Thermie Project

THERMIE

E.V.D. POST

Measurements performed in Nacka, Sweden
February 2000

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1. Introduction

In the framework of the Thermie E.V.D.Post project, CITELEC is responsible for evaluation of the electric vehicles deployed in the framework of this project, on a common basis, in order to have the opportunity to make a comparison of the different electric vehicle technologies that are used in this project.

In this framework, measurements are being performed on postal vehicles used for the project on different sites. After defining the used methodology during the first measurement campaign performed in Kajaani, Finland, in February 1998 (where special attention was given to the winter operations), a second Finnish measurement campaign was held in Turku in August 1999. The current report describes the measurements held in Nacka, Sweden, in February 2000; other measurements were held in Belgium in March 2000.

The underlying report gives an overview of the methodology used and of the results obtained.

2. Background: Electric vehicles in Swedish Post

Posten Sverige AB has a total delivery fleet of 5900 vehicles (bicycles not included). During one year, 100 million kilometres are driven, for typical delivery duties once a day, 258 days a year.

- 2700 thermal-engined vehicles are used for delivery in city areas, their average delivery route is 45 km per vehicle and day.
- 2700 thermal-engined vehicles are used for delivery in the countryside; their average delivery route is 100 km per vehicle and day.
- 500 electric vehicles, three- or four wheelers, are used for delivery in city areas; their average delivery route is 15 km per vehicle and per day.

The use of electric vehicles in Swedish postal services is clearly aimed at local delivery, using appropriate vehicles which represent a technology comparable with industrial electric vehicles. Two main types of vehicles are used: the four-wheel type (as the subject of this measurements), and the specially developed three-wheel Tugger vehicle. These vehicles are all of a quite “conventional” technology, featuring lead-acid batteries and direct current series-excited motors. This technology is proven and reliable however, and well suited for the stop-and-go local service they are deployed for by the Swedish Post, a service which is has a strong resemblance to the use pattern of industrial vehicles, where electric traction has proven very strong.

Figure 1: The Tugger vehicle

3. The CITELEC measurement system[1]

The CITELEC data-acquisition measurement system is constituted as follows:
An intern serial datalogger, built in a portable 19”-rack, provides all the signal conditioning, multiplexing, discretisation and digitalisation. The rack is small and meets the needs that are demanded for such a device (electric and electromagnetic isolation, proof against external shocks, no obstacle for driver or passengers,...). In Figure one can see the principal outline of the measurement system.
Voltages, currents and digital speed measurements are converted into load-independent output signals by internal transducers with linear characteristics. Outputs from the LEMs (Hall effect shunts) are converted into input voltages for the transducers by means of precision measuring resistances. The transducers provide filtering and galvanic isolation for the signals. Other parameters pass a buffer and a low-pass filter (Butterworth 5th order). The logger accepts input voltages up to 10 V. Data-acquisition is done by a serial logger, consisting of a 16 channel data-acquisition card and a 64 Kbytes buffer microcontroller card. The system is powered by two external 12 V batteries providing both 24 V for the system proper and 12 V for the speed sensor.

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1 Cf. W. Deloof et al., *On-Road Measuring and Testing Procedures for Electric Vehicles*, EVS-14, Orlando, 1997

