Thermie Project

★THERMIE★

E.V.D. POST

Measurements performed in Kajaani, Finland
February 1998

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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.

A first measurement campaign has been done on an electric vehicle used by Finland Post in Kajaani, Finland, in February 1998. The aims of these measurements were as follows:

- to define the methodology of measurements to be performed in other participating sites
- to assess the operational characteristics of electric vehicles in winter conditions

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

1. Background: Electric vehicles in Kajaani

The city of Kajaani, population 35000, capital of Kainuu province, is an important regional centre and in the heart of Finland. Located north of the 64th parallel, it is also the theatre of the northernmost electric road vehicle operation in the world. Since several years now, the Finnish Post is operating in Kajaani a fleet of five Elcat electric vans for its delivery duties. This fleet is due to be extended in the framework of the EVD-Post project.

The typical duty of the postal delivery vehicles is as follows:

- 03:00 – 06:00: newspaper delivery duty
- 09:00 – 11:00: mail delivery duty
- 11:00 – 13:00: mail delivery duty

The total distance covered during the delivery rounds is 55 km. Opportunity charging is performed between rounds.

1. The CITELEC measurement system[1]

The measurement system used test equipment is composed of the following instruments:

Figure 1: the measurement system installed on board the Elcat

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 2 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

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

microcontroller card. A 24 V NiMH-battery inside the rack provides the supply of all the electronics and auxiliary devices, except for a speed sensor that has its own external 12 V maintenance-free Pb-battery.
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.

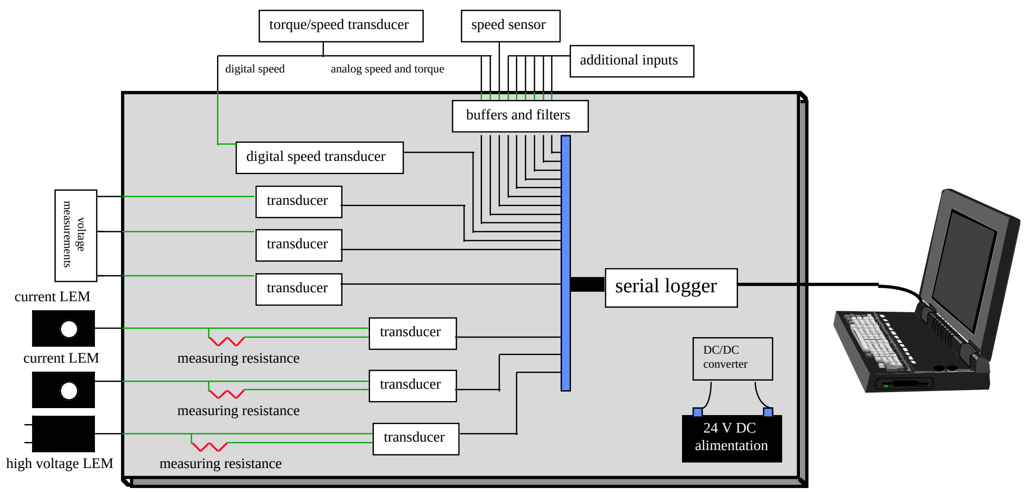

Figure 2: principal outline of the measurement system

Description of the external components

device	measuring range	overall accuracy
current LEM module LT 1000 SI	0-1500 A	± 0.3 % of nominal current (1000 A)
high voltage LEM module LV 100	0-1200 V	± 0.7 % of nominal voltage (800 V)
speed sensor DATRON LM-sensor	0.5-400 km / h	± 0.2 %

Table I: Sensors in use by 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 as can be seen in fig. 3 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 3: the speed sensor in use

2. Practical realisation of the tests

The tests took place in the week from 23 to 27 February 1998.
The first day, Monday 23 February, the measurement system was built into the vehicle, and a first short test performed in order to verify its operation.
The next three days, the vehicle was normally used on both morning rounds (9:00 and 11:00), with full measurements taken.
On Wednesday 24 February, the early morning newspaper round was also covered.
Finally, on Friday 27 February, some additional road tests were performed (acceleration, deceleration, behaviour on snowy surfaces).

3. The postal delivery service in Kajaani

Let's first consider the way postal distribution is organised in Finland. In city centres, the mail carriers usually go on foot. In the residential suburbs however, clusters of mailboxes are grouped on kerbside. The number of mailboxes together can be between 3 and 30.
The postman drives by and serves the boxes from his vehicle window.
Only for some multiple dwellings he has to leave his vehicle for delivery inside the building.

The first mail round: 09:00

This round starts at the main post office and delivers letter mail to the suburbs. The characteristics of this round are as follows:

		24/02	25/02	26/02	Average
Trip length	m	11219	11298	11227	11248
Total time spent	h:mm:ss	1:59:18	2:02:51	1:56:04	1:59:24
Stop time	h:mm:ss	1:14:02	1:17:01	1:12:02	1:14:22
%stop		62%	63%	62%	62%
Run time	h:mm:ss	0:45:19	0:45:50	0:44:02	0:45:04
%run		38%	37%	38%	38%
Number of stops		161	145	158	155
Stops per km		14,4	12,8	14,1	13,8
Average interval	m	70	78	71	73
Commercial speed	km/h	5,64	5,52	5,80	5,65
Maximum speed	km/h	49,88	50,76	46,96	49,20
Average speed (when moving)	km/h	14,85	14,79	15,30	14,98
Ah/km	Ah/km	6,20	5,88	5,79	5,96
% recup	%	4,6%	5,4%	5,7%	5,2%

Table II: 09:00 delivery round

The average length of this round is 11248 m. This is covered in about two hours, with 155 stops on average. The difference in the number of stops between the three runs is mostly due to traffic conditions.

