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Home charging of electric vehicles in Belgium

Bram Rotthier[1], Thomas Van Maerhem[1], Pascal Blockx[2], Peter Van den Bossche[2], Jan Cappelle[1]
[1]*KU Leuven - campus Ghent, E&A Research Group, Gebroeders De Smetstraat 1, 9000 Ghent, Belgium*
bram.rotthier@kahosl.be
[2]*Vrije Universiteit Brussel*

Abstract

The demand for green alternatives in the transportation sector is resulting in an expanding supply of electric vehicles. This triggers the need for both public and home charging infrastructure. In Flanders, five living-lab platforms were launched and funded by the government [1]. The main goal of one of these projects, i.e. the EVA-platform, is to deploy and monitor a public charging network. Nevertheless, in those five living-lab platforms no special attention is paid to home charging infrastructure. However, fleet tests have shown that 90-95% of the time electric vehicles will be charged at home [2]. This proves that home charging infrastructure is an indispensable part of electric driving.
Regarding home charging, the electrician will often be the first point of contact for the general public. At this moment however, electric vehicles and home charging are still unknown concepts for this stakeholder group. Therefore, it is important to provide them with appropriate information concerning standardization and safety, to give an overview of the existing variety of home charging stations and to suggest the possibility of self-assembly of home charging stations.
This paper describes the content of the current hands-on training sessions, organised in the context of the Flemish research project "Home charging of electric vehicles", which has started to fill this hiatus. Special attention is drawn to the given installation guidelines of three phase charging stations and to problems experienced by some electric vehicles when charging on the 3x230V part of the Belgian distribution grid.

Keywords: electric vehicle, charging, regulation, education, training

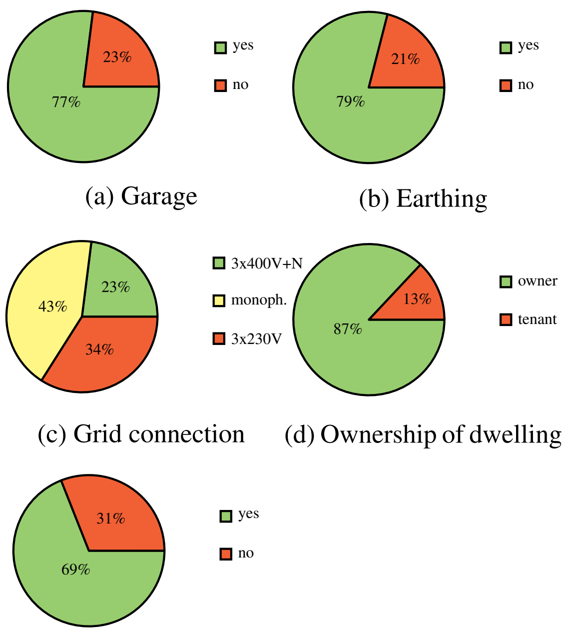
1 Introduction

Home charging of electric vehicles is an important issue concerning the introduction of electric driving for the general public. Nevertheless, appropriate, objective information is not easy to find. In the narrative of electric driving, electricians - the first point of contact for the general public - have until now been overlooked.
The main goal of the Flemish project "Home charging of electric vehicles" (THEO [3]) is to provide basic information on the home charging of electric vehicles to this stakeholder group. Therefore it is important to familiarize them with the existing regulation concerning home charging, such as the different charging modes, the Mode 3 communication protocol and the different plug types. To aid this purpose, workshops are organised to shed some light on the home charging world of electric vehicles. In these workshops, also an overview of different existing home charging stations is given, together with information about possible self-assembly of those stations.
The project is coordinated by KU Leuven and the Vrije Universiteit Brussel. The main strategy of the project is determined by meetings with the user committee every four months. This committee consists of the government, the distribution network operators, manufacturers of home charging infrastructure, electric control bodies and electricians.

