GROEP T
INTERNATIONALE HOGESCHOOL LEUVEN

SSV Case Simulink

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21 march 2014

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Building a small solar vehicle

Lightweight

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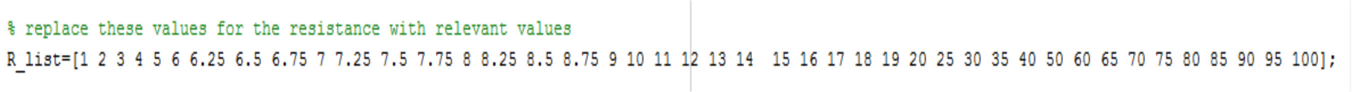
Introduction

The general idea of this report is to determine the optimal mass and gear ratio of our solar vehicle. To generate these values, we used Matlab and Simulink. These are some mathematical programs to help with an analytical analysis. Before determining the optimal parameters, some other simulations were done. With these simulations a better view of the behavior of our SSV is created. However in race situations these values won't be the same but the general idea of what to expect is present.

1. Behavior of the solar panel

1.1 Matlab simulation

The first case is a simulation of the behavior of our solar panel when different values of loads are connected. Firstly the maximum power that the solar panel could deliver has to be determined. The loads vary from 0 to 100 [ohm]. In the beginning a lot of resistor values were taken (**Fout! Ongeldige bladwijzerverwijzing.**). This point is a crucial section.



```
% replace these values for the resistance with relevant values
R_list=[1 2 3 4 5 6 6.25 6.5 6.75 7 7.25 7.5 7.75 8 8.25 8.5 8.75 9 10 11 12 13 14  15 16 17 18 19 20 25 30 35 40 50 60 65 70 75 80 85 90 95 100];
```

Figure 1: Resistor values

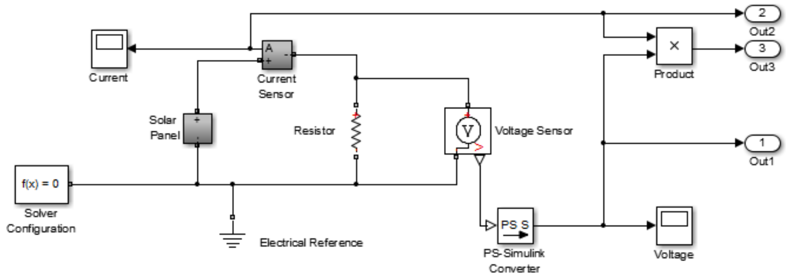


Figure 2: Solar panel with resistor

For each resistor value, Matlab determines the corresponding current and voltage those are the outputs out1(current) and out2(voltage. This is also what is visible in figure 3.