Figure 4: Kerb-side delivery

The second mail round (11:00)

		24/02	25/02	26/02	Average
Trip length	m	12968	11926	12029	12308
Total time spent	h:mm:ss	1:42:01	1:36:02	1:41:28	1:39:50
Stop time	h:mm:ss	0:45:55	0:40:13	0:48:53	0:45:00
%stop		45%	42%	48%	45%
Run time	h:mm:ss	0:56:05	0:55:49	0:52:35	0:54:50
%run		55%	58%	52%	55%
Number of stops		153	162	153	156
Stops per km		11,8	13,6	12,7	12,7
Average interval	m	85	74	79	79
Commercial speed	km/h	7,63	7,45	7,11	7,40
Maximum speed	km/h	39,24	55,24	87,96	60,81
Average speed (when moving)	km/h	13,87	12,82	13,73	13,47
Ah/km	Ah/km	3,71	3,59	4,07	3,79
% recup	%	4,7%	4,4%	4,8%	4,6%

Table III: 11:00 delivery round

This round is a bit longer (12308 m average), but is usually covered much faster, due to shorter stop times. This is mainly due to the fact that on this round there are less multiple dwellings where the postman has to leave his vehicle.

It is interesting to see that the energy consumption is much lower than for the first round. This phenomenon can be attributed to the following factors:

- The characteristics of the round, the first one containing a few more slopes
- The influence of the driver: the postman allotted to the first round having a “heavier foot” than the other one.

The early morning newspaper round

In the early morning, the vehicle is used for newspaper delivery. The mission consists of several parts:

- A feeding traject, where the empty vehicle runs from the main post office to a roadside facility where local newspapers (“Kainuun Sanomat”) are delivered by lorry. (In some cases, the vehicle is stabled overnight at the driver’s home instead of at the post office).
- The delivery round proper, starting as early as 03:00. The vehicle takes its load of newspapers and delivers them to subscribers. Afterwards it returns to the roadside facility to wait for delivery of national newspapers.
- A second delivery round for deliveries of national newspapers. This round terminates around 06:00 when the vehicle returns to the post office and is put in charge.

		Feeding	Newspaper
Trip length	m	3218	8155
Total time spent	h:mm:ss	0:08:24	1:02:52
Stop time	h:mm:ss	0:00:47	0:20:56
%stop		9%	33%
Run time	h:mm:ss	0:07:37	0:41:56
%run		91%	67%
Number of stops		4	115
Stops per km		1,2	14,1
Average interval	m	805	71
Commercial speed	km/h	22,99	7,78
Maximum speed	km/h	43,16	37,96
Average speed (when moving)	km/h	25,35	11,67
Ah/km	Ah/km	3,06	4,23
% recup	%	4,9%	8,5%

Table IV: Early morning newspaper delivery

The characteristics of these trajects (covered on 25/02) are given in Table IV. The second delivery round has not been covered due to a corrupt measurements file.

One can easily see the difference between the nearly non-stop feeding traject and the newspaper delivery traject, the characteristics of which (14,1 stops/km) are much in line with the mail delivery.

Overall average

The average of all delivery rounds give the following values:

		AVG
Trip length	m	11260
Total time spent	h:mm:ss	1:42:57
Stop time	h:mm:ss	0:54:09
%stop		51%
Run time	h:mm:ss	0:48:48
%run		49%
Number of stops		150
Stops per km		13,4
Average interval	m	75
Commercial speed	km/h	6,71
Maximum speed	km/h	52,57
Average speed (when moving)	km/h	13,86
Ah/km	Ah/km	4,78
% recup	%	5,4%

Table V: Average delivery trips in Kajaani

This table gives the main characteristics of mail delivery services in Kajaani.
These data enable to determine some typical characteristics of postal delivery traffic:

- The actual stop time exceeds 50 % of total mission time
- The average distance between stops is 75 m.
- The commercial (end-to-end) speed is very low, and approaches walking speed, due to the long stop times
- The average speed when running is about 15 km/h, corresponding to urban traffic
- The maximum speed of the vehicle rarely exceeds 50 km/h

- Energy consumption is considerably more than the value of ordinary traffic (see also below). The influence of energy recovery (braking) is quite small.

These are the basic characteristics of postal traffic in one particular place. They will be compared with results from the other cities involved in the E.V.D.Post project, in order to allow characterisation of post delivery cycles in different cities.

Graphical representation of postal delivery cycle

The following graphs give some examples of postal traffic curves.