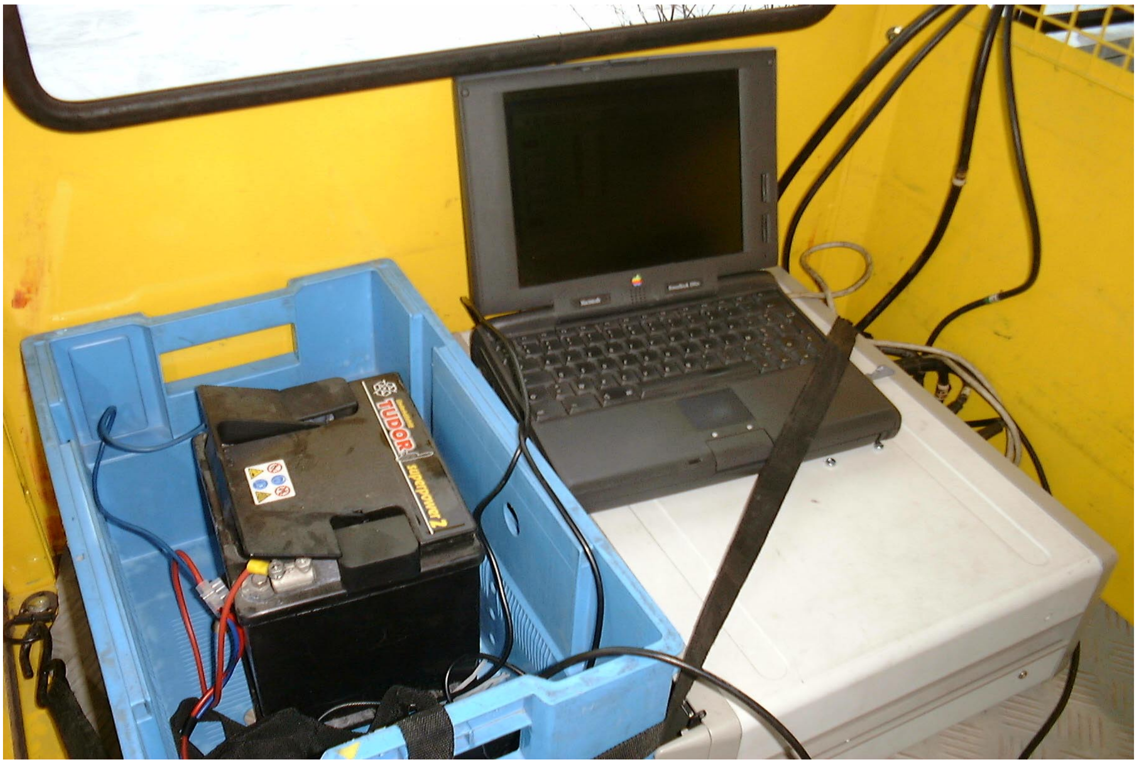

Figure 2: the measurement system installed on board the Carryall vehicle

The logger is controlled by a Macintosh PowerBook via a serial connection, and is controlled by a specific application, EV-Powerlogger, written in LabVIEW™. On the front panel, the setting parameters include: scan rate (Hz), number of channels, path name,... While measuring, the data are stored in ASCII-files for easy data processing.

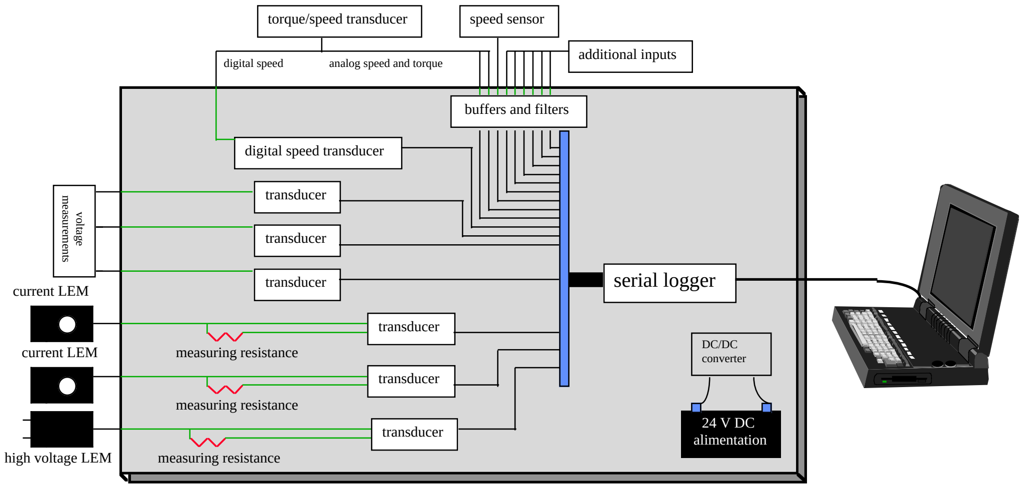

Figure 3: principal outline of the measurement system

The speed sensor is based on a correlation optical method with spatial-frequency filtering and produces an excellent result with very high accuracy. It is easy to mount on the vehicle through a magnetic plate or through suction caps. A 12 V lead-acid battery provides the supply voltage.

