Charge System for EVs

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Work Reference: WRE-2013-04

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Abstract

The EVs (Electrical Vehicles) have experienced a fast development during the last years because of the technological progresses in the field of batteries and electrical motors.
The goal of this project is to be a final push for the EV to become established in our daily lives.

Objetivos

Keywords

Electrical Vehicle, Renewable Energy, Solar Panel, Bidirectional converter, Flyback converter, Boost Converter

I. - INTRODUCTION

The proposed charging system will be able to use renewable energy to charge a set of batteries which will later be used for our vehicle. Furthermore, when the batteries are full loaded, the energy will be injected to the electricity grid which makes it even more profitable.

We will use low price solar panels and wind turbines both tracking the maximum power point in order to get the energy.

All this elements will interact through a small DC Smart Grid.

The following picture is a mock-up:

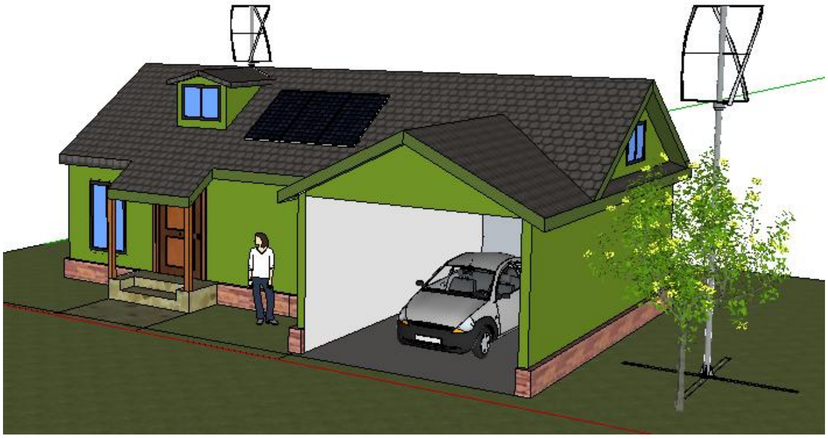

Fig.1. Full system (Concept)

As we can see, it is a quite easy-to-use system mainly thought for a domestic use. We are permanently absorbing renewable energy which will be used when needed just by plugging in the car.

This system is prepared to charge the vehicle with 100% renewable energy and also in case of need, to both inject and get energy from the grid.

Besides, from the point of view of the electricity companies it should be a magnificent idea since it would solve the problem caused by the huge currents required by the vehicles during the charge.

The wind turbines are standing in the yard while the solar panels can be placed in the roof:

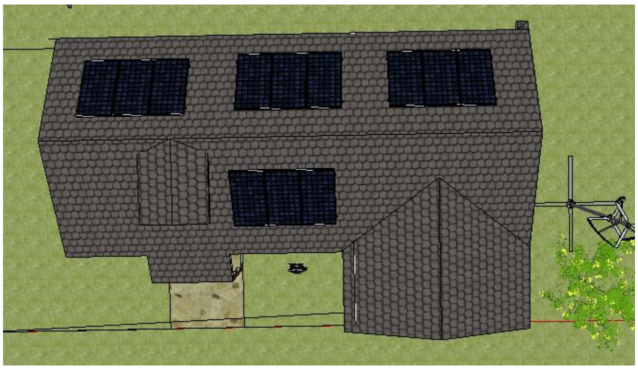

Fig.2. Sky view

Regarding the batteries, they are in a small closet which can be placed in the garage:

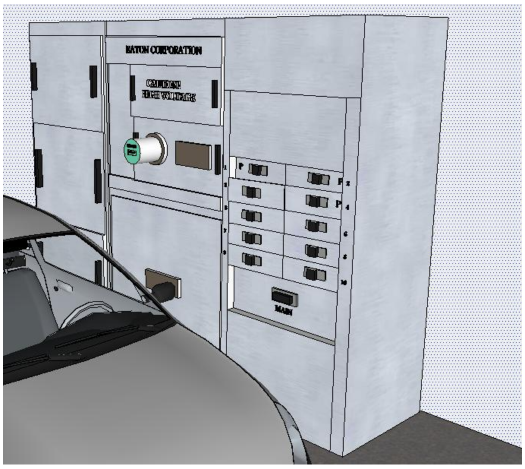

Fig.3. Batteries closet

We will use lithium batteries in small packages.