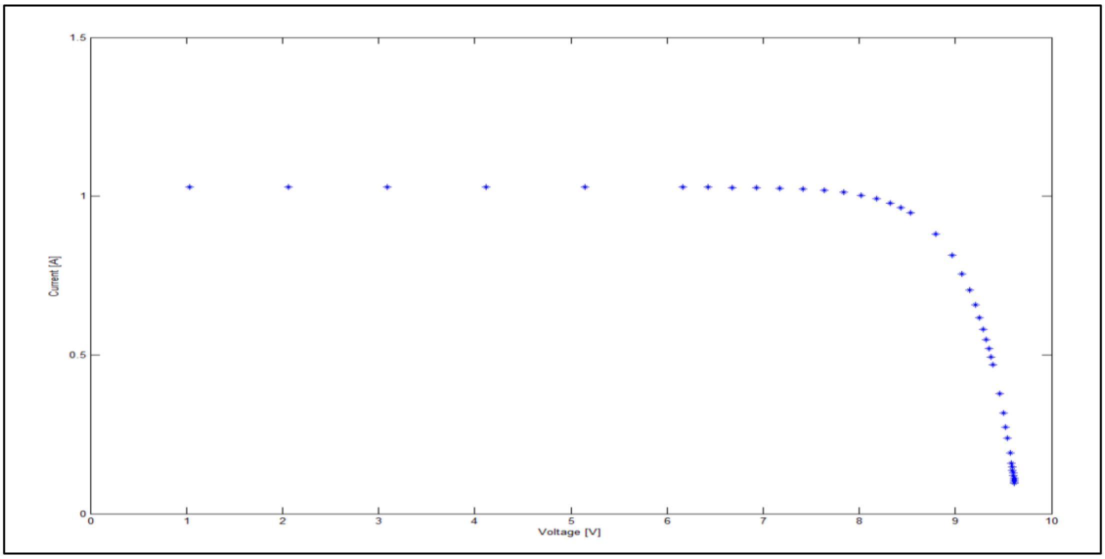


Figure 3: Current-Voltage relation

Now that the current and voltage have been determined, Matlab can use the Simulink model to calculate the maximum Power by multiplying the current with the voltage, then store in a matrix. This allows us to find the maximum value in that matrix and find the corresponding resistance. The result was a maximum power value of 8.137 [Watt] with a resistor of 8.5 [ohm]. Figure 4 shows the maximum point at on the power graph.

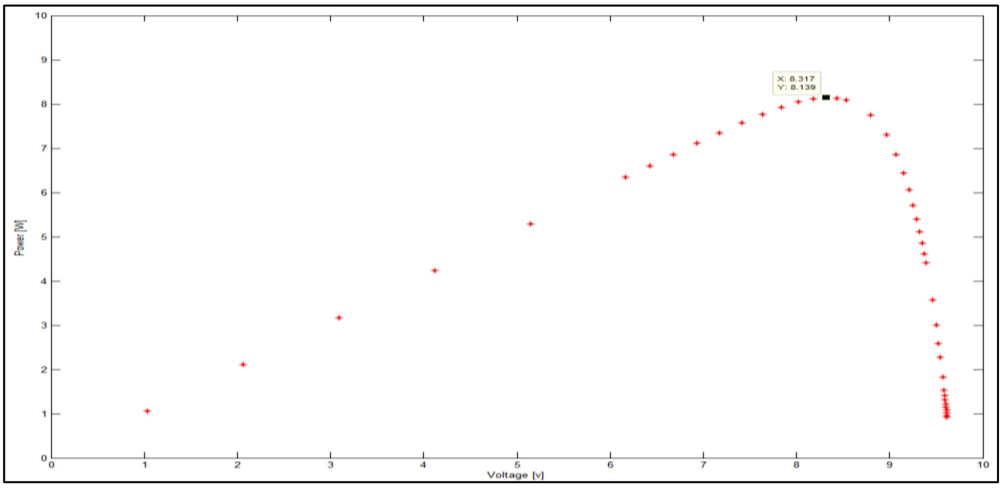


Figure 4: Power Graph

1.2 Measurements

At the beginning of the project, the max power was determined. This was in a laboratory using a bright lamp. For the measurements the max power is 4,28 Watt (Figure 5).

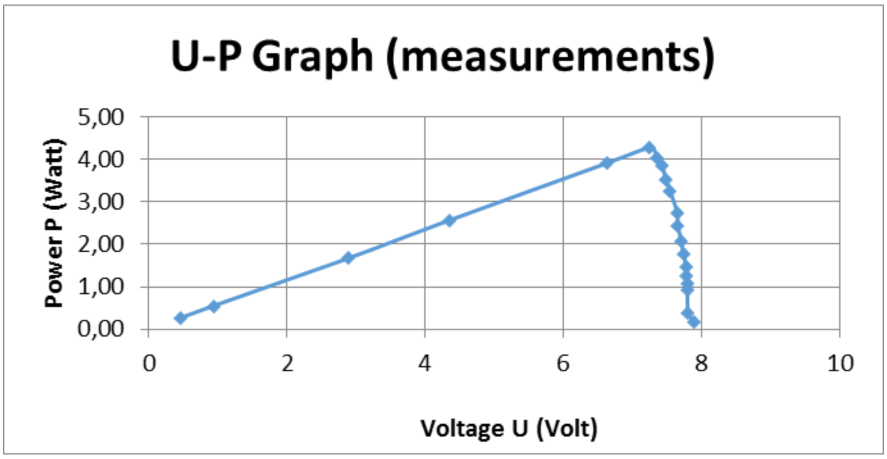


Figure 5: U-P Graph (measurements)