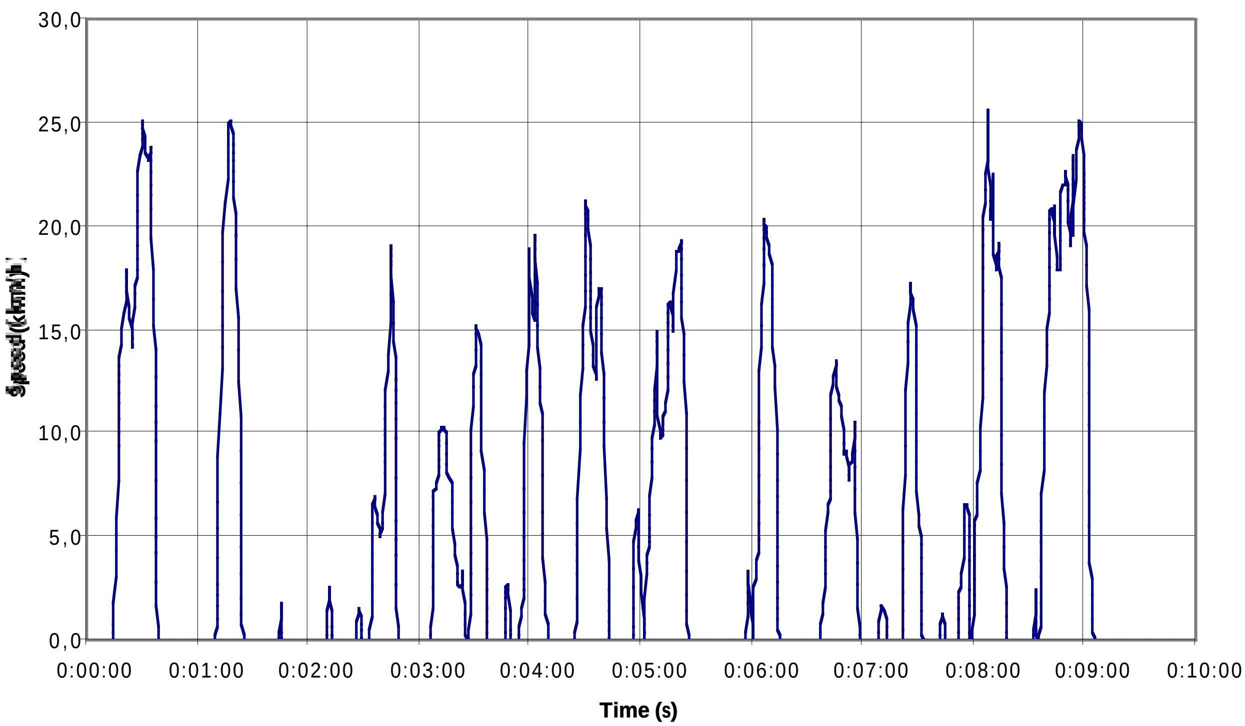

Figure 5: Typical delivery profile

Figure 5 shows a 10-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 6. This figure gives a better image of the geographical distribution of the stop points (i.e. mail boxes)