This article begins with a discussion of the results of a survey, conducted to determine if the "average" Flemish house is ready for the electric vehicle. Next, the structure of the workshops for electricians is explained, together with a description of the developed demonstration set-ups. The second part of the paper deals with problems regarding home charging of electric vehicles in Belgium. First, a charging problem of some electric vehicles on the Belgian 3x230V-grid is explained. Second, a contradiction between Belgian law and the standard residential electrical installation requirements is discussed.

2 Survey

An on-line survey was conducted to examine the average condition of domestic electrical installations in Flanders and Brussels in order to determine how often adaptations are required for home charging of electric vehicles. This survey reached a total of 815 respondents in Flanders, including Brussels.
Mode 2 charging, using a standardized socket-outlet and an in-cable control box (ICCB), is often regarded as a makeshift, transitory alternative between Mode 1 (standard residential plug-socket connection) and Mode 3 (dedicated charging point) charging or as a solution for occasional charging [4]. Nevertheless, a sound electrical installation is always essential for the safe charging of electric vehicles.
The survey showed that, of the sample of respondents, 23% of the Flemish households do not have a garage to park their car, as shown in Figure 1a. Houses without a garage are mostly lo-



(a) Garage (b) Earthing

(c) Grid connection (d) Ownership of dwelling

(e) Interest in buying EV

Figure 1: A selection of survey results

Table 1: Preferred charging spot

	Number (%)
Garage	67,49
Ramp	11,85
Street	11,74
Carport	7,34
Different	1,58

cated in city centres, where short travel distances are common and thus suited for electric vehicles. These households will have to search for alternatives, such as public charging or charging at work. The survey has also shown that 19% of the houses do not have a proper electric connection point at the preferred charging spot, shown in Table 1. In Figure 1b, it can be seen that 21% of the electrical installations are not properly earthed. Without an earthing system or a proper electric connection point, extra investments are needed to enable the safe charging of electric vehicles at home. Figure 1c shows that 34% of the Flemish households are connected to the 3x230V grid and that a further 23% has a 3x400V+N connection. These values are comparable to data obtained from Eandis, a Belgian distribution network operator [6]. Thereby, only 23% of the Flemish households has the possibility of three phase charging at home without further investments to the home charging infrastructure. In some cases, charging on a 3x230V-grid can cause charging problems, as will be explained in Section 5. In Figure 1d it is shown that 13% of the Flemish population lives in a rented house. The threshold to invest in proper charging infrastructure is higher in a rented house, with reasons ranging from system ownership to legal issues. The survey also showed that 69% of the respondents would be interested in an electric vehicle if they had a minimal range of 300 km and the cost would be the same as the cost of a car with internal combustion engine, as can be seen in Figure 1e.
An important lesson learned from the survey is that home charging is not possible for everyone and that also for Mode 2 charging adaptations to the electric installation are often needed to safely charge electric vehicles. The large variety of electrical installations in Flanders also makes a "one size fits all" solution not feasible. This indicates the value of the THEO project to inform and educate the stakeholders of electric vehicles.

3 Workshops

Charging infrastructure for electric vehicles is currently an unknown topic for electricians. Workshops are organised in Flanders and Brussels within the framework of the THEO project to fill this knowledge gap. They are conceived as an initial acquaintance with electric vehicles in general and with the charging of these vehicles. Topics brought to the participants' attention are:

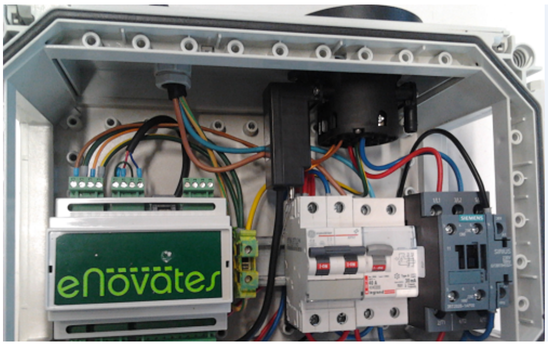


Figure 2: Self-assembled home charging station

- Survey results: current state of the residential electrical installations in Flanders and Brussels.
- Informing about charging infrastructure and its components.
- Explanation of the Mode 3 charging protocol.
- Self-assembly by electricians of Mode 3 home charging stations.
- Charging problems on 3x230V TT grids.
- Issues between safety considerations and current legislation in Belgium.