A last external device is the Macintosh PowerBook 190cs, which controls the serial logger and stores the measured data in ASCII-files. These files are further treated in a spreadsheet application (Excel)

Figure 4: The speed measurement system mounted on the back of the Carryall vehicle

4. Practical realisation of the tests

The tests took place from 16 to 23 Februay 2000.
The first day, the measurement system was built into the vehicle, and a first short test performed in order to verify its operation.
The next three business days, the vehicle was used in the normal postal service in Nacka.

Figure 5: Postal delivery in Nacka

5. The postal delivery service in Nacka

Nacka is a commune of 56000 inhabitants located about 8 km south-east of Stockholm. Its green location amidst lakes and sea lakes makes it a premier residential area of a high affluency, mostly consisting of detached housing.
The post delivery in this area is mostly done with bicycles or electric vehicles; the daily round runs from about 10.00 to 14.00. The load carried on one round depends on the day, and is on average between 6 to 10 boxes[2].
The area where the vehicle under test is operating is illustrated in the figure 6. The envelope in the lower left corner shows the location of the post office.

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[2] During the measurement campaign, part of the loading space of this (small) vehicle was occupied by the measurement system. For this reason, boxes were carried in a relief vehicle and delivered in the electric vehicle as necessary.

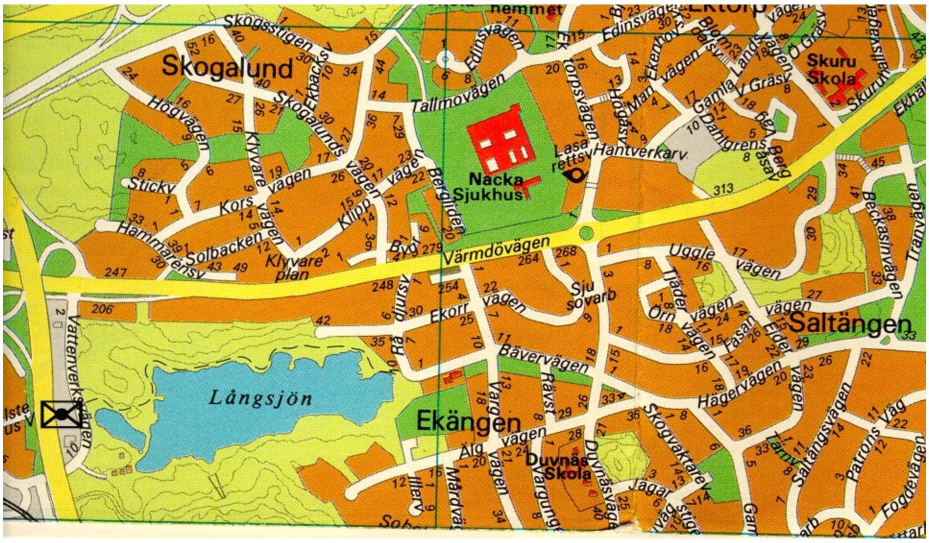

Figure 6: The Nacka delivery area

Where possible, the post boxes are served from kerbside; this practice is however not so common in Sweden as it is in Finland, and in practice the postman has to leave his vehicle quite frequently.
The data are summarised in Table I:

		17-févr	18-févr	21-févr	Average
Trip length	m	14003	13940	13877	13940
Total time spent	h:mm:ss	02:23:37	02:22:33	02:21:29	02:22:33
Stop time	h:mm:ss	01:07:56	01:08:34	01:09:12	01:08:34
%stop	%	47%	48%	49%	48%
Run time	h:mm:ss	01:15:41	01:13:59	01:12:17	01:13:59
%run	%	53%	52%	51%	52%
Number of stops		328	319	311	319
Stops per km		23,4	22,9	22,4	22,9
Average interval	m	43	44	45	44
Commercial speed	km/h	5,9	5,9	5,9	5,9
Maximum speed	km/h	32,7	35,3	31,9	33,3
Average speed	km/h	11,1	11,3	11,5	11,3
Consumption	Ah/km	6,1	6,1	6,1	6,1