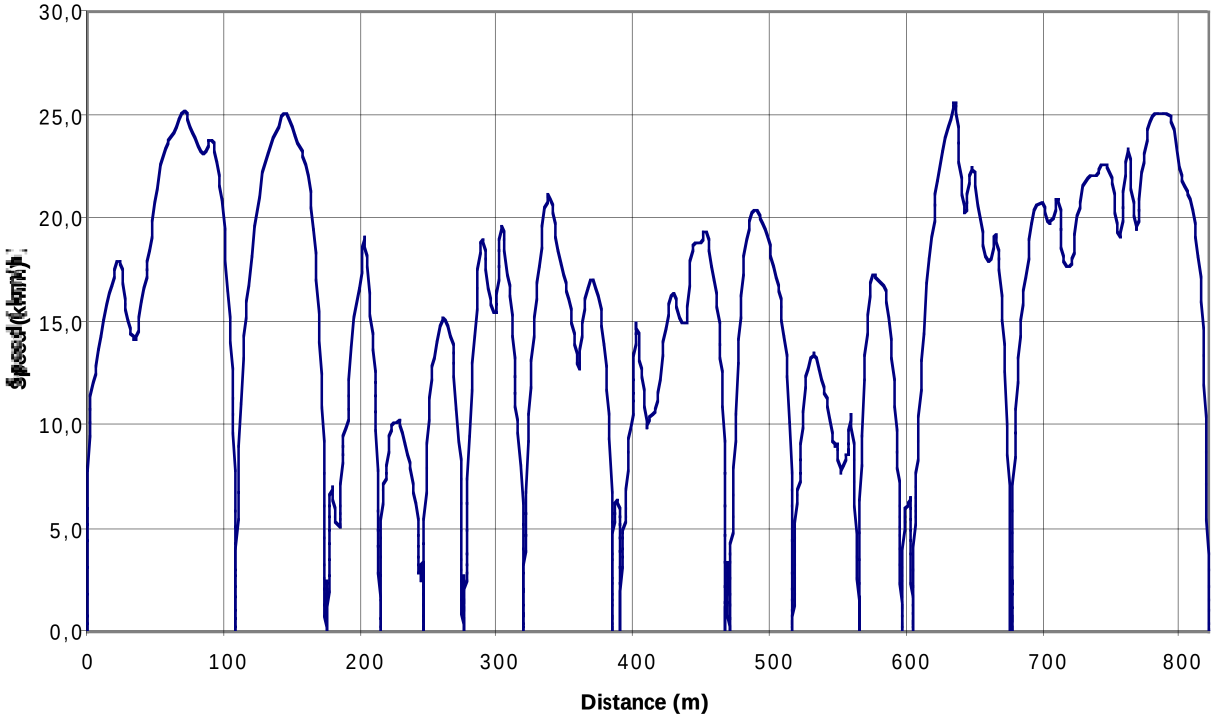

Figure 6: Speed/distance profile

4. Road tests of the vehicle

Road use

The figures for postal delivery use can be compared with a "normal" trip with the vehicle (road traject of 5,1 km):

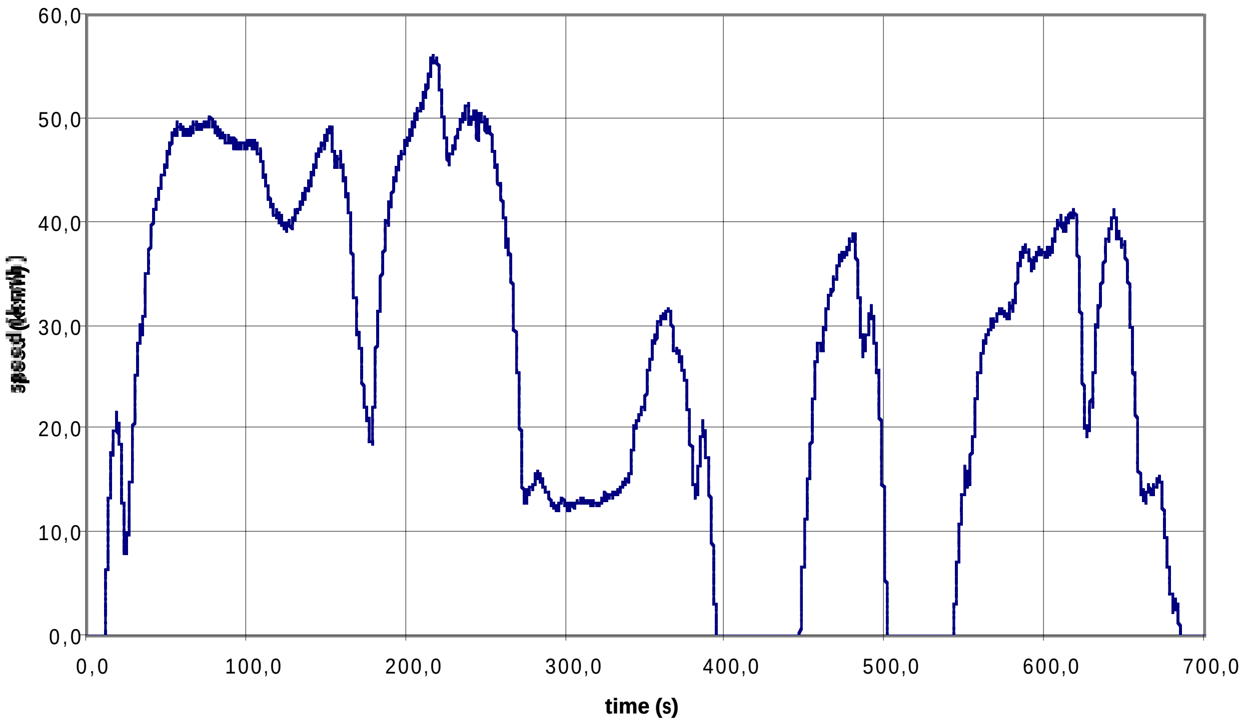

Figure 7: Normal street use

The energy consumption measured during this trip amounted to 2,74 AH / km (with 4,6% regeneration).

Pseudo ECE cycle

To take further this comparison, one may consider the ECE urban cycle. A "pseudo ECE cycle"[2] has also been covered; this gives the following results:

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[2] Under "pseudo ECE cycle" one understands the following of the typical ECE speed profile while using the vehicle on the road, as opposite to the real ECE cycle where the vehicle is used on a roller bench