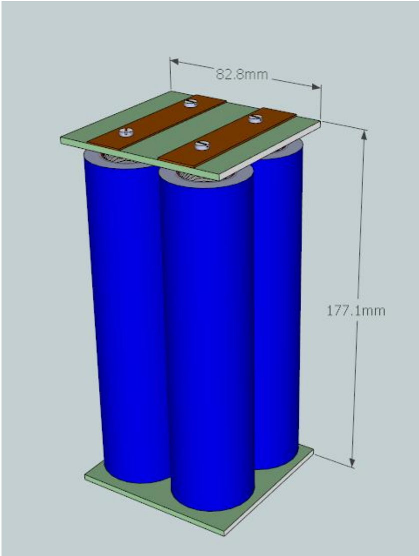

Fig.4. Battery

The whole system can be divided into the following parts:

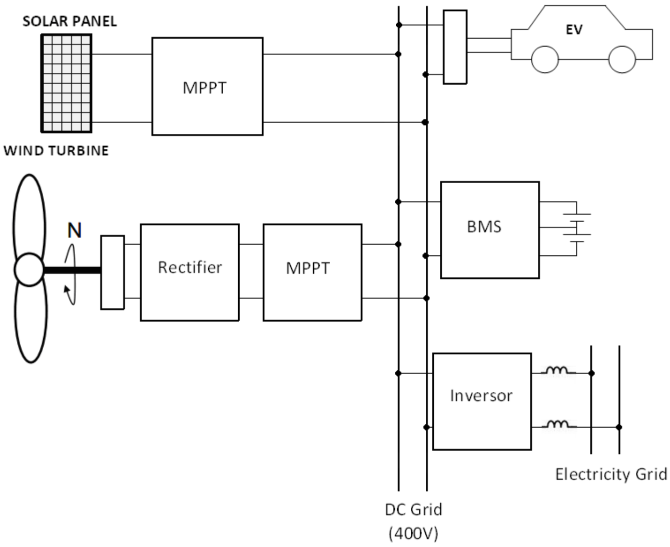

Fig.5. Sketch of the system

We use a DC-Converter for both the panel and wind turbine tracking the maximum power point (MPPT). Besides, in the case of the wind turbine we have to add a rectifier in order to rectify the output voltage. Thus, with the proper DC Converters we have a voltage of 400V, which is the voltage of the DC Grid.

The inverter allows us to inject energy to the grid when the batteries are full loaded or to get energy if the batteries are unloaded.

Regarding the batteries, to make possible the charging and discharging we have a BMS (Battery Management System).

In this paper we will develop the DC Converter for the solar panel and the BMS.

II. - BOOST CONVERTER

TOPOLOGY

Since the solar panel will be connected to a 400V DC grid, we need to raise the output voltage. To do so, we will use a boost-converter which has the following topology:

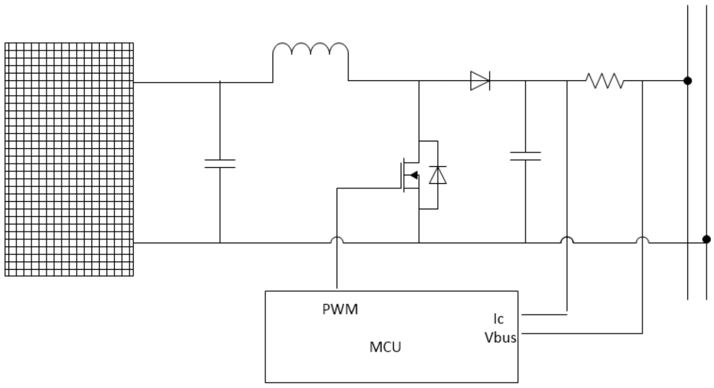

Fig.6. Boost-Converter

We will add some resistive dividers to be able to measure all the parameters needed for the control.