1.3 Conclusion

Both the graphs contain some ‘errors’ so to determine the max power it’s necessary to discuss them both. The measurements were done under a bright lamp but the SSV will be powered by the sun so the real maximum power will be slightly higher. For the ideal solar panel the Isc (Short-circuit current) was used as written in the data sheet of the solar panel: 1,03 Ampère. In our Matlab calculations, a Shot-circuit current of 0.9 Ampère was used. The ideal solar panel is near the maximum power but the measured power isn’t. This is because we used 0.59 as Isc and that is almost the half(of 0.9) so that explains also why we measured half the maximum power

2. SSV without solar panel

The goal of this case is to calculate the total distance the SSV will travel when the solar panel is disconnected. To calculate this distance a little trick is applied.

First the speed of the ball is calculated it will have when it starts rolling from a slope with a height of 1 meter. In the begin situation, there's only potential energy, because of the height. When the ball starts rolling the potential energy is transferred to kinetic energy. When the ball descends 1 meter, all the potential energy is transferred to kinetic energy. This principle is also known as the conservation of energy.

Situation 1: the ball is at rest at a height of 1 meter

So at this situation there is only potential energy. The potential energy could be calculated with this formula:

$\mathbf{E_{pot} = mgh}$ =7.21 [J]

<u>With the follow parameters:</u>

m : the mass of the ball: 0.735 [kg]

g : the gravity: 9.81

h: the height: 1[m]

Situation 2: the ball has descend 1 meter

So at this situation the potential energy has transformed into linear and rotational kinetic energy (**Fout! Verwijzingsbron niet gevonden.**). To calculate the rotational energy, the inertia moment has to be calculated. So for calculations, this equation is used:

$$\mathbf{E_{kin} = \frac{mv^2}{2} + \frac{I\omega^2}{2}}$$

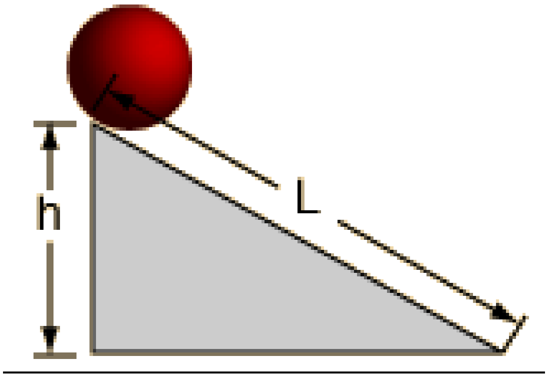


Figure 6 slop with ball

With the following parameters:

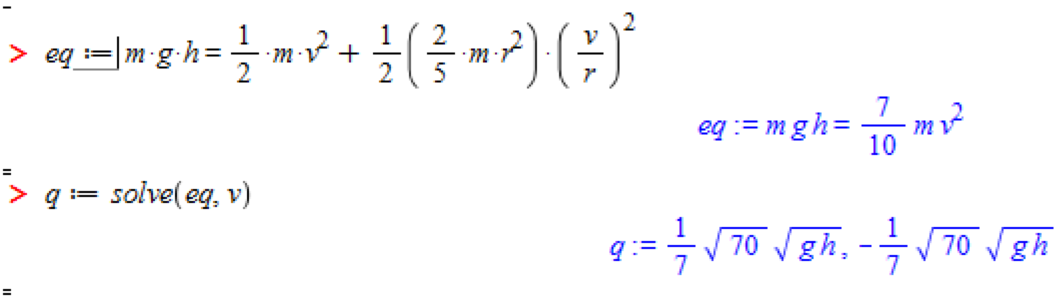
$I = \frac{2mr^2}{5}$ [kg*m²]

m: the mass of the ball = 0.735[kg]

v: the velocity [m/s²]

In this equation the velocity is the missing parameter. So it's not possible to solve this equation (Figure 7) separately. This is possible with the conservation of energy.

$$\mathbf{E_{pot}} = \mathbf{E_{kin}}$$



$> eq := m \cdot g \cdot h = \frac{1}{2} \cdot m \cdot v^2 + \frac{1}{2}\left(\frac{2}{5} \cdot m \cdot r^2\right) \cdot \left(\frac{v}{r}\right)^2$

$eq := m\,g\,h = \frac{7}{10}\,m\,v^2$

$> q := solve(eq, v)$

$q := \frac{1}{7}\sqrt{70}\,\sqrt{g\,h},\ -\frac{1}{7}\sqrt{70}\,\sqrt{g\,h}$

Figure 7 Maple calculation

Using the equation above, the velocity of the ball, after descending 1 meter, can be calculated.

$$v = \sqrt{\frac{10}{7}gh}$$

$$v = 3.74\ [\frac{m}{s^2}]$$

So when you take a closer look at the equation, there's a little remark. The mass of the ball doesn't come back in the equation.