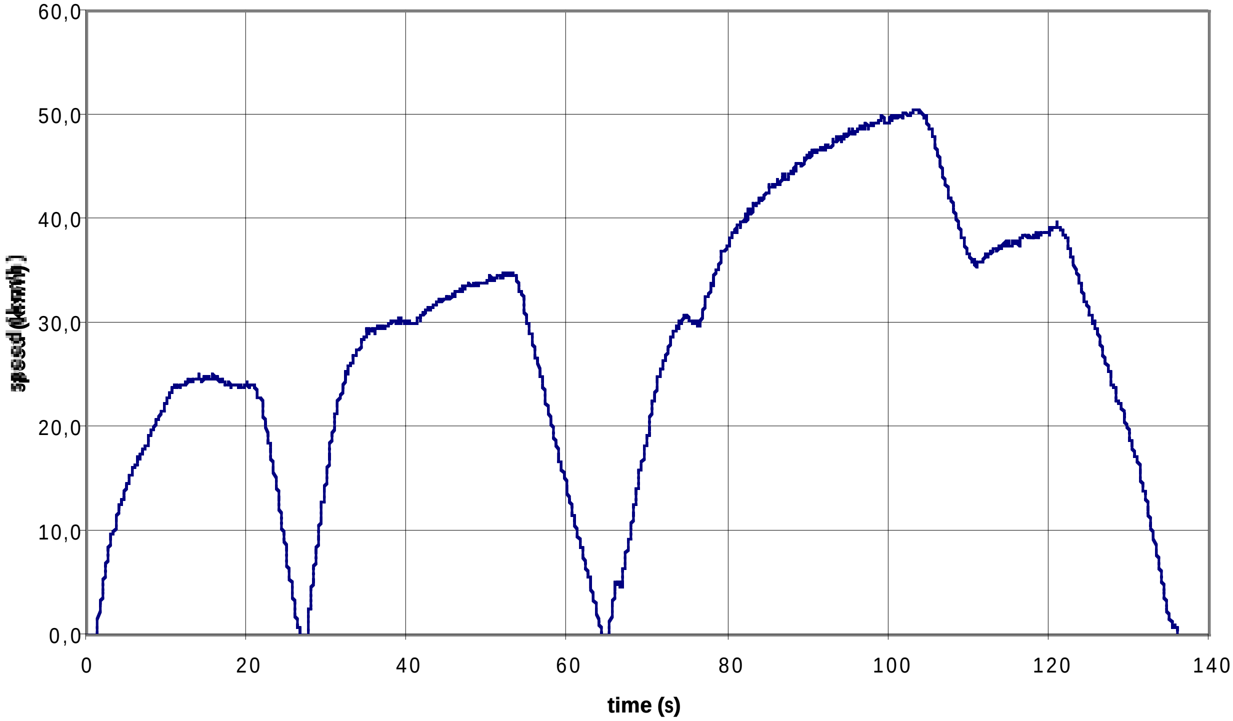

Figure 8: Pseudo-ECE cycle

The road data for the pseudo ECE cycle become as follows:

Trip length	m	1068
Total time spent	h:mm:ss	0:02:16
Number of stops		3
Stops per km		2,8
Average interval	m	356
Commercial speed	km/h	28,24
Maximum speed	km/h	50,56
Ah/km	Ah/km	3,16
% recup	%	11,4%

Table VI: Pseudo ECE cycle on the road

It is striking that the regenerated energy is much more important in this case (11,3%). This is due to the more controlled aspect of the ECE cycle compared with real traffic.

5. General description of the vehicle

The ELCAT is an electric van derived from the Subaru Cityvan.

The vehicle is powered by a *13,1 kW DC* motor acting on the rear axle through a five-speed manual. The motor is fed through a Mosfet chopper with possibility of energy regeneration during braking.

The traction battery consists of 12 monoblocs of 6 V, 180 Ah to obtain a nominal voltage of 72 V.
The vehicle is fitted with an on-board charger; the plug is located in front of the vehicle.

The auxiliaries are powered through an isolated DC/DC converter 72/12 V; a buffer battery is present.

Access and loading

Access to the vehicle is identical to the thermal version.

Batteries are located in the middle of the vehicle, taking a part of the loading space. The battery cover can also be used for storage upon it.

For postal use, the vehicle comes with in right-hand drive version, enabling kerbside delivery without leaving the vehicle. The window is fitted with Finland Post’s proprietary easy opening system.
The passenger seat is removed and replaced by a receptacle for a standard plastic letter container. Additional containers can be stored in the back.

Driving behaviour - Acceleration

The traction circuit of the vehicle consists of a series DC motor, fed by a chopper and coupled to a five-speed manual gearbox.

Due to the high starting torque of the electric motor, the vehicle can be started and stopped with the clutch engaged; this is very interesting for city driving with frequent stops.
The starting torque is very high in first gear (and in reverse); in most cases, second gear can be used for starting. First gear is only necessary for starting on steep slopes.

Figure 9 gives an acceleration curve measured on a flat road in Kajaani. It should be stated however that this acceleration curve is not to be considered as a real typical curve for the Elcat, as it has been measured on a road which was lightly covered with snow and ice (as all roads in Kajaani during the winter); while still allowing safe driving without problems, it prevented full acceleration potential. See also below (winter driving)