Table I: Summary of delivery routes

These data enable to determine some typical characteristics of the postal delivery traffic in Nacka:

- A daily distance is driven of about 14 km.
- The actual stop time is about 50 % of total mission time[3]
- The average distance between stops is only about 44 m, with a total number of stops on the round exceeding 300.
- The commercial (end-to-end) speed is very low, of the order of walking speed, due to the frequent stops times
- The average speed when running is about 11 km/h
- The maximum speed of the vehicle is just about 33 km/h, consistent with the characteristics of the vehicle
- Instantaneous energy consumption is consistent at 6,1 Ah/km.

Graphical representation of postal delivery cycle

The figure 7 shows a 5-minute extract of a typical delivery run. One can clearly see the progress between the stops deserved, as well as the stop time between them.
The speed can also be plotted against the distance covered; this gives the results in figure 8. This figure gives a better image of the geographical distribution of the stop points (i.e. mail boxes).

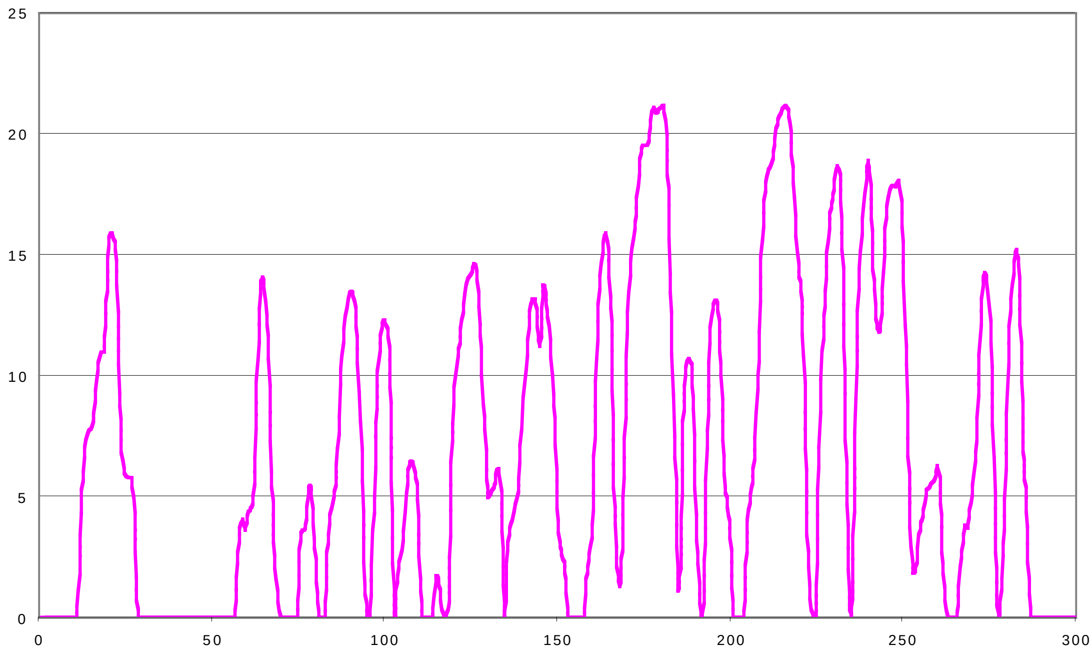

Figure 7: Speed/time profile

[3] This refers to the time spend in the delivery round proper. The stop time taken by the driver to take his lunch break, at the middle of the delivery round, has not been taken into account.

