# Mechatronics Project

## Electric power supply for road vehicles, on road

### Group 3

Mikael Borg

Herman Lingefelt

Max Åkerman

John Åkesson

Tan Lin

# Table of Contents

## Problem Formulation

The comfort factor has always been considered to be one of the most important properties of a product. That is why we have chosen to design our product in such a way that optimizes the comfort factor. The electric cars that are on the market today have for the moment two basic ideas for the charging of the batteries. The hybrid cars utilize an online charging of the batteries and the plug-in car uses the online charging as well as the hybrid. But the charging can also be done with a connection to the power grid. One can see that this is a major drawback for the plug-in cars. Our solution will present an online charging of the car batteries. This is done due to the fact that we wanted to increase our comfort factor. In the report we will present our two different solutions which are based on the technology of the train's drive. One of the solutions utilizes the train pantograph and the other one uses a rail which is fed with electricity. These two solutions require a major reconstruction of the infrastructure. It will take time to adapt to these kinds of systems and requires a lot of investments for the government. Due to the expenses this will lead to that only the most travelled routes will have this kind of system. Our solutions will be further presented in the report.

# Project Specifications

## Background

Electric cars have been around for a long time, but it isn't until recently that the technology has made it possible for hybrid cars. Due to the fact that our environmental awareness has increased drastically this decade, hence increasing demands for environmentally friendly transportations occurred. This has lead to a continuous race between the car manufacturers, which enables the development of the technology to be kept pushing forward. The difference between a purely electrically driven car and a hybrid car is that in a hybrid car you have an electric motor as well as a traditional combustion engine. Both motors can be used simultaneously for driving or they can be used separately where the electric motor is used mainly for city driving and the combustion engine charges the batteries when used for long rides where its efficiency is best.

## Marketing Analysis

The market for alternative cars has exploded during this decade and one of the reasons is the intense marketing from the car companies. But the development has been prolonged for many years, by powerful stakeholders within the oil industry. A perfect example of this is General Motors EV1, which was launched in 1990 and had very sophisticated technology for that time. But strong forces within GM and the oil industry decided to stop the project. They realised the potential of the project and saw the electric car as a threat for the old-fashioned combustion engine. Today, the demands from the people are different and the car industry is adapting to it. The leading manufacturer at the moment is Toyota with its hybrid car Prius which was introduced in 2001.

## Requirements and desired features

Of course when we try to develop a product of any kind, we need to have a list of requirements and desired features. In this list the requirements have the higher priority for the actual product. Desired features should be taken into account for the development, but they could one by one be denied or cut down if they are negative for the requirements. In many cases the cost for the product is required to be low. Other products may have to be small and so on. Therefore we may not be able to implement all desired features.

### Requirements

- Easy to use
- Reliable in any weather condition
- Easy to connect to the power grid
- High security
- Environmental awareness
- Galvanically isolated

### Desired features

- Cheap
- Silent
- Small
- Light
- Quick to use
- User-friendly interface
- Automatic as far as possible
- A possibility to use the product manually

### Comments on the list above:

As described above some features are more or less compulsory for the final product. If we study the main purpose of the product it is obvious that environmental awareness is required. It is also worth to notice that the cost actually is not as important as in many other products. We can think of this product as an investment both economically and environmentally, thus the cost is not very important, but of course, still favorable. A required feature is the user-friendly interface.

## Stakeholders

The future users of hybrid cars

The sub suppliers and aftermarket companies for spare parts

## Goal and expected result

The goal for this project is to acquire the right amount of knowledge to be able to come up with different solutions for the task.

## Dissemination of results

The results of this project will be presented to the other groups in two ways. We will first hand in our report which will show the whole projects procedure. The results will also be presented in front of the other groups in the mechatronics course.

Note that the presentation will be presented by another group.

## How the immaterial right will be handled

It is of course very important that our idea is not already patented or in use. It’s not yet decided how this will be handled, but it's discussed and will be dealt with later on.