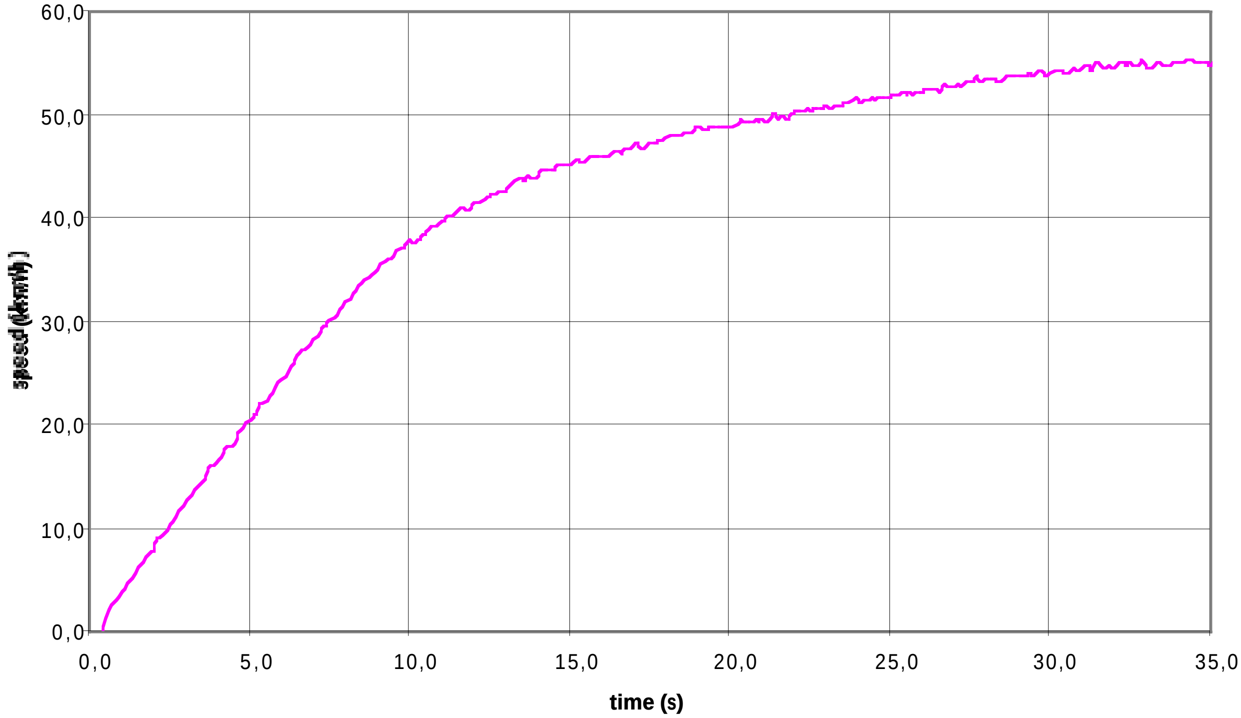

Figure 9: acceleration curves

As one can clearly see, the acceleration values are high at low speed; this is a typical characteristic of the series excited DC motor. When speeds go up, torque goes down, and acceleration decreases until the vehicle reaches a steady speed where the motor torque equals the rolling and wind resistance.
During maximum acceleration, current is limited by the current the motor can absorb on one hand and the current limit of the chopper on the other hand. When acceleration is done in 4th or 5th gear, the chopper limits the current and acceleration is lower.

The vehicle behaviour is different from a petrol vehicle, because of the shape of the torque/speed characteristic of the motor, which is quite different from a petrol or diesel engine.

Electric braking

The new model of Elcat comes with electric regenerative braking. An extra contactor is used to invert the field of the motor, thus enabling braking.

The deceleration characteristics are shown in figure 10: deceleration with and without regenerative braking enabled.

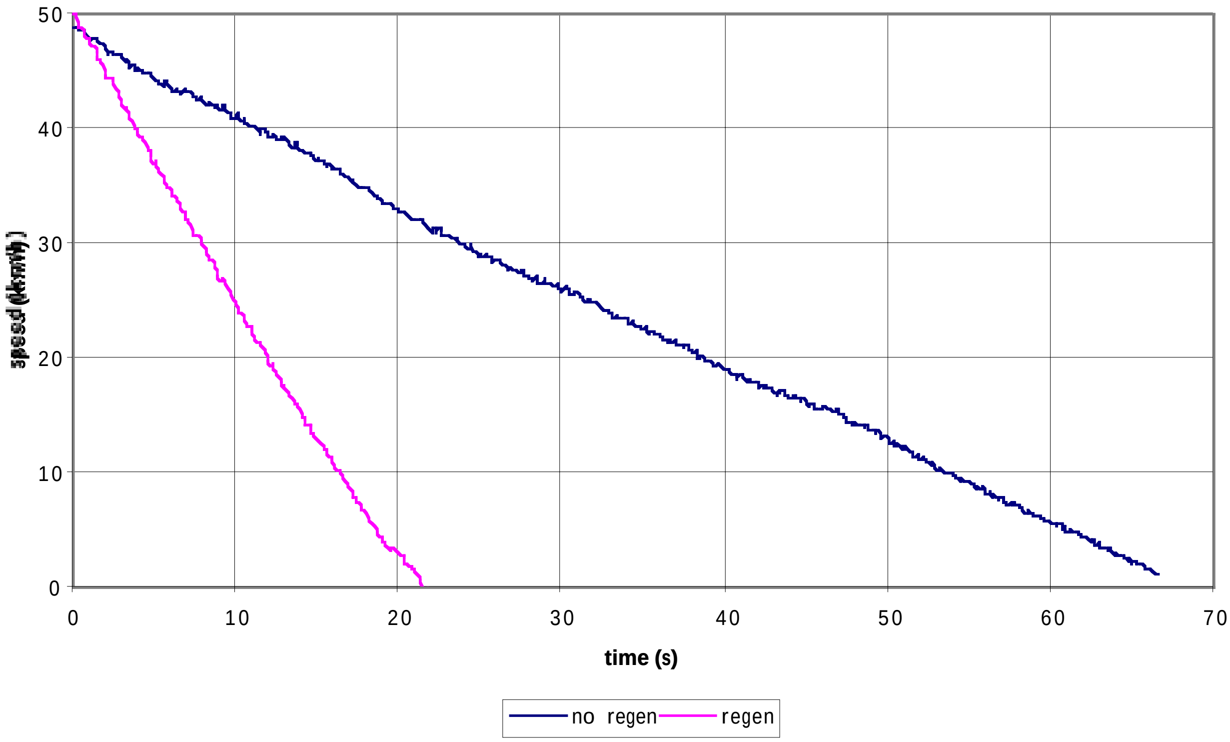

Figure 10: Deceleration

The traction system is completely silent.