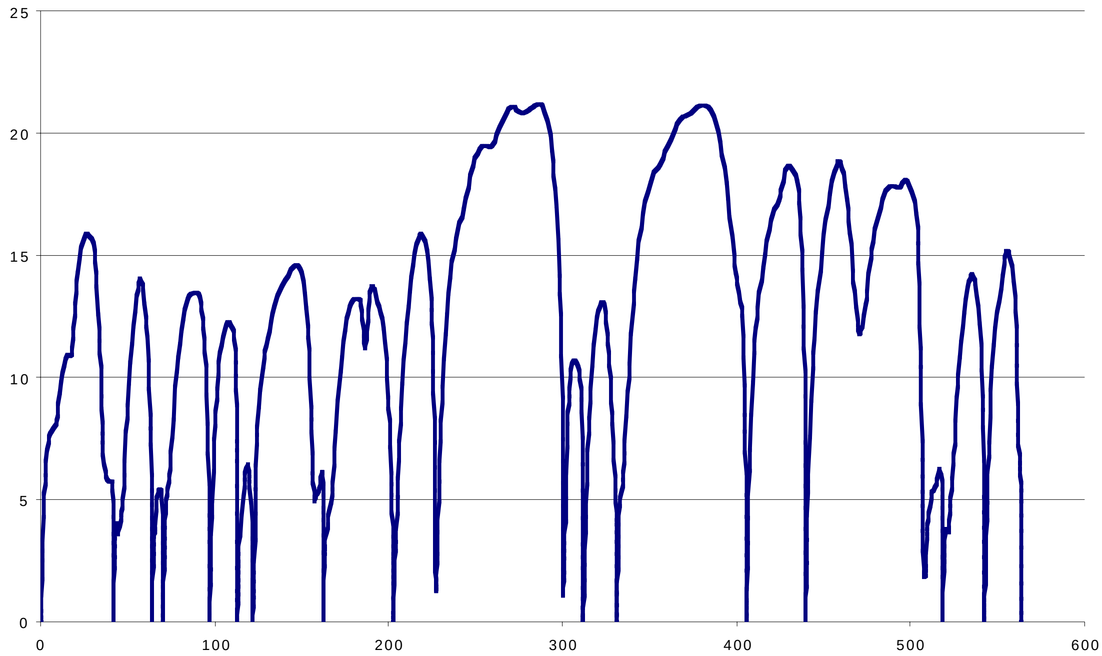

Figure 8: Speed/distance profile

6. General description of the vehicle

The Club Car Carryall II is an electric utility vehicle which finds a variety of uses, both in the industrial field (light utility or personal carrier) as for leisure applications.
The vehicles used by Swedish Post are fitted with a purpose-built body, allowing secure storage of letter containers in the rear, and easy access to mail boxes from the driver's seat, where a receptacle for a standard letter container is also provided.

Motor and battery

The vehicle is powered by a series-excited DC motor acting on the rear axle through a fixed transmission. The motor is fed through a Mosfet chopper; energy regeneration is not provided.

The traction battery consists of 6 monoblocs (of the rather unusual block voltage of 8 V), to obtain a nominal voltage of 48 V. The batteries are fitted under the driver's seat, allowing for easy access and watering.

The vehicle comes with an off-board charger; the plug is located in front of the vehicle.

Driving behaviour - Acceleration

The traction circuit of the vehicle consists of a series DC motor, fed by a chopper and connected to the wheels via a fixed transmission. The high starting torque of the series motor gives a good acceleration well suited for stop and go traffic. The maximum speed of the vehicle is limited however, and the Carryall is not really to be considered a road-going vehicle. In the residential areas where it is deployed, this is presenting no problem however.

Appreciation

The Carryall is an industrial utility vehicle which has been succesfully deployed for postal duties.
Driving the vehicle is simple and straightforward.
Once a driver has been acquainted with the vehicle's behaviour, the characteristics of the vehicle are generally appreciated. The small size of the vehicle ("not a car") might present acceptance problems with a number of drivers. This underlines the essential aspects of driver training and preparation for electric vehicle projects.
Range and speed are sufficient for the intended duties of the vehicle.

7. Energy consumption

Energy consumption at mains level

The operation costs of the vehicle are function of the energy consumption at the mains when charging the vehicle's batteries.
The average weight of the vehicle during the tests can be estimated at 650 kg (including postal load and the measurement system).

	17-févr	18-févr	21-févr	Average
kWh	6,09	5,92	6,78	6,26
Wh/km	435	425	362	407
Wh/Tkm	669	653	556	626

Table II : Energy consumption

How to evaluate this result?