So the ball will hit our car with a speed of 3.74 [m/s²]. A little trick was used to simulate this in Simulink. The normal circuit is used (see **Fout! Verwijzingsbron niet gevonden.**), but with a switch within it. When the SSV has traveled 8.45 meters, the switch will disconnect the solar panel. At this distance the velocity of the SSV will be 3.74[m/s²]. From now on the motor will run without the solar panel. No power is delivered to the motor, so at a certain moment the SSV will stop.

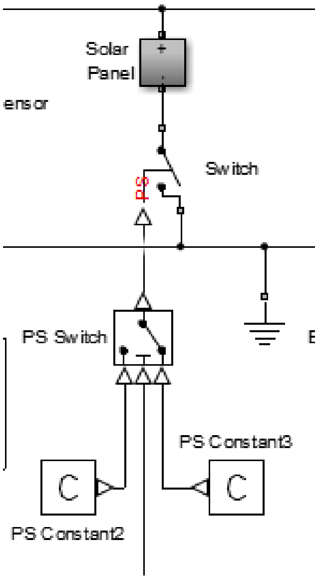


Figure 8 : Switch reverse race

The switch could also be connected to the velocity output of the Ideal Translational Motion Sensor. When the velocity reaches 3.74 [m/s²] the switch will disconnect the solar panel. This is another approach. The PS-switch is used to control the real switch. It checks if the chosen threshold (position) has been exceeded or not. It then sends one the PS constant and it's those PS constant that will determine if the switch is closed or not

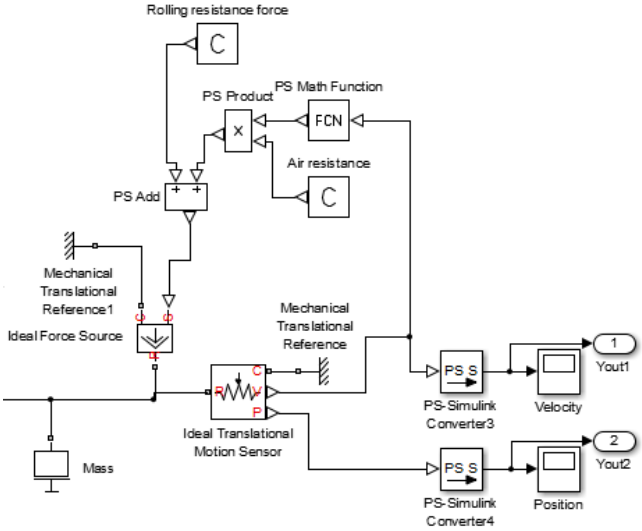


Figure 9 Loads for the ideal Force Source

To have a realistic simulation we had to add the loads to the Simulink model. Those are the air resistance and the rolling resistance. The velocity is connected to a PS math function which is going to take the square of the velocity. It's needed to calculate the air resistance.

So in the Figure 10 it is possible to see that when the velocity reaches 3.744 [m/s²], the solar panel is disconnected and the motor will get no power supply. The speed will decrease and after 25.461 seconds the speed will be zero. When an analytical approach is performed, the SSV will reach faster the speed of 3.744 [m/s²]. In an analytical approach losses caused by rolling and air resistance aren't taken in count.

