GROUP T
LEUVEN ENGINEERING COLLEGE

Team Apollo

Simulation report

with Simulink

25-3-2011

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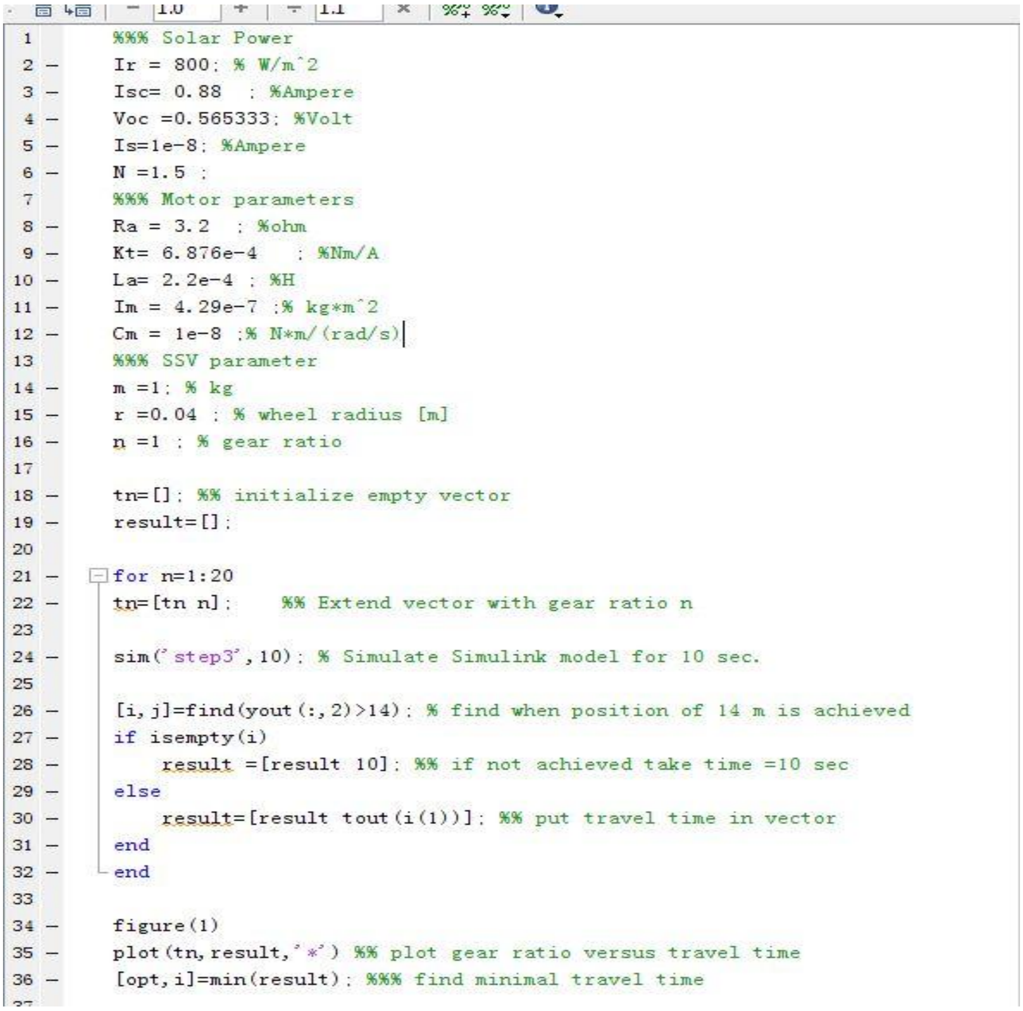
Simulation Report: Simulink

In this report, our Simulink case is explained and worked out to show how we worked. Simulink is a software program which is part of the Matlab program. In Simulink, you can simulate all kinds of situations. In our case, we had to simulate two different situations. The first simulation was just the race itself. Our solar car started standstill and raced until the end of the slope. In the second simulation, we had to try to found how far the SSV would travel if we put the car one meter up the hill and just let it roll (without any driving force).

The assumption of the parameters:

- **The weight of our solar car:** $m = 1\ kg$
- **The formula of the air resistance:** $F_W = \frac{1}{2} \cdot C_W \cdot A \cdot \rho \cdot v^2$
- **The assumption in the formula:** $C_W = 0.2$;
  $A = 28 \times 21.8\ \sin 20° \ cm^2$;
  $\rho = 1.29\ kg/m^3$; v is velocity.