One could take into account the well-known empirical formulas to assess electric vehicle energy consumption (C is the consumption in Wh/Tkm; W the weight in tons):

- "Average" value corresponding to today's usual technology:

$$C = 150 + \frac{100}{W}$$

- "Minimal" value, corresponding to state-of-the art technology and an economic driving style:

$$C = 80 + \frac{80}{W}$$

- "Maximal" value, corresponding with a less efficient technology:

$$C = 220 + \frac{120}{W}$$

For a 650-kg vehicle, this gives respectively 304, 203 and 405 Wh / Tkm.
The actual consumption is well above this values. This may be contributed to the following factors:

- The empirical formulas are geared towards vehicles over 1 ton weight, and thus are not really applicable on a small vehicle
- The energy consumption in stop and go traffic for postal duties is much higher than ordinary energy consumption
- The efficiency of the charger is limited, adding extra losses.

Instantaneous consumption

The instantaneous consumption is measured at the battery terminals during the vehicle operation, and is expressed in Ah / km.
It gives a more clear idea about the influence of traffic conditions and driving style.
As stated above, an instantaneous energy consumption of on average 6,1 Ah / km has been recorded in postal delivery duty.

Range

After the delivery round last day of testing, the vehicle has been driven on a second round, simulating the stops of the postal round, to assess the maximum obtainable range of the vehicle.
This has allowed to cover another 4,9 km, with 13,9 km covered in the actual round, before the battery voltage sank to the lower threshold value of 36V under load.
The total range attainable in postal delivery is thus about 18 km.
Unlike the other vehicles tested in the framework of the EVD Post project, a full range test in normal on-road traffic (as opposite to postal distribution work), as the Carryall vehicle is not designed for this purpose.

8. Energy flows in the vehicle

The energy flows during a typical start-stop cycle are illustrated on the following figure:

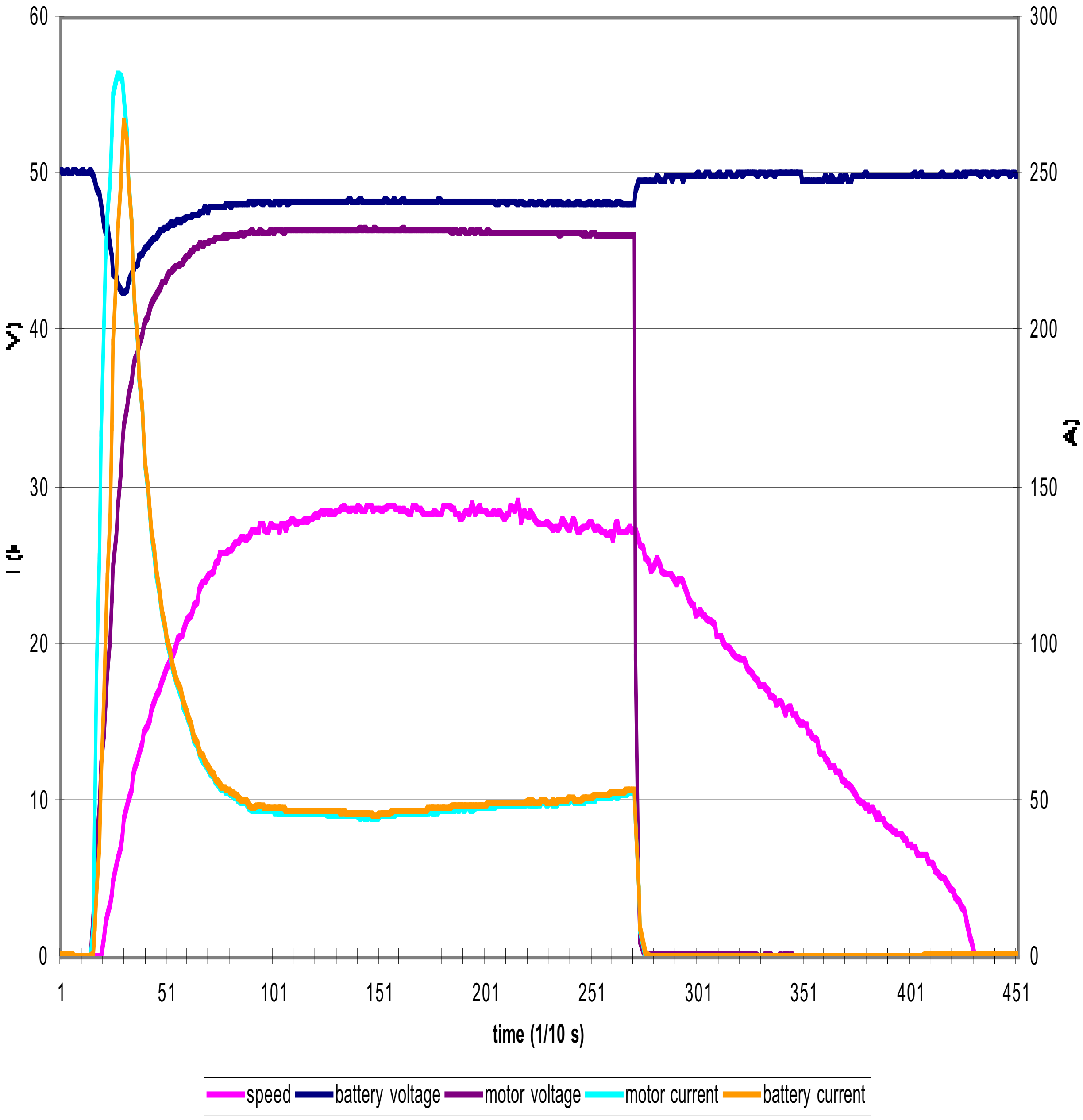

Figure 9: Energy flows in the vehicle

One can see the typical high acceleration current of the series motor, which allows the high starting torque, and allows the vehicle to reach a speed of 25 km/h in just five seconds. This makes the vehicle very suitable for frequent stop and go traffic at low top speeds like encountered in postal delivery.

Only during the first few seconds of the acceleration the chopper is actually at work; after this phase, the motor and battery currents become equal, and the difference between motor and battery voltage represents the voltage drop over the chopper which is now in full conduction mode. Since the system voltage is relatively low, this voltage drop can be clearly seen in this example.

The battery voltage drops quite significantly when a high current is absorbed during acceleration.
This phenomenon will become more obvious when the battery discharges; at end-of-discharge, battery voltage during acceleration can drop as low as 36 V (i.e. 1,5 V per cell) which is to be considered a minimum value for the preservation of the battery.

9. The battery charger

The vehicle comes with an off-board battery charger, which can be connected to a special vehicle inlet. It is fed through an ordinary 230 V outlet. This charger is compact and easy to use, terminating its charge automatically through a I-U cycle. Such chargers however are not always optimised for efficiency (taking into account its relatively low power rating), which may contribute to the high specific energy consumption of the vehicle.

Figure: The battery charger

10. Safety aspects

Electrical safety

The system voltage in the vehicle is low enough not to present a direct electrocution danger. However, live parts must be protected also in order to avoid short circuits. Live parts are only accessible after lifting the driver's seat for battery access, which is in principle only allowed for qualified service personnel.

Functional safety

The functional safety characteristics are satisfactory: the structure of the vehicle permits safe operation of the control system. Special measures have been taken to avoid unwanted operation of the vehicle, as is customary for industrial-type electric vehicles

11. Conclusions

The measurement campaign performed for the E.V.D. Post project in Nacka has been performed using the methodology developed during the first campaigns in Finland.
The use of electric vehicles for postal distribution continues to show itself as an ideal opportunity to improve the energetical and environmental characteristics of postal services. The commitment of Swedish Post towards the electric vehicle is providing a major showcase for other operators, particularly taking into account the choice for compact, industrial-type vehicles. This report brings forward the information about the postal experiences, in the framework of E.V.D. Post project.

12. Acknowledgements

The authors wish to thank the people of Swedish Post, and particularly Mr. Hans Bengtsson, for making this measurement campaign possible.

Table of Contents