CALCULATIONS

The first thing we have to consider is the output voltage that we will get from our solar panel.

Supposing a maximum radiation of 1000W/m², the output on the MPP (Maximum Power Point) will be 47V and 0.92 A:

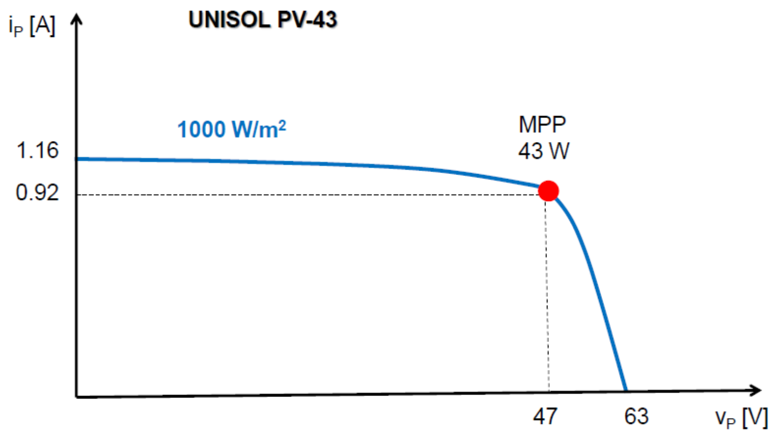

Fig.7. Solar panel output with maximum radiation

Now that we know the input on the MPP, we can calculate the necessary duty in order to have the desired output voltage. According to the formula, the duty on that point will be 0.8825.

We have to set the switch frequency. Usually it goes from 20 kHz up to 50 kHz. We choose 20 kHz so the switch period will be the inverse, thus 50µs.

Afterwards, we choose the theoretical values of both the inductance and the capacitor.

With the inductance we will limit the maximum current and also the current ripple. For its part, the capacitor sets the maximum output voltage ripple.

Carrying out these calculations, we come to the conclusion that an inductance of 3.3mH and a capacitor of 100µF would be appropriated for our design.

CONTROL STRATEGY

We cannot forget that the input voltage depends on the solar radiation, which means that it's not constant. Nevertheless, the output voltage of our system has to be constant. We will use a PI regulator with feedforward which will measure the output voltage and compare it with the desired one and depending on the difference; it will change the duty signal. We will also measure the current in order to be able to track the maximum power point.

Furthermore, to avoid both current and voltage peaks on the start, the duty will be increased slowly from zero to the nominal value in open loop. Once it's set to its nominal value, the regulator starts working.

SIMULATION

Next step, we have to verify that both the boost converter and the regulator work properly. In order to do so, we make a simulation with PSIM:

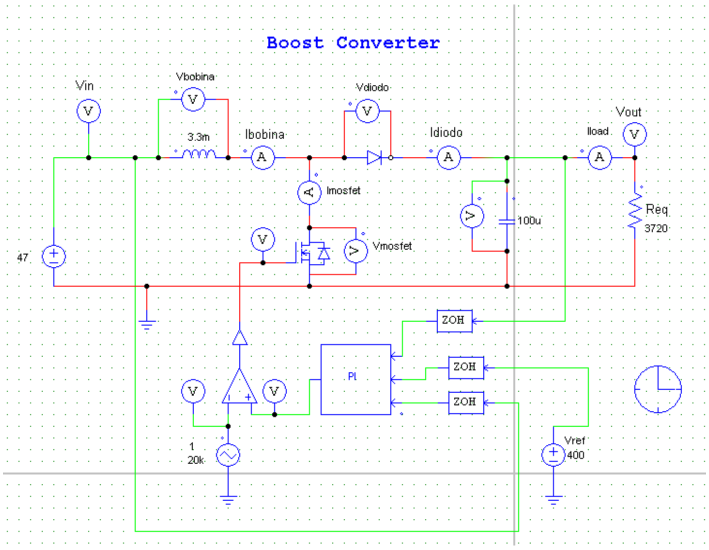

Fig.8. Boost in PSIM

First, we see the relation between the input and the output voltage:

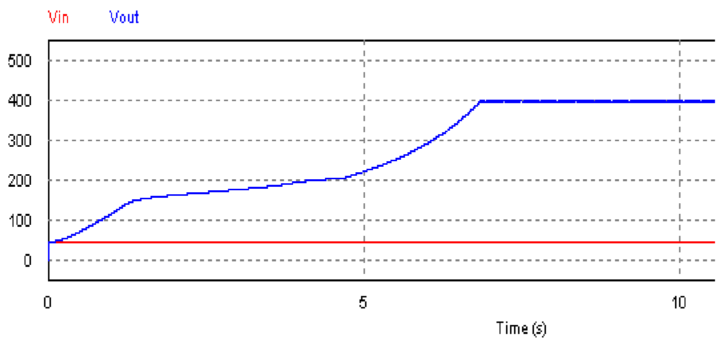

Fig.9. Input voltage (red) and output voltage (blue)

We notice how the output voltage slowly increases till 400V avoiding any voltage peak.

Regarding the current of the load, the graphic obtained is:

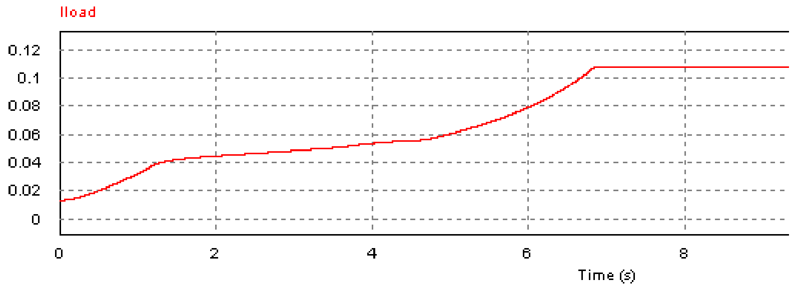

Fig.10. Current of the load

CHOOSING THE COMPONENTS:

-<u>Inductance</u>:

Due to the slowly increase of the output voltage, the current peaks on the inductance aren't a determining factor when it comes to choosing the inductance.

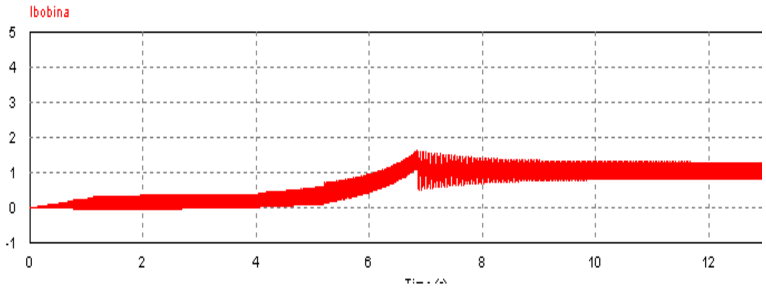

Fig.11. Evolution of the current through the inductance

The maximum current is 1.6 A.

Using a core E 49/16/12 and copper wire of 1mm we need 95 turns and an air gap of 2mm

We confirm that we have enough space to wind the wire.

-<u>Diode</u>:

According to the results obtained in the simulation, the maximum current through the diode is 1.3A and the maximum voltage is 400V. Thus, we choose *Vishay S07J-GS18* (1.5A, 600V).

The losses of the diode are very low 0.12 W and for this reason we decide that it doesn't need a heat sink.

-<u>Mosfet</u>:

The maximum drain current is 1.3A and the maximum voltage drain-source is 400V so we choose *Infineon IPD90R1K2C3* (5.1A, 900V).

The losses of the mosfet are 4.22 W. After all the calculations we conclude that we need a heat sink. We choose *SK75* which thermal resistance is 10ºC/W

-<u>Capacitor</u>:

It must be able to work with a voltage of 400V. Thus we choose the *RS 105 LHK* (100µF, 450V).