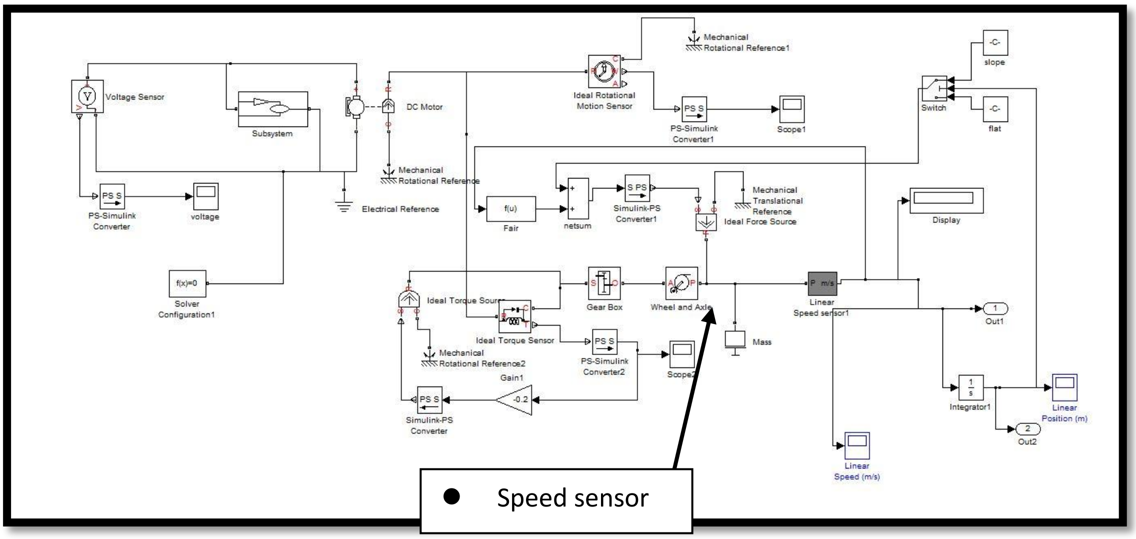
- **The gear ratio we take:** $i = 10$
- **Coefficient of rolling friction:** $C_{rr} = 0.015$
- **The diameter of the wheel:** $D_{wheel} = 0.08\ m$
- **The angle of the slope:** $\theta = 3°$
- **The length of the flat road**: $L_1 = 6\ m$
- **The length of the slope**: $L_2 = 8\ m$



```
%%% Solar Power
Ir = 800; % W/m^2
Isc= 0.88   ; %Ampere
Voc =0.565333; %Volt
Is=1e-8; %Ampere
N =1.5 ;
%%% Motor parameters
Ra = 3.2   ; %ohm
Kt= 6.876e-4    ; %Nm/A
La= 2.2e-4 ; %H
Im = 4.29e-7 ;% kg*m^2
Cm = 1e-8 ;% N*m/(rad/s)
%%% SSV parameter
m =1; % kg
r =0.04 ; % wheel radius [m]
n =1 ; % gear ratio

tn=[]; %% initialize empty vector
result=[];

for n=1:20
tn=[tn n];    %% Extend vector with gear ratio n

sim('step3',10); % Simulate Simulink model for 10 sec.

[i,j]=find(yout(:,2)>14); % find when position of 14 m is achieved
if isempty(i)
    result =[result 10]; %% if not achieved take time =10 sec
else
    result=[result tout(i(1))]; %% put travel time in vector
end
end

figure(1)
plot(tn,result,'*') %% plot gear ratio versus travel time
[opt,i]=min(result); %%% find minimal travel time
```

Figure 1: the parameters

Simulation for case 1



● Speed sensor

Figure 2: Overview

- This is the whole program for case 1. There are four main parts to realize the simulation: the solar energy part, the driving part, the resistance part, the measure and output part. As the figure shows, we can see two subsystems, the solar panel and the linear speed sensor:

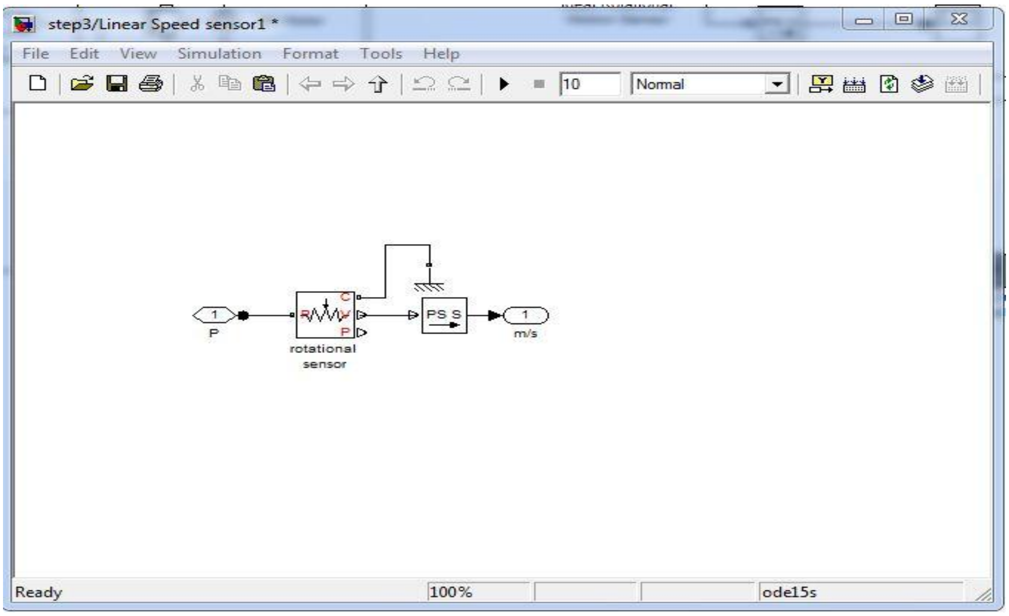


Figure 3 speed sensor

- **Rotational sensor**
  We use a rotational sensor to measure the speed of the wheels. The rotation speed of the wheels ‘enters’ in port 1, the sensor measures the speed and converts the physical signal into a Simulink output signal, this signal is sent out from port 2.

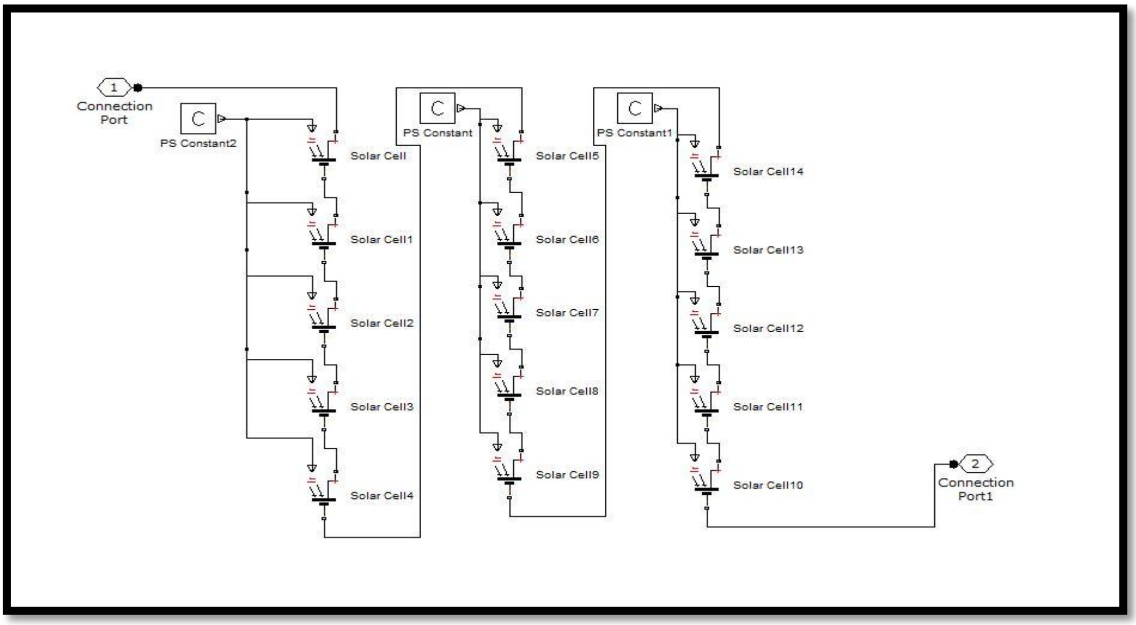


Figure 4 solar panel

- **Solar panel**
  The subsystem of the solar panel are fifteen cells combined as a whole solar panel. They are connected in series so the voltage of the panel is the sum of fifteen solar cells.