## The methodology

Brainstorming is very important. But before we start to brainstorm, we have to read some papers, search literatures about the hybrid vehicle.

Besides theoretical report, the project management is also significant. With the WBS we can control the process of the project so that everything will be on time.

## Project scheduling

| Gant Scheme | V9 | V12 | V13 | V14 |
|---|---|---|---|---|
| Project description | | | | |
| Acquire Knowledge | | | | |
| Interviews/discussion | | | | |
| Model constructing/different solutions | | | | |
| Rapport typing | | | | |
| Presentation | | | | |

Due to the fact that all the engineering students have different backgrounds in electrical and mechanical it is natural that we will divide the work in that way. Nevertheless the group goal is to share our knowledge in between the members to widen our horizons.

Mechanics:

John Åkesson

Tan Lin

Herman Lingefelt

Electronics:

Mikael Borg

Max Åkerberg

## Product suggestions

1. **Pantograph, Scissor lift**

   Very similar design to what the trains use today.

2. **Tracks**

   Tracks down in the road.

3. **Arm**

   An arm that extends from the side of the car to the side of the road where it is connected to rails on the side.

4. **Induction**

   Transfer electricity to the car via induction.

After a while of brainstorming we got a couple of ideas. To make a choice of solution for the problem we decided to make a ranking system with different weight factor. We used a scale from 1-5 to give the different solutions points in the different categories, where 1 is the lowest and 5 is the highest.

Our different factors were safety, control, cost, construction, efficiency, design, and flexibility.

After discussion we decided to rank our 3 best ideas and this is the result.

| **Solution** | **Safety** | **Control** | **Cost** | **Construction** | **Efficiency** | **Design** | **Flexibility** | **Tot. Score** |
|---|---|---|---|---|---|---|---|---|
| Pantograph | 5 | 4 | 3 | 4 | 3 | 2 | 4 | 25 |
| Tracks | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 25 |
| Arm | 4 | 3 | 3 | 2 | 3 | 2 | 3 | 20 |

Two solutions got the same final score, so we decided to investigate them further.

# Selected Products

## Pantograph, Scissor lift

The basic principle is to transfer electric current from overhead wires to a pantograph.

### Basic design

An easy way to connect to a power grid would be to use the same idea that trains use, but a bit modified. To connect to overhead wires you must have some kind of device that pushes a conducting material onto the wires. The device that a train uses is called a pantograph.

We had two different solutions for this. One was to have a scissor lift that pushes up the contact shoes onto the wires. The other one was to have a Z-shaped pantograph. Both the pantograph and the scissors lift will be powered with a pressured air piston.

The conductor on the pantograph itself is a very complicated part. The contact shoe that lies against the copper wire must have a sheet of a soft conducting material. If not, the contact shoe will tear on the wire itself, and after a while the wire will break and that will cost both money and time.

The contact shoe itself must also be applied with the right amount of force to the wires. Enough force to ensure good contact, but not enough to damage or even tear down the wires. This is managed by mounting the conductor on leaf springs or torsion bars. Torsion bars give a lower air resistance, but leaf springs are cheaper. The spring and pantograph then make sure that the right amount of force is applied and compensate for small bumps in the road.

The car must also have a wire hanging out underneath the cars. This wire grounds the car if only one pole is connected to the overhead wires.