The participants follow a tour of different information posters with relevant demo material. First, the most important results of the previously discussed survey are provided by two posters. In this manner visitors learn that the charging of an electric vehicle is more than just plugging a plug into a socket and that there is a real interest for this technology among the population. Second, the differences between the various plug/connector types are explained. After the introduction of the plug types, the different charging modes are introduced. Mode 3 charging of an electric vehicle is simulated with a demo set-up and explained by a powerpoint presentation, as detailed in Section 3. After the description of Mode 3 charging, the functioning of commercially available charging stations is demonstrated. At the workshops, leaflets are provided, comparing the technical aspects of most Mode 3 charging stations available on the Belgian market. Next to the “all-in-one solutions”, the self-assembly of Mode 3 charging stations is illustrated. Here, electricians are shown an example containing a pilot box, a relay, a circuit breaker, a residual current device (RCD) and a Type 2 socket. This example self-assembled home charging station used in the workshops is depicted in Figure 2. At the end of the tour, charging problems that some electric vehicles may experience on the Belgian 3x230V grid are expounded.

4 Demo set-up

In Figure 3, the demo set-up clarifying the functioning of the Mode 3 communication protocol [5] is shown. In the electric wiring schematic of the demo set-up, shown in Figure 4, it can be seen that the different charging states of the EV can be simulated. It is also possible to simulate some basic charging problems, such as a ground fault or a broken charging cable. The functioning of this set-up is explained below.

The operation of switch S1 simulates the connection of the EV to the Mode 3 charging station. At this point the circuit between the control contact (CP) and the earthing contact (PE) is closed. The resistor R1, placed between the PP-contact and PE-contact, can be changed according to the desired standardized values. This resistor, found in the plug of the charging cable, indicates the maximum permissible charging current through the cable.

By operating switch S2, resistors R2 and R3 (which are found in the vehicle) are placed in parallel, indicating that the vehicle is ready to receive energy from the grid. This starts the charging process. Electrical energy will be provided to the demo set-up and the appropriate signal lamps will light up.

A broken charging cable can be simulated by pushing button S3. By operating button S4, a ground fault current will flow. It is also possible to measure the voltage over resistor R2 with an oscilloscope. Thus the changing pulse-width modulation (PWM) waveform, generated in the charging station, can be visualised.

In the workshops the demo-set up is accompanied by a powerpoint presentation, explaining the functioning of the communication protocol. Through the combination of the presentation and the demo set-up, the visitors get a clear insight in the functioning and the advantages of Mode 3 charging.

