solarcell.html>





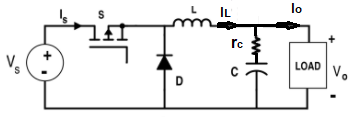
**DC-DC Buck Converter**  
 

Figure 2 DC-DC Buck converter circuit diagram

**Mathematical Model:**

When the switch s is ON:

= ……….(1)

……….(2)

D=TON/T ………(3)

T=1/f ………(4)

**Design Requirements**

You can first test the buck converter circuit operation. Start with modeling the converter to come up with some design criteria. When the input voltage vS(t) is a step voltage of amplitude of 12 V, RL=0.08 , L=4.1H, and C=376 , rC=0.005 , RLoad=1 , the output is vO(t) is the output. It is required that the output voltage settles down in less or equal to 2.5 seconds. Use a duty cycle of D=0.5.

Keeping the above in mind, we have proposed the following design criteria for this problem:

Rise time < 0.15 sec  
Overshoot < 5%  
Steady state error < 2%

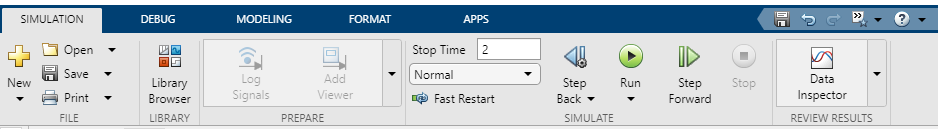
**MATLAB representation**

1. **Transfer Function**

To find the transfer function of the above system, we need to take the Laplace transform of the modeling equations. When **finding the transfer function, zero initial conditions must be assumed.**

1. SIMULINK Model

Open MATLAB then click on SIMULINK , open blank model and you will have the Simulation pane as shown below:



From the SIMULINK Library browser you can use these blocks to reflect the second order differential equation derived for the DC-DC Buck converter circuit:

Integrator block, Step block, Sum block, Gain block, Scope block.

Then we connect them by lines to satisfy the differential equation of the circuit in fig.1.

* Insert a Gain block (from the Linear block library) connected to the integrators input line and draw a line leading to the input of the gain.
* Edit the gain block by double-clicking on it and change its value.
* Change the label of the Gain block by clicking on the word "Gain" underneath the block.
* Insert a Step block (from the Sources block library) and connect it with a line to the positive input of the Sum Block.
* To view the output voltage, insert a Scope (from the Sinks block library) connected to the output of the second integrator.
* To provide a appropriate step input of 12 V at t=0.01, double-click the Step block
* and set the Step Time to "0.01" and the Final Value to "12".

Click on the green run button and you should get the time response of the output voltage.

**Closed-loop transfer function**

To solve this problem, a unity feedback controller will be added to improve the system performance. The controller will to be designed to satisfy all design criteria. You may choose on PID, Root-locus, Frequency response, or State-space.

**Assembling the system components and test its operation efficiency:**

Battery modelling follow this link: <https://uk.mathworks.com/solutions/power-electronics-control/battery-models.html>

References:

<https://uk.mathworks.com/products.html?s_tid=gn_ps>