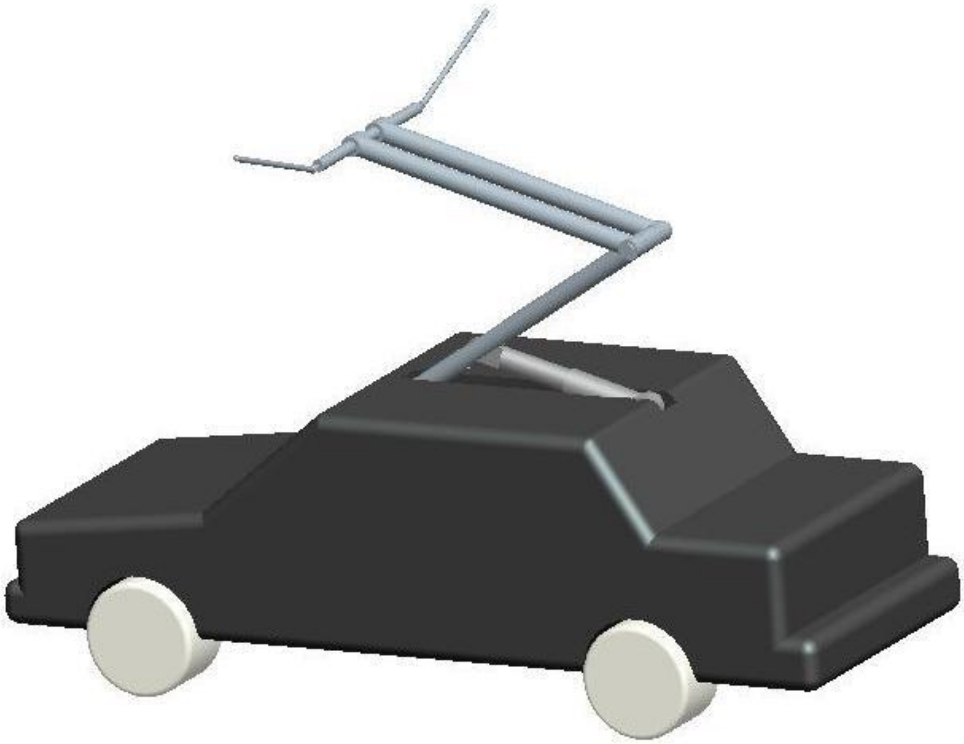

**Figure 1: The Pantograph design**

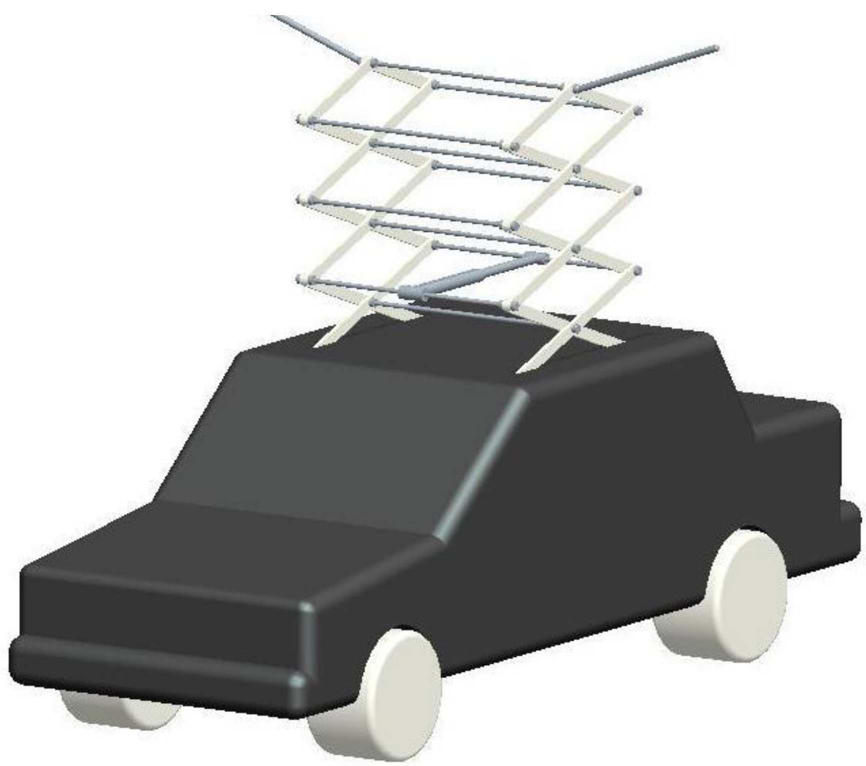

**Figure 2: The scissor lift design**

## Material

The pantograph itself should consist of a metal alloy that can cope with hard weather and oxidation. The sheet of a conducting material on the pantograph must be soft. A suitable material that is used on trains is graphite.