PCB DESIGN

Finally we make a design of the PCB with Design Spark:

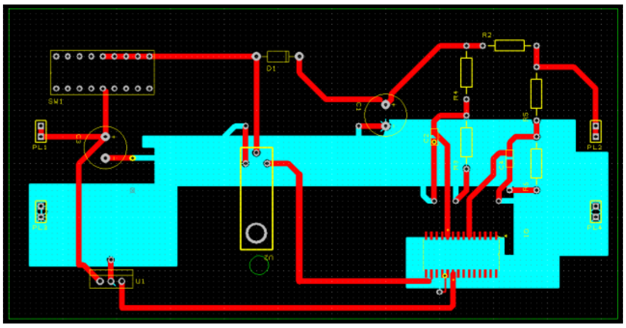

Fig.12. Sketch of the printed circuit board

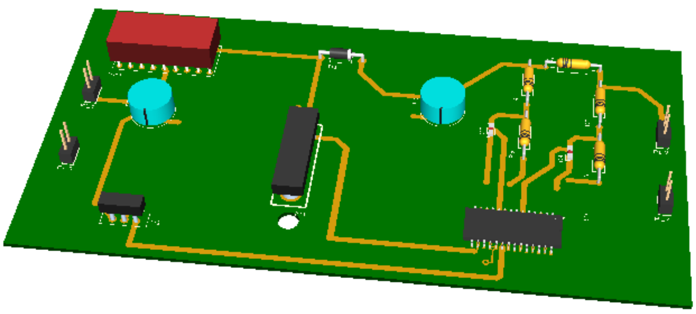

Fig.13. 3D View of the printed circuit board

III. - BATTERY MANAGEMENT SYSTEM

To control the charge and discharge of the batteries we need a bidirectional DC-converter. Due to the huge voltage difference between the DC-grid (400V) and the batteries (12.8V full charged), we have decided to use a bidirectional flyback for our design.

TOPOLOGY

The bidirectional flyback has the following topology:

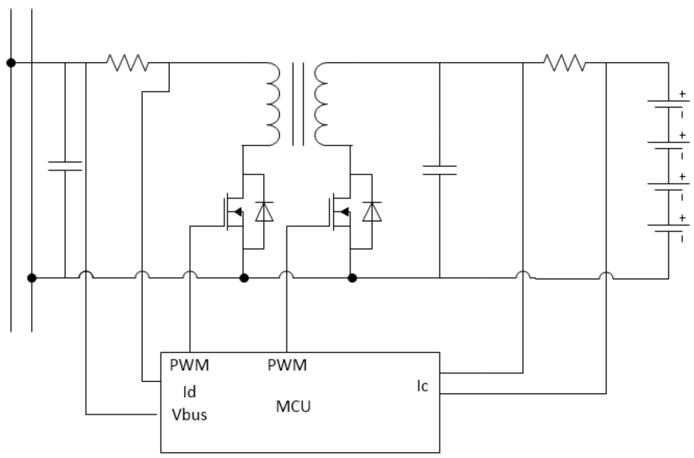

Fig.14. Flyback

We will add some resistive dividers to measure the voltage to be able to control the converter. On the side of the batteries we will divide the voltage by 3 (1K and 2K resistors) and we will measure the voltage drop across a resistor of 0.25Ω (4 resistors of 1 ohm in parallel) to calculate the voltage drop. In parallel with the previously stated resistor we will add a Schottky Diode in order to protect the PIC during the discharge. On the side of the DC-Grid the resistors used are 1K and 100K. Finally, in order to get rid of the noise in the measure we will place capacitors in parallel with the 1K resistors.

CALCULATIONS

First we calculate the necessary duty to control the mosfets. With a turn ratio of 20/1 in the transformer, we need a duty of 0.39 during the charge and 0.61 during the discharge. Besides, we choose a switch frequency of 20 kHz.

With these values, we are already able to make a first simulation and depending on the results we will choose the appropriate values for the capacitor (100 µF) and the Lm of the transformer (15 mH).