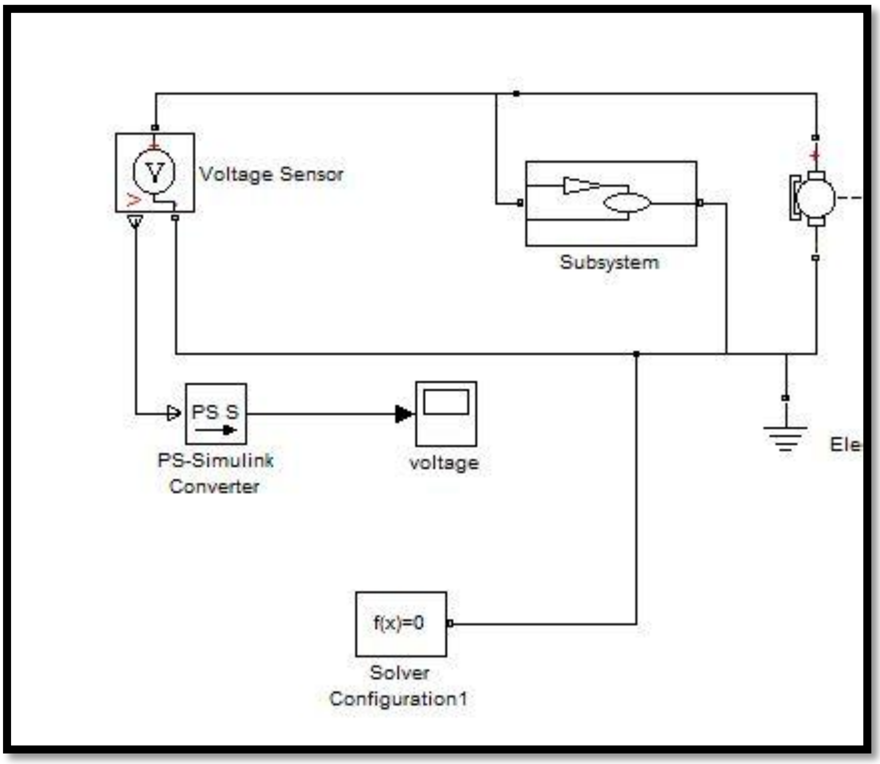


Figure 5 solar energy part

- **Solar energy part**
  Here, we just connect the solar panel with the DC motor. The voltage sensor is used to measure the voltage of the solar panel.

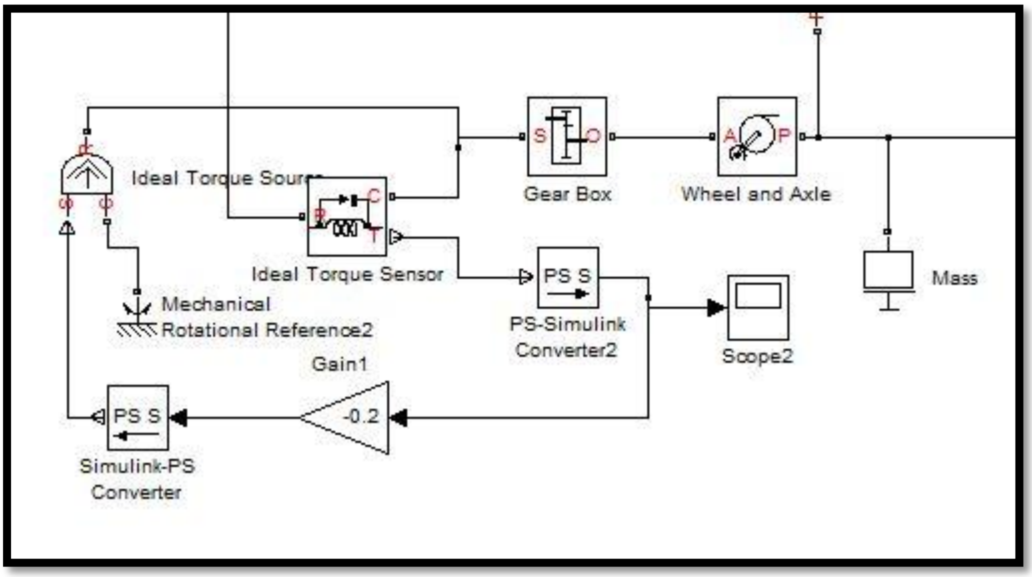


Figure 6: The driving part

- **Driving part**
  The output of the DC motor is torque. We connect the torque to the gear box to generate driving torque. The torque sensor can measure the output torque. 20% of the torque is lost due to some internal friction. The loss can be generated by a ideal torque source, in which the parameter is 80% of the original torque. After the gear box, there are the wheels and the axle with a radius of 0.04m. Finally, the mass is 1kg.