## Negative aspects

The major malfunction that causes delays in the train traffic in Sweden today is that the graphite sheet on the contact shoe is damaged. A damaged graphite sheet could damage or even tear down the wire. So this must be prevented at all costs. It also means that it must be very easy for anyone to repair and replace a damaged graphite sheet on the contact shoe. Or maybe even replace the whole contact shoe. This must be done without getting too close to the wires.

One way to detect a damaged graphite conductor is to make a hollow contact shoe with a pressure gauge inside. When the gauge senses a change in pressure it should automatically lower the pantograph from the wire to avoid any damage to the wires.

To even the tear on the graphite conductor the wires should go in a crisscross pattern. This should give a uniform tear on the graphite sheet on the contact shoe, and maximize the lifetime of the graphite sheet.

There is a big height difference between original cars and for example trucks. Therefore the pantograph must be able to reach high up.

The most vulnerable part in this design is the overhead wires. A torn down wire causes a life threatening situation for humans.

## Positive aspects

The systems for putting up and maintain overhead wires are already well known.

A pantograph could be made fairly cheap.

You could design it like a module that you could just bolt on.

### Conclusion

The idea of a pantograph on a car is doable. A requirement though is that the contact shoes must be easy to replace and fairly cheap.

## Tracks

This idea of transferring energy to the car while driving is based on using electrical rails in the road and connecting rods under the car.

### Basic design

The basic construction of this system is that the connecting rods are under the car on a rail that lets the rods slide sideways. This is because a car driver never drives in a straight line. The rails are milled down in the road so that cars can drive over the rails. To lower the rods, an electric or hydraulic actuator would be mounted between the rods. In the case of using a hydraulic actuator it must be both possible for it to push and retract. The slider has bearings so that it will slide easily on the beam under the car. It also has to have a little electric motor so that the control system could sync up the position with the rails in order to connect properly. There also has to be some way to actually connect the rods to the rails, since it has to connect to the sides of the rails. Maybe the connectors should be spring loaded.

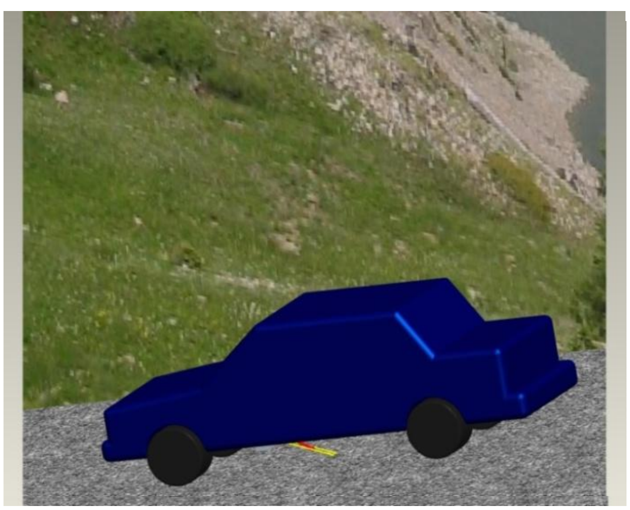

Figure 3: Rendered car driving on mountainside.

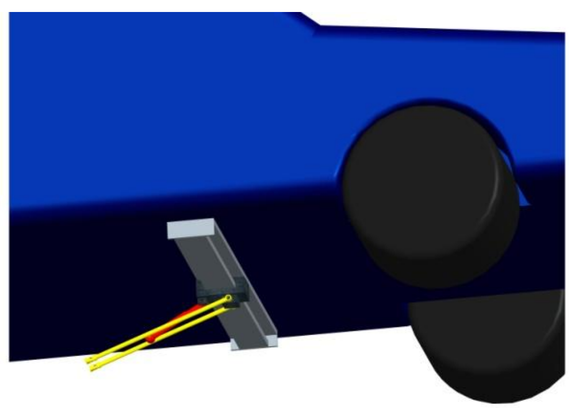

Figure 4: Mounted slider under car.