Note that with this inductance, the system would work in CCM during the discharge (which is critic) but in DCM during the charge. To avoid it, we would need a significantly bigger inductance, but that would be unviable since it would require a much bigger transformer. Nevertheless, we can solve this problem with our control strategy.

CONTROL STRATEGY

Our BMS will have to control several parameters. The first and also the most important one is the DC-Grid voltage which needs to be permanently controlled. If it lowers, it would mean that a car has been connected to our system and then the batteries will discharge. On the other hand, if it rises, it would mean that there is no demand of energy and that the solar panel and the wind turbine are injecting energy so in this case the batteries will charge.

During the discharge we have to control the DC-Grid voltage of 400V. To do so, there is a PI regulator with feedforward. Moreover, to avoid an overshoot on the start which could damage our system, we will slowly increase the duty in open loop to its nominal value and then start controlling.

Regarding the charge, we will control the current that we are injecting to the batteries. In our case it will be 1 A.

SIMULATION

Once we have designed the control, we will make a simulation of our system.

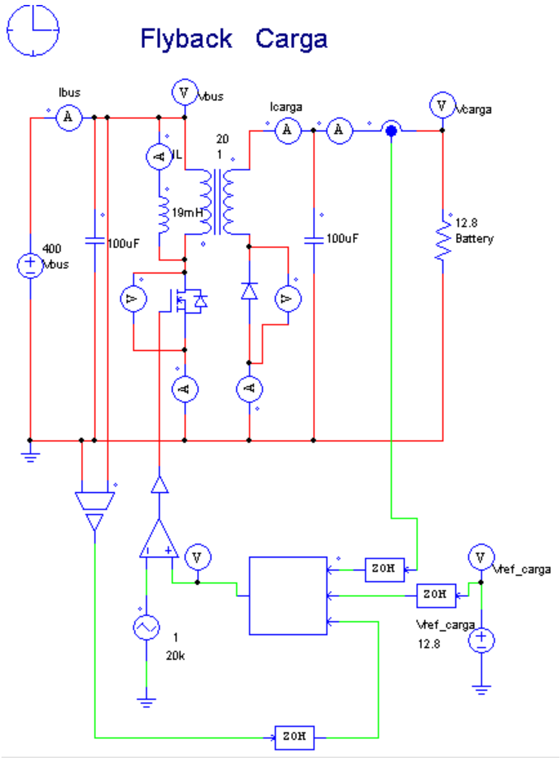

Fig.15. Charge

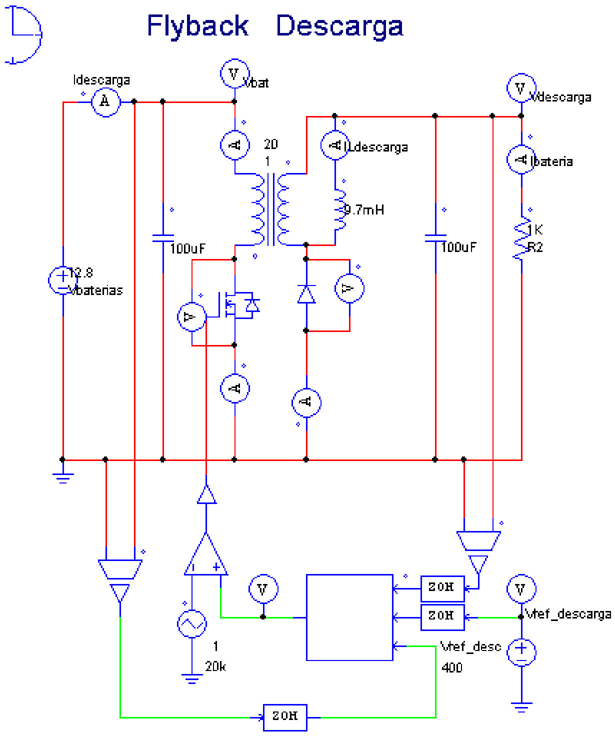

Fig.16. Discharge

As we previously noted, during the discharge we need and output voltage of 400V

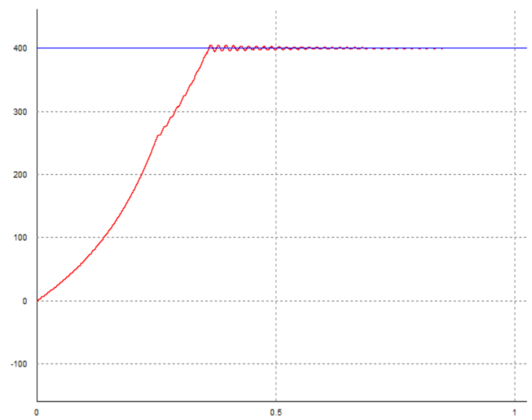

Fig.17. Output voltage evolution during discharge

During the charge, we focus on the current (1A):

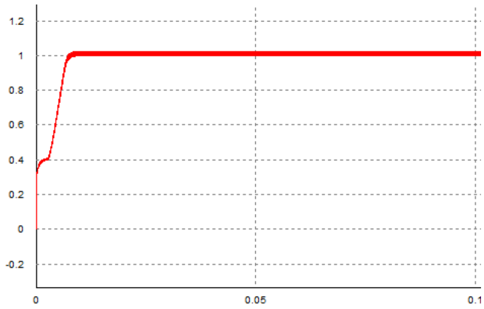

Fig.18. Current evolution during charge

We observe that in both cases we eliminated the big overshoot during the start.