Heating

The vehicle interior is heated by means of a petrol-fired water heater.
Even in extreme temperatures (down to –25°C), the operation of this device is satisfactory. While not providing room temperatures inside the cabin (which is anyway not realisable due to the frequent opening of doors and windows in postal duty), the heater keeps the atmosphere within the vehicle liveable.

Appreciation

The Elcat is an electric vehicle designed for use in urban traffic; the vehicle performs this job in a very satisfactory way.
Driving the vehicle is simple and straightforward; prospective drivers however must be acquainted to the characteristic behaviour of the electric traction motor to get the best results. Once a driver has been acquainted with the vehicle's behaviour, the characteristics of the vehicle are generally appreciated.
Range and speed are sufficient for urban or suburban use.

6. 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 consumption for postal delivery duty during the test was 523 Watt-hours per kilometre. The average weight of the vehicle during the tests can be estimated at 1350 kg, the average specific consumption was 387 Wh/Tkm. These values however were varying according to the covered distances per day:

date	km	kWh	Wh/km	Wh/Tkm
24/02	25,0	12,8	512	379
25/02	56,6	22,9	404	300
26/02	23,5	14,9	653	484
average	35,0	16,9	523	387

Table VII: Energy consumption

It is clear that the lowest values are obtained with longer trajects. This is mainly due to the use of opportunity charging during these trajects, the latter technique being more energy efficient because it avoids the gassing phase.

How to evaluate this result?

One may recall the tests done by CITELEC on the first generation Elcat vehicle, which gave a result of 204 Wh/Tkm on average. In this case however, normal road traffic had been considered, and not the postal delivery work, the energy consumption of which is considerably higher.

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:

$$C = 150 + 100 / W$$

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

$$C = 80 + 80 / W$$

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

$$C = 220 + 120 / W$$

For a 1350 kg vehicle, this gives respectively 224, 139 and 309 Wh / Tkm.
The best value of the tests (25 February) with its 300 Wh / Tkm, falls just below the “maximal value”. In this case, this has nothing to do with efficiency of the technology, but with the operation mode of the vehicle.
Also, it has to be considered that for internal-combustion engined vehicles, the energy consumption during postal distribution service is significantly higher than the standard consumption values, even in city traffic, for that vehicle.
It is clear that the above formulas are referring to ordinary use of the vehicle.

Furthermore, the battery heating (see below) may add a few kWh to the daily energy consumption in wintertime. The energy use of this heating can be estimated at maximum 4 kWh per 24 hours.

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 4,78 Ah / km has been recorded in postal delivery duty. This is to be compared with the value of 2,36 Ah / km measured on the Elcat in Brussels.

Range

Even if a full range test has not been performed, forecasts about the range of the vehicle can be taken from the instantaneous energy consumption.
Given the average consumption, and given the available capacity of the battery, one can forecast the available range of the vehicle.
The battery has a nominal capacity of 180 Ah; when considering, a depth of discharge of 80% (144 Ah), which is the normal recommended practice, one becomes a theoretical range of just 30 km with the 4,78 Ah / km consumption in postal duty. This is under half the range that may be expected in “ordinary” traffic.
It is thus clear that for longer duties (the two rounds combined with the newspaper delivery job, amounting to 56 km in total), opportunity charging is a necessity.

7. Energy flows in the vehicle

Figure 11 gives the energy flow (battery and motor current and voltage) during a typical start-stop cycle.
The evolution of battery and motor current can be visualised easily:

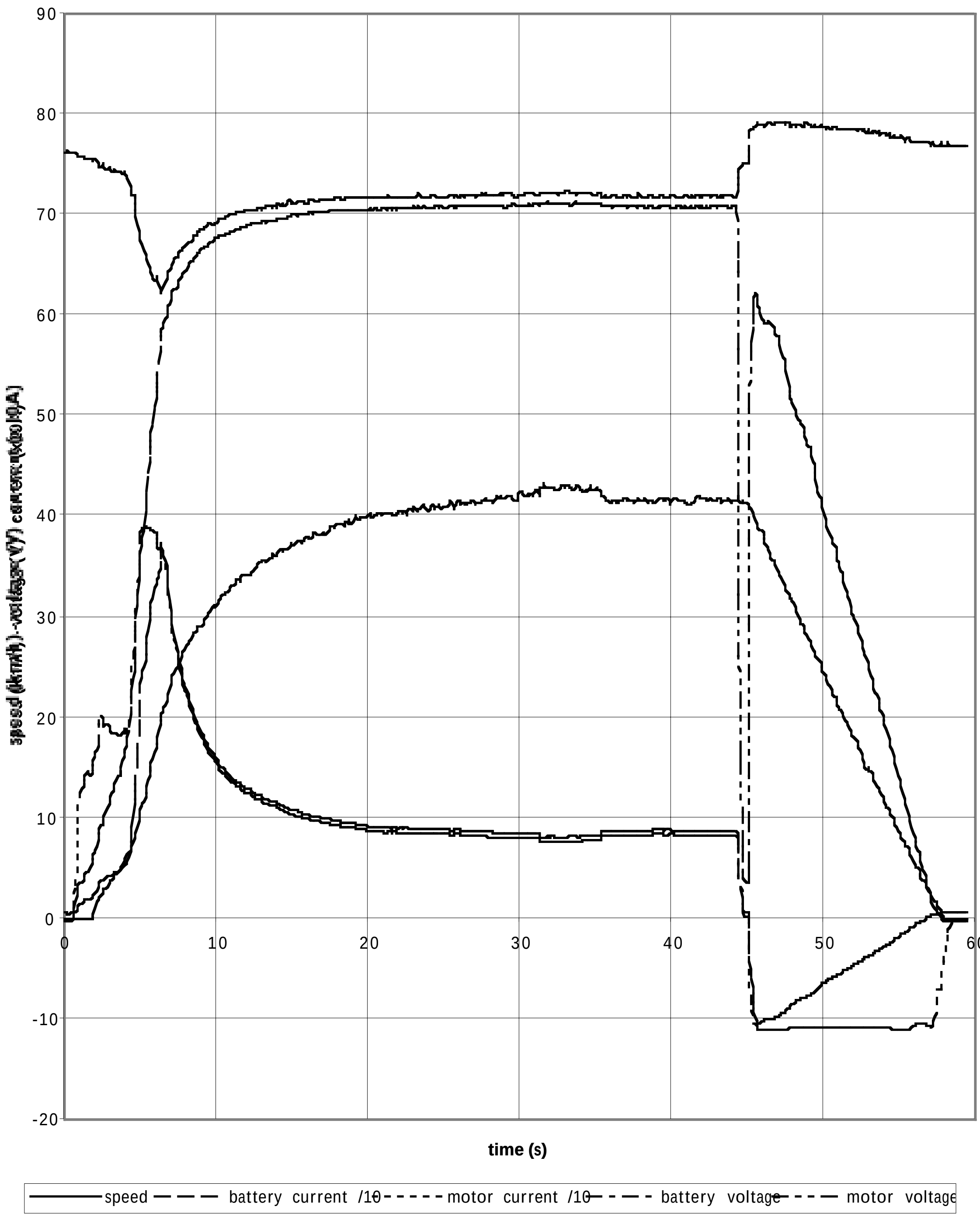

Figure 11: Current evolution during acceleration, driving, and stop

- At the first phase of acceleration, the chopper is multiplying the battery current. Motor currents up to 400 A allow for a fast acceleration. The variation jumps in the current are due to gear shifting.
  The battery voltage takes a strong dip under these high current drains while the motor voltage gradually builds up with the speed.
- When the motor voltage (representing the counter-electromagnetic force of the motor) equals the battery voltage, the chopper goes in full conduction mode and battery current equals motor current.
  The vehicle now follows the characteristic curve of the series traction motor, and the speed stabilises on the value where the motor torque equals the driving resistive forces. This self-regulating driving mode is typical for the series motor.
  The motor voltage equals the battery voltage minus the conductive losses of the chopper, which are very limited (one volt or less)
  Before braking is initialised, the motor voltage briefly drops to zero; this is when the braking contactor is energised to allow regenerative braking.
- During deceleration, a constant braking current of about 100 A is delivered by the motor, which acts as a generator. The chopper sends this current back to the battery; however, since motor voltage decreases during deceleration, so does the battery current.

8. Winter driving

The opportunity was also taken to assess the influence of wintry road conditions on the electric vehicle. It has been seen above that cold temperatures do not affect the battery, due to the battery heating system provided. But what is the influence of the road surface?

During the test period, weather in Kajaani was quite variable and included both cold and dry periods (down to –25 °C), as well as “warm” periods (0 °C to –5°C) with snowfall.

Road surfaces are being treated with sand and salt to keep them practicable in winter; furthermore, virtually all vehicles, including the tested Elcat, are fitted with studded winter tyres. Normal traffic is possible on main roads; however, fierce accelerations may lead to loss of adhesion (spinning weals) and driving has to be done carefully. For this reason, the acceleration test presented above is for indication only and does not show the maximum performance of the vehicle.

A special test has been done on a secondary road, which was covered, with fresh snow, at a temperature of –7°C. On this road, a pseudo-ECE cycle was driven. This gave the speed profiles of figure 13.

It should be stated that these tests do not represent a normal driving behaviour on snow by a careful driver.

One can immediately see that the speed values are less smooth than the ordinary pseudo ECE cycle (Figure 8).

Note that the speed measurements are done with the optical transducer and thus correspond to the real speed of the vehicle.

Figure 12: Driving on snow