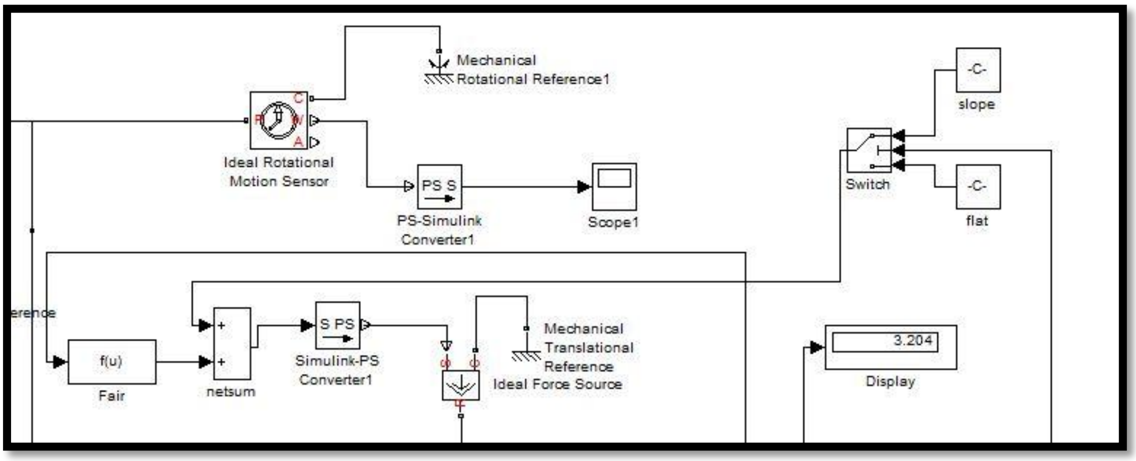


Figure 7 resistance part

- **Resistance part**
  In this part, we can see two kinds of resistance on the flat road and three kinds of resistance on the slope. When the car is on the flat road part (the first 6m of the race), aerodynamic drag and rolling resistance are exerted on the car. When the car reaches the slope, another force is added, i.e. part of the gravity. We use a switch to control when the slope model should start.

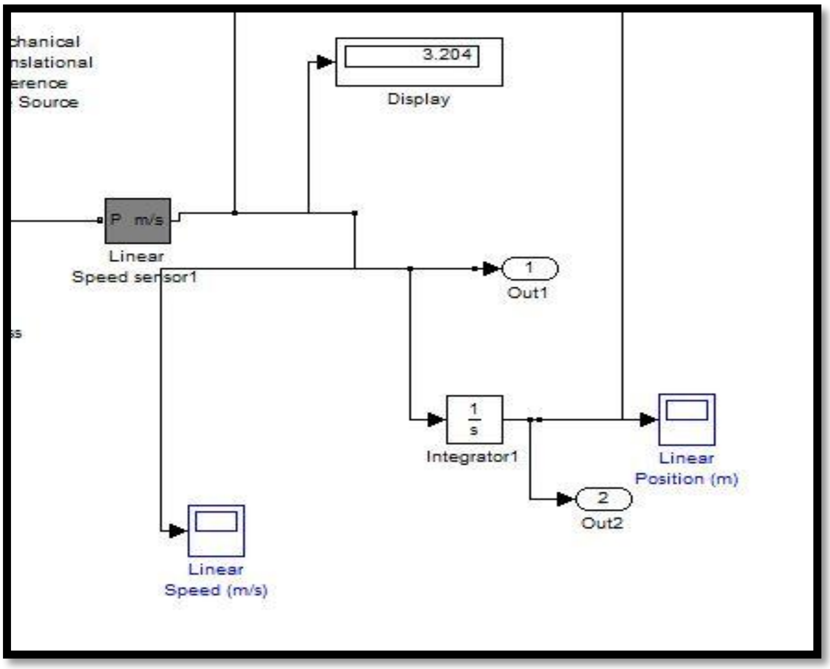


Figure 8: Measure and output part

- **Measure and output part**
  The linear speed sensor discussed above can measure the speed of the wheels. We add a display to show real-time speed. The integrator is a integration of speed, which means the change in position. Two scopes display the speed and position. The output ports can send the results to Matlab.

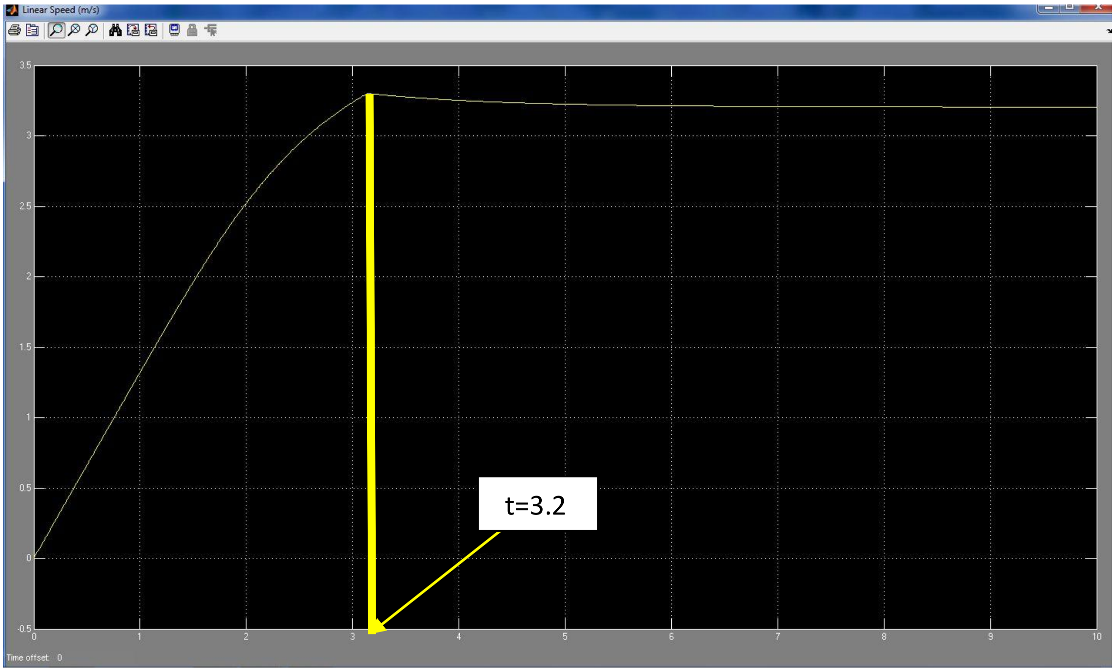


Figure 9: Speed

- **Speed graph**
  Here we can see the speed shown by the speed scope. At about 3.2 seconds, the speed reaches maximum. Then it drops a little because the car is riding on the slope.