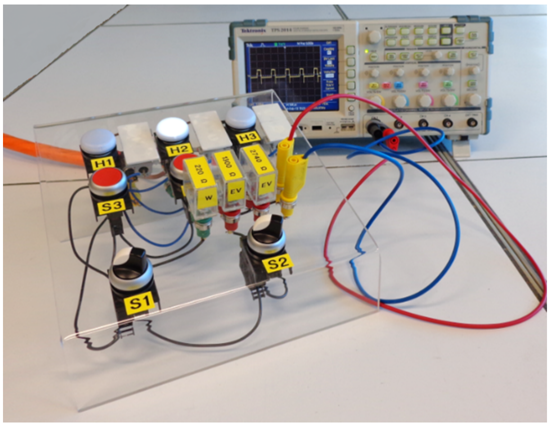


Figure 3: Demo set-up for the illustration of the Mode 3 charging protocol

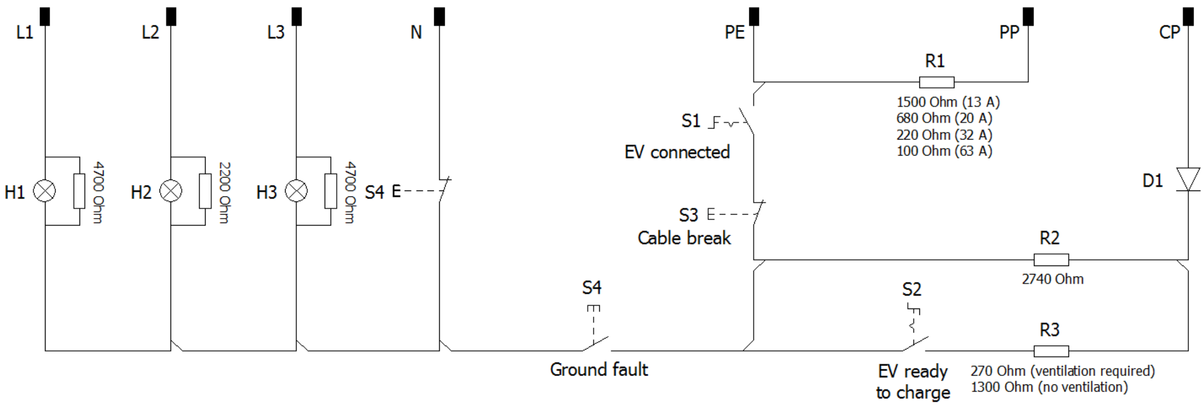
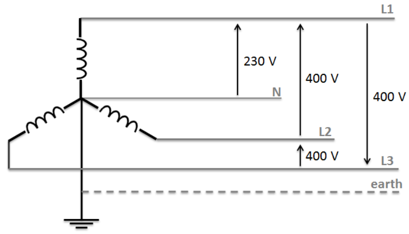


Figure 4: Electrical wiring schematic of the demo set-up

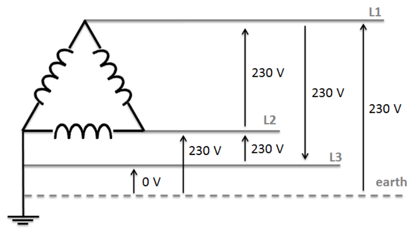
5 Charging problems

In the workshops, a problem experienced by some electric vehicles when charging on a part of the Belgian electrical grid is discussed. The cause of this problem is the existence of a 3x230V-grid in Belgium, next to the "standard" 3x400V-grid.
A typical European 3x400V TT-grid is shown in Figure 5a. This type of grid is characterized by a line-to-line voltage of 400V, a line-to-neutral voltage of 230V and an interconnected neutral and protective earth conductor. In this network, standard appliances (working on 230V) are connected between the neutral conductor and one of the line conductors. The current electric vehicles are designed to be charged on this type of network. In Belgium however, some parts of the distribution grid are still provided as a 3x230V TT-network, as shown in Figures 5b and 5c. This type of network is characterized by a line-to-line voltage of 230V and the absence of a dedicated neutral conductor. A neutral conductor is defined as a conductor, equipotential to the protective earth conductor. In the 3x230V TT-grid, normal appliances are connected between two line conductors. The possibility exists that an appliance is not connected to a neutral conductor. This applies both in the case of single-phase connections as well as for three-phase connections. According to data of the distribution network operator Eandis, 30% of the Flemish households are connected to such a network [6]. The results of our survey, discussed in Section 2, point in the same direction.

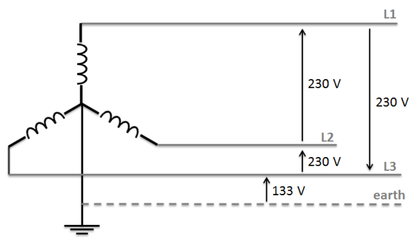
Some electric vehicles require a true neutral conductor for charging. As can be seen in Figures 5b and 5c, a "true" neutral conductor is not always available. A 3x230V TT wye network does not provide a neutral conductor. A 3x230V TT delta network gives the possibility of a neutral conductor, although this depends on the particular household connection. Therefore some vehicles may experience problems when charging on the Belgian 3x230V grid. This charging problem is usually solved by the installation of an isolation transformer before the charging point in the home. After this transformer, a suitable network, thus with a proper neutral conductor, is started as shown in Figure 6. [7, 8]



(a) Typical European 3x400V TT-network



(b) 3x230V TT-network, delta



(c) 3x230V TT-network, wye

Figure 5: Distribution network topologies encountered in Belgium

A 3x230V grid must not be confused with an Isolated-Earthed (IT) grid. In a 3x230V TT grid, both the transformer and appliances are earthed.