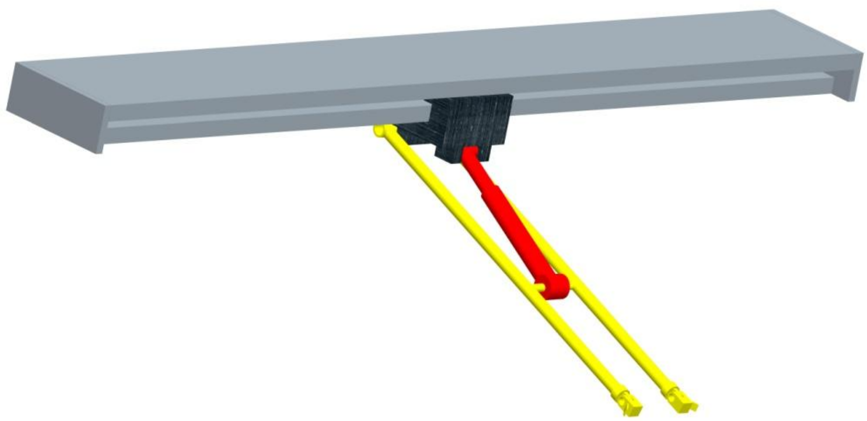

**Figure 5: The Slider mounted on the beam.**

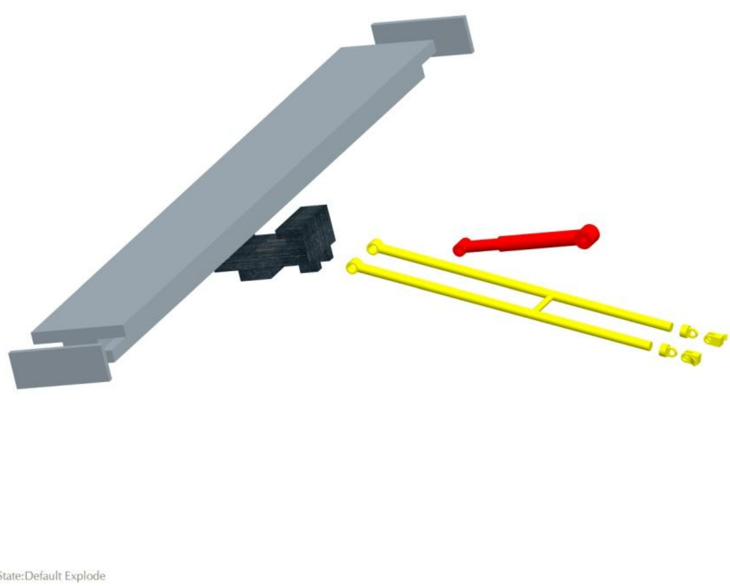


**Figure 6: The Slider in an exploded view.**

## Material

The slider and mounting part should be of some sort of metal alloy. The rods should be made of some sort of hard composite. The connecting cables then could run inside the rods. The connecting part of the rods should be made of graphite so it won’t wear down the connecting part. The graphite should be very easy to replace.

## Positive aspects

If the design would work, it would be quite easy to implement on any electric car because of the connecting rods are under the car. The ride height of various cars doesn’t differ that much so maybe manufacturers don't have to make a model for every car model.

## Negative aspects

The design we have right now wouldn't work flawlessly because when cars swing on the road there would be some forces on the side of the rods and the construction. Maybe this could be solved somehow. A difficult part would be the control system. This is because the rods would have to retract when driver shifts lane. There must be some failsafe system too if there is a crash or the car gets out of control.

A very big negative aspect is that rain and dirt would fall down in the rails, and that would be a hard task to solve. Also if it would rain a lot, water gathers in a large pool and that would be devastating because water conducts electricity.

## Conclusion

This design would be quite hard to get to work. It has too many negative aspects and difficulties. The basic thought with the design would be quite nice if it would work.