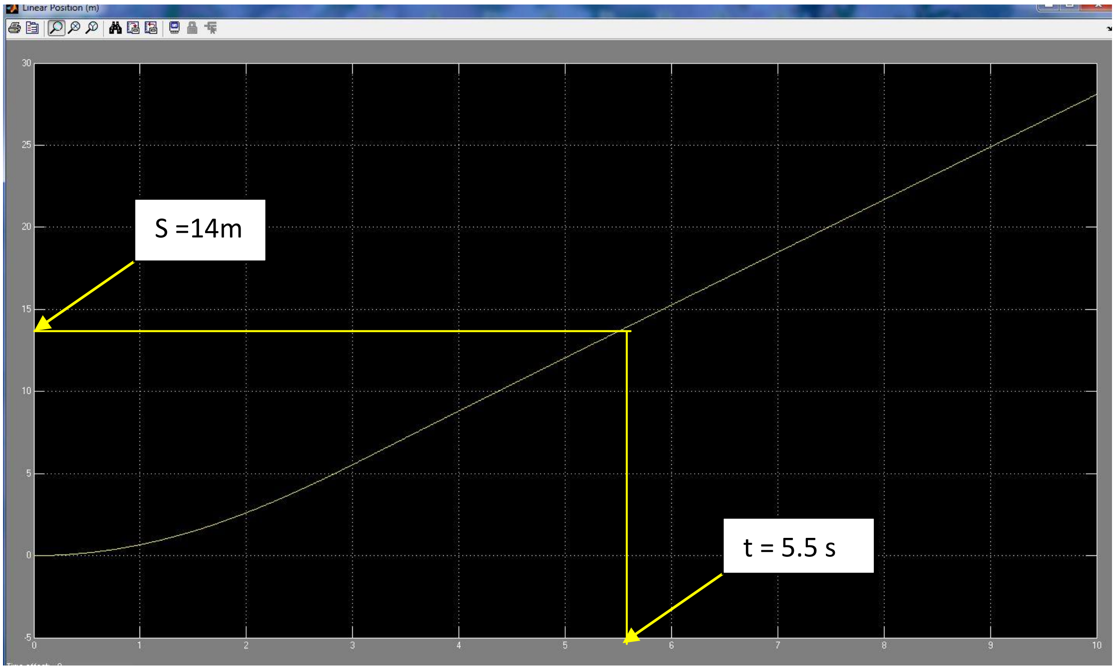


Figure 10: Position

- **Position graph**
  Here is the position graph. It increases during ten seconds. From this graph, we can determine the car needs about 5.5 seconds to travel 14m.

From the table above, our gear ratio **i** is equal to 10. Now, we will take some different gear ratios in order to see how long it will take for the solar car to travel 14 meters:

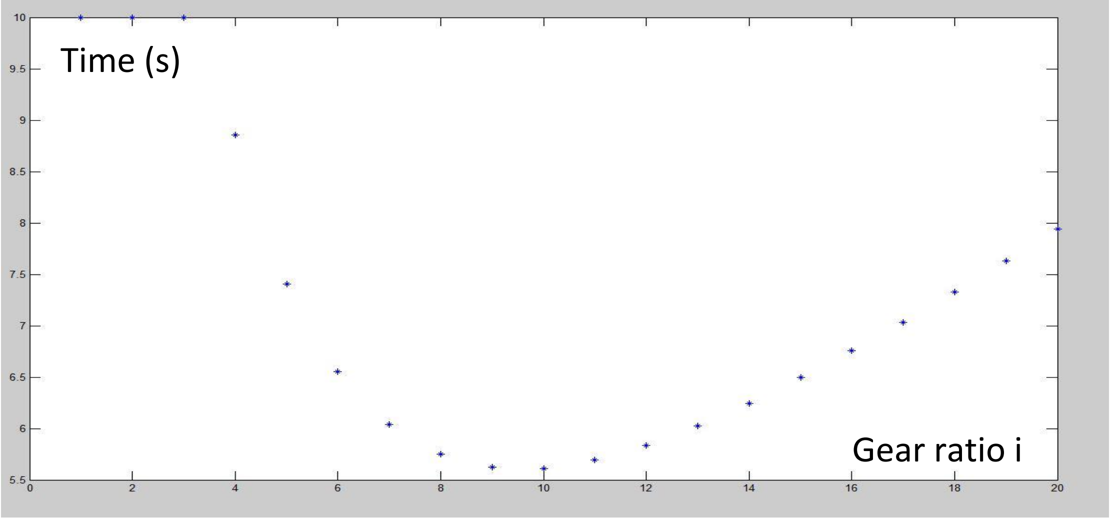


Figure 11 Different gear ratio

- **Different gear ratio graph**
  From the table above, we can see that when the gear ratio is small or large, the solar car will take a lot time to travel 14 meters. When the gear ratio is equal to 10, it will take the shortest time to travel the distance of 14 meters and when the gear ratio is equal to 9, it will take a little bit more time then when the gear ratio is equal to 10.

In the real situation, we can take different gear ratios depending on the information which this graph gives us.

Simulation for case 2

In a second simulation, we let our solar car ride down from the 3 degree slope without any driving force. The length between the top of the starting point and the bottom of the slope is 1 meter.

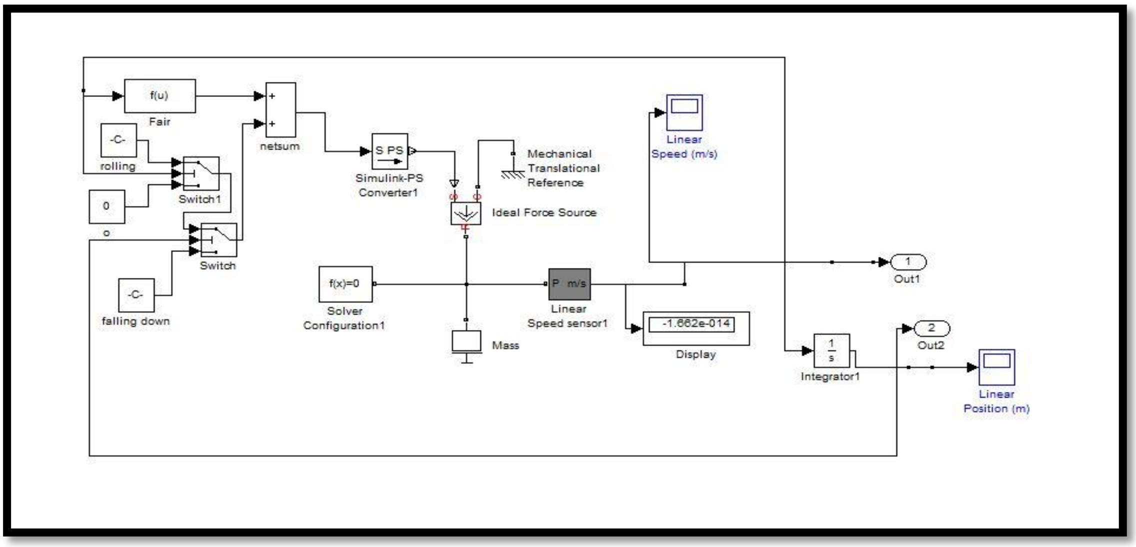


Figure 12: Case 2

This is the program for case two. The car will roll down because of the 3 degree slope (gravity is the only ‘driving force’). Due to resistances, the car will stop at certain moment. In this case we will simulate how far the car will roll without any driving force.

A force source is connected to two kinds of force, these are the driving force (due to gravity) and resistance (both rolling resistance and aerodynamic drag). We still use a switch to control when the car will reach the flat part. Another switch is used to make the resistance disappear when the speed reaches zero.

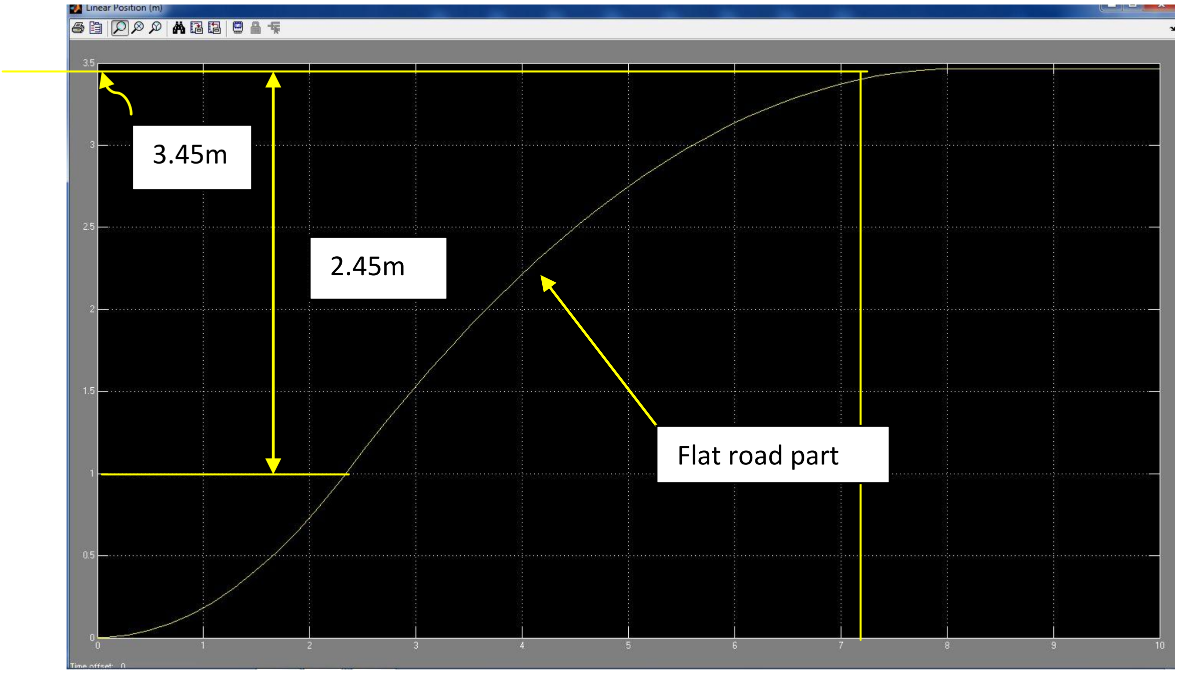


Figure 13: Position (2)

- **Position**
  Of course, when the car stops, the position keeps constant at a certain value. In this situation, the value is 3.45m, which means on the flat part, the car can continue to roll for 2.45m.

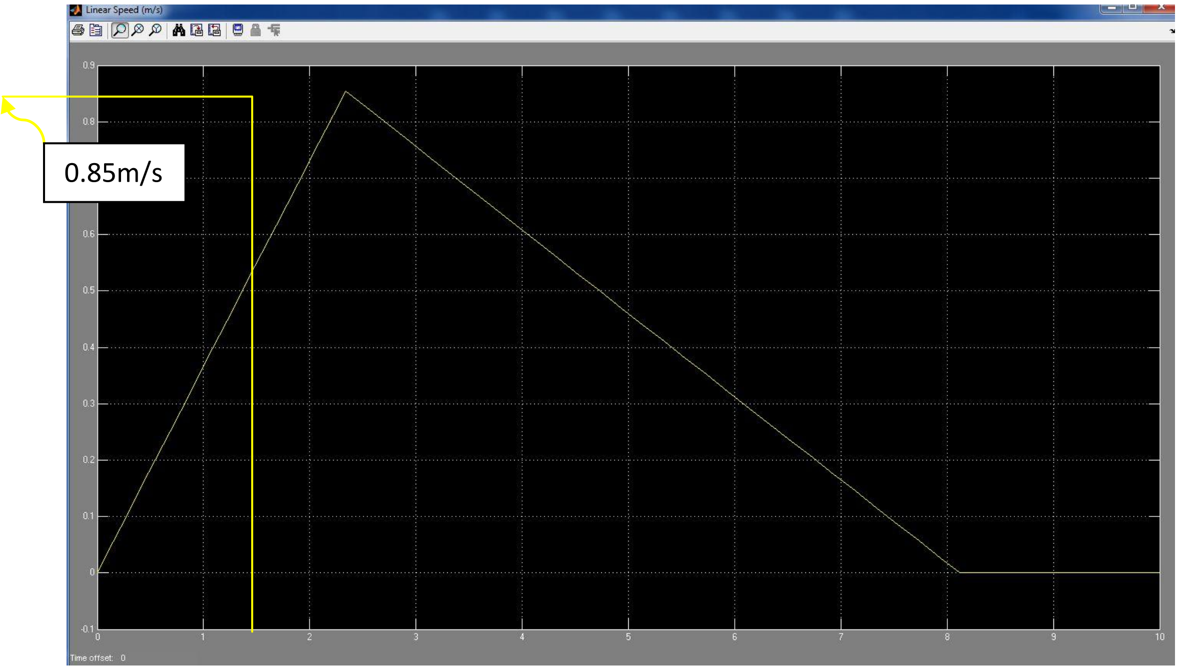


Figure 14: Speed (2)

- **Speed**
  The speed graph shows that at the end of the slope the car will reach the highest speed of 0.85m/s. then the speed decreases until standstill.

Conclusion:

The results we get from the simulation (almost) matches with the results we get from the calculation of the gear ratio. The difference is that the top speed we get from the simulation is a little bit smaller than the speed we get from the calculation of the gear ratio. The reason for this error is just some parameters have little difference and the calculation errors.

In this simulation, the values of some parameters are from the ideal situation in our system. So in the real situation, there will be some difference between the simulation and the real situation. As a result, we will have to modify a lot of things when we are building and testing our solar car.