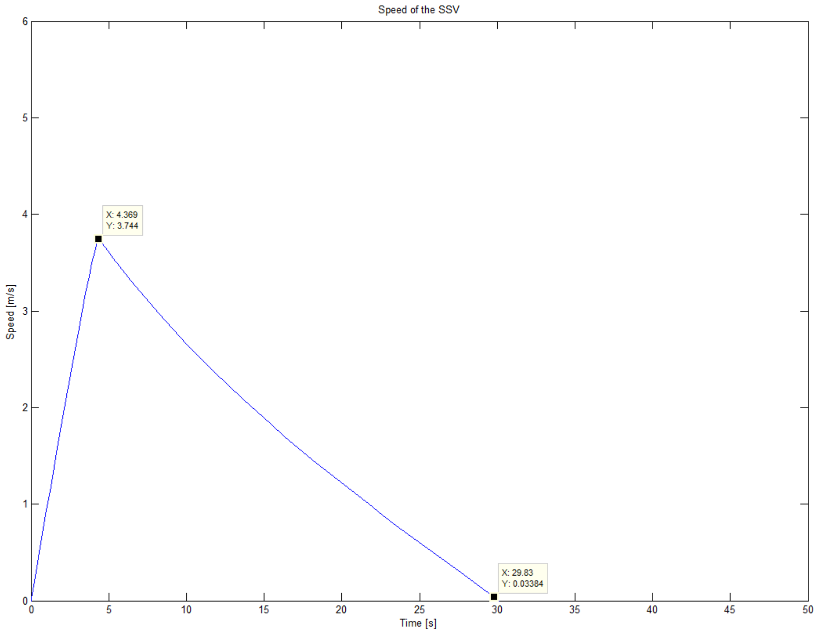


Figure 10: Speed of the SSV

Now when looking at the position graph (Figure 11) where the position of the SSV is displayed at 29.83 seconds and looking at figure 2, you can see that the SSV has traveled a distance of 51.7 meters. But this is total distance, only the distance it will travel after the solar panel is disconnected is needed.

$$51.7 - 8.45 = 43.25\ [\mathrm{m}]$$

The graph has the shape of a parabola with the top in 51.7 (Y-coordinate). After is has reached this value the graph will descend. This is impossible for the SSV, because this means that the SSV will ride backwards.

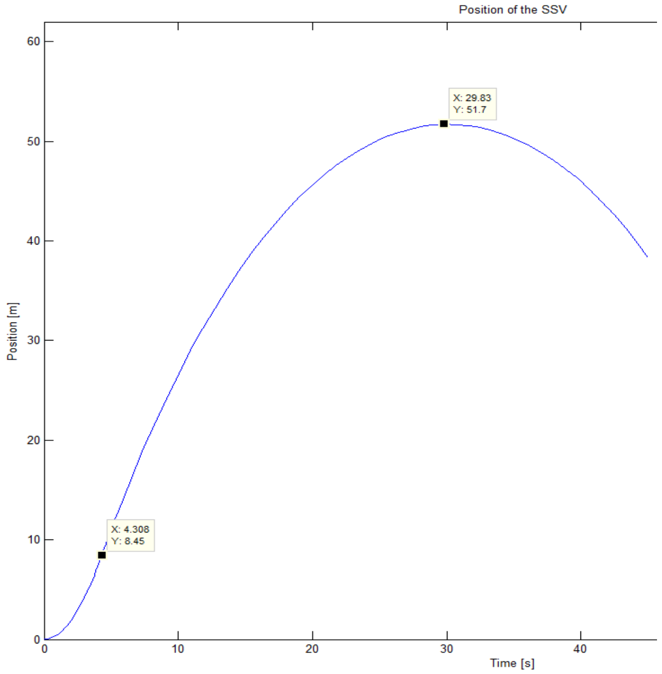


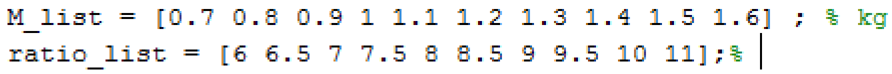
Figure 11: Position of the SSV

3. The real race simulation

Now a real simulation of the race is performed, the solar panel is connected with the DC-motor. The goal of this simulation is to determine the optimal gear ratio and the optimal mass of our SSV.

For this simulation the same circuit as in the attachment is taken, the only difference is that in this simulation no switch is used.