Apart from Belgium, this type of grid also exists in Italy and Norway.

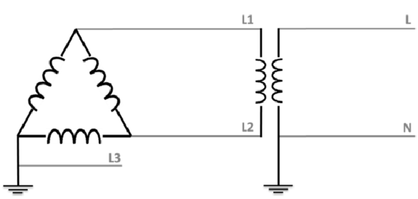


Figure 6: 3x230V network with isolation transformer

6 Residual current device

Another problem covered in the workshops is the contradiction between Belgian law and safety regarding the residual current device (RCD) to be installed. Belgian law requires the installation of a type A residual current device in a household installation [9]. However, a type A RCD is not guaranteed to interrupt a dc fault current above 6mA [10], which may occur with multiphase charging. In particular, this IEC standard indicates that for a load with an unknown characteristic, a type B residual current device is suggested [10]. Thus, in Belgium it is currently impossible to install a three phase charging point in a both safe and legally compliant way. Based on the four-monthly consultation with the user committee of the THEO project, a recommendation is given to electricians. It is recommended to install a three phase electric cable, but to connect only one phase of the cable to the charging point. In this manner, the home charging point can be modified to a three-phase connection as soon as the legislation is updated.

7 Future developments

Until today only try-outs of the workshops for electricians were organized. Those workshops were mainly focused on the home charging aspects. In the near future the content of the workshops will be extended to the technology inside the electric vehicle and the target audience will be extended to all different interest groups. In the fall of 2013 and the spring of 2014, the workshops will be organised at least one time in each Flemish province and in Brussels.

8 Conclusion

In the framework of the Flemish project “Home charging of electric vehicles” (THEO), workshops have been organised to inform electricians on the main aspects of home charging. The main target group has been chosen to be electricians as they are the point of contact for the general public for questions on electricity. In the workshops, results from a survey on the condition of electrical installation of households in Flanders and Brussels are presented, together with the general concepts of home charging of electric vehicles. Additionally, some issues with which electricians may come in contact have been explored, such as charging problems on the 3x230V grid and the installation of an RCD. To explain the functioning of the Mode 3 communication protocol and to demonstrate the self-assembly of home charging stations, demonstration set-ups have been developed. In the near future, the workshops will also contain information on the technical aspects of the electric vehicle. The target audience of these workshops will be extended to a broader public.

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Authors

Bram Rotthier graduated in 2012 as electrotechnical engineer at the Catholic University College Ghent. His master's thesis, written at Tampere University of Technology in Finland, dealt with the dielectric properties of ceramic coatings. He works as a researcher for the E&A research group in the domain of electric vehicles.

Thomas Van Maerhem graduated in 2008 as electrotechnical engineer at the Catholic University College Ghent. Modelling internal faults in transformers and synchronous generators was the subject of his master's thesis. As member of the E&A research group his current research topic is standalone hybrid power systems.

Pascal Blockx graduated in 2012 as industrial engineer in electromechanics at the Erasmushogeschool Brussel. His thesis handled about the optimization of a seismic bearing and the construction of a testbench. He works as a researcher at the MOBI/ETEC department of the VUB in the domain of electric vehicles.

Peter Van den Bossche promoted in Engineering Sciences from the Vrije Universiteit Brussel on a thesis "The Electric vehicle, raising the standards". He is currently lecturer at the Erasmushogeschool Brussel and the Vrije Universiteit Brussel. Since more than 15 years he is active in several international standardization committees, currently acting as Secretary of IEC TC69.

Jan Cappelle graduated in 1999 as electro-mechanical engineer at the Katholieke Universiteit Leuven. In 2008 he obtained a PhD in engineering sciences at the Vrije Universiteit Brussel. His PhD thesis was an objective and subjective study of the performance of electric bicycles. As an associated professor of KULeuven in power systems, he runs a research group in the domain of standalone hybrid power systems.