### Summing up of selected products

If we weight the positive and negative aspects of the designs, we came to the decision that we would use the Pantograph design.

## Power electronics and control system of the Pantograph

### The power electronics

In order to get high energy value and still a relatively small and low cost power supply to the electrified roads, we need to have high voltage through the power lines. Exactly how high is still not determined. Because of this high voltage it is crucial that we transform the voltage to a more suitable value. An advantage of this transformation is actually the galvanic isolation which is needed for safety reasons. One thing to take into reconsideration is the possibility to charge the battery while driving. This means we have to DC-transform the power and later on AC-transform it to be able to rotate the electric engine. Probably it would be better to have a control system which detects a full-loaded battery or a disconnected one. This could give us the option to only transform the power once, or more specifically, from the high voltage lines to a voltage that fits the electric engine. The control system will be more described later on.

## The control system

When a car travels along a road there could be many things happening which could damage the power supply or the adapter. Consider the driver changing lane as an example. This could damage the lines or the adapter if there was no system for detecting the driver maneuvers. As mentioned above we also need a system to control the battery charging and the power transformation. Actually it would be possible to implement these two control systems in one larger system with a microcontroller. The events which need to be controlled could be described in a list:

### Power control

Is the battery connected?

Is the battery fully loaded?

Is the voltage or the current right?

The voltage is controlled by a filter which will handle any disturbance in the grid.

### Event control

Is the adapter connected right?

Is the driver driving straight?

Is the car stable in the vertical position?

In this application there could come up some different obstacles. Consider the driver to change lane in order to overtake another car. This would make the lines intercept each other. We need to be able to drop the connection a short time in order change lanes and so forth. The same thing is required if the car moves too much vertically, maybe as a result of any bump or object on the road.

## Selection of cable

Considering the cable of trolley busses and trains, we know that normally the cable will not suffer tremendous impact. That means that the most important factors of choosing cable are tensile strength and conductivity.

As conductive material, copper is most widely used. But as we know, copper has the disadvantage of tensile strength. Normally we should add some other material in the copper alloy to increase the tensile strength.

The characters of material in 20℃

| Material | Conductive/（%） | Tensile strength/ ($kgf/mm^2$) | X in Material/ (%) |
|---|---|---|---|
| Cu-Cr alloy | 88 | 45 | 1.2-1.4 |
| Cu-Sn alloy | 40 | 70 | 1.5 |
| Cu-$Ni_2Si$ alloy | 35 | 89.8 | 3-4 |
| Cu-Be alloy | 25 | 135 | 2.5 |

The materials above have been used widely in the cables of trolley buses and they all have their own advantages. Cu-Be has the highest.

## Final Conclusion, Our solution vs. the existing solutions

The solutions that we have come up with during this project are ground braking in many ways. Such goals as sustainability design, user friendly interface and comfort factor are clearly fulfilled. One of the major drawbacks of our solutions is the extent it requires to implement. It is most likely very unrealistic to be put in use in the future. When looking at the other solutions that are available on the market today one can clearly see the trends that the plug-in cars will win more market shares over the coming years. Thus making it even harder for our product to win any ground in the dog eats dog industry of automobiles. The batteries of the modern electrically driven cars have the most focus and have an enormous prolongation. It's considered to be the single component that is holding back the further progress of electric cars.

## References


http://en.wikipedia.org/wiki/Ev1 - cite_ref-0 http://ev1-club.power.net/ev1faq/faq4.htm

http://www.greencar.com/features/gm-ev1/

http://www.autobloggreen.com/2008/09/05/at-witz-end-gm-ev1-the-real-story-part-iii/

http://www.evuk.co.uk/hotwires/rawstuff/art9.html

http://ev1-club.power.net/vin.htm

http://www.ev1.pair.com/charge_across_america/charge_html/faqs.html

http://www.kingoftheroad.net/charge_across_america/charge_html/gen2delivery.html

http://www.ka9q.net/ev/ev1fire.html