To find the optimal mass and gear ratio, a lot of different values for the mass and the gear ratio are entered in the program (**Fout! Verwijzingsbron niet gevonden.**). Matlab will simulate this and give the optimal combination.



```
M_list = [0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6] ; % kg
ratio_list = [6 6.5 7 7.5 8 8.5 9 9.5 10 11];%
```

Figure 12Mass - Ratio:

The optimal mass of our SSV will be 1.4 [kg] with a gear ratio of 8.5. When these parameters are taken into account, the expected height of the ball will be 1.75 meters.

The following figures will give you a better interpretation of our SSV during the race. They show the speed and the position of our vehicle. Of course these calculations are based on approximations. The conditions during the race will never be the same but it gives us a good idea.

It will take +- 4.5 seconds to travel the 10 meters(figure 11), in the other graph you see that our vehicle will have a final speed of 3.5 [m/s²].

<u>Remark:</u>

We also have to give some graphs based on the mass and gear ratio. For this graphs, please look in our other report (Case SSV 1).It has already been made for the Matlab case. The reasoning is the same

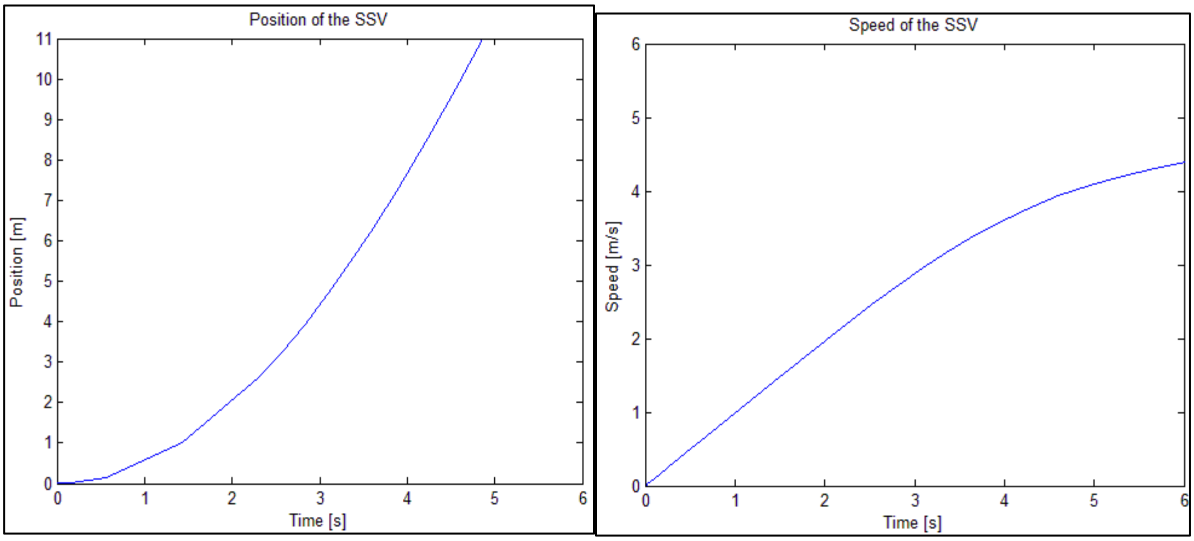


Figure 13 Position and Speed of the SSV

4. A deeper look at the simulations

Before a design it is very useful to know how your object, in our case the SSV, will react. Matlab and Simulink are very useful to get this information. Matlab and Simulink make these difficult calculations very easy and fast. With the plots the behavior of the SSV can be determinee immediately. This is much more difficult with an analytical approach. When 1 parameter is changed, the calculations have to do be done all over again.

5. Attatchments:

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5.1 Parameters for the Simulink simulation

```
%%% Solar Power
Ir = 800;   % solar irradiance [W/m^2]
Is = 1e-8; %A/m²
Isc = 0.9;  % short circuit current [A]
Voc = 9.6;  % Open circuit voltage [V]
Ir0 = 700;  % irradiance used for measurements [W/m^2]
m = 17.28;    % diode quality factor

%%% Motor parameters
Ra = 3.36;
Km = 1/1120; %V/rpm
L  = 0.222; %mH
Cm = 8.93e-4;

%%% Gearbox
efficiency = -0.25;

%%% SSV parameter
Cw  = 0.5;
A   = 0.03;
rho = 1.290;
Crr = 0.012;
g   = 9.81;
%%% Wheel radius
r = 0.04;
```

5.2 Simulink model