CHOOSING THE COMPONENTS

-Transformer:

The chosen core for the transformer is E55/28/25 with an air gap of 2mm. The first winding will have 200 turns (diameter 1mm) and the second 10 (diameter 3mm). We will have an interleaving winding in order to minimise the proximity effect.

With these values we obtain a Lm of 14 mH and a Bmax of 251mT.

Regarding the losses, the total amount is 17 W, which are mainly caused in the core (15 W), due to its size.

-Mosfet:

According to the topology our system requires two mosfets which will be exposed to different working conditions.

The mosfet that will work during the discharge (the closer to the batteries) has a current of approximately 30 A and a voltage of 35 V. We choose *STD65NF06* (60A, 60V)

The losses of the mosfet are 9.25 W. The diode will work during the charge with significantly lower currents and thus the losses will be insignificant in comparison (1.5W).

After calculating the losses and with the thermal information of the datasheet we come to the conclusion that we need a heat sink of 12.14ºC/W we will choose TV40 (9.9 ºC/W).

On the other hand, the second mosfet will have to work during the discharge with high voltage (up to 675 V) but low currents (lower than 1 A). We choose *IPD90R1K2C3* (900V)

As for the losses, in this case it will be 0.7 W for the mosfet during the charge and 0.08 W for the diode during the discharge. Since both values are very low, we decide that there is no need of a heat sink.

-Capacitor:

Regarding the input and output capacitors, we will choose the same used by the boost, *RS 105 LHK*

PCB DESIGN

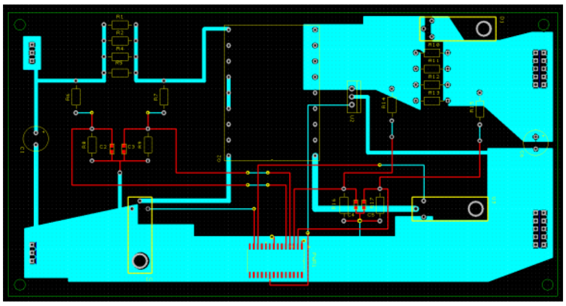

Fig.19. Sketch of the printed circuit board

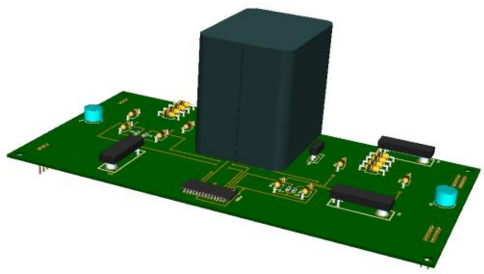

Fig.20. 3D View of the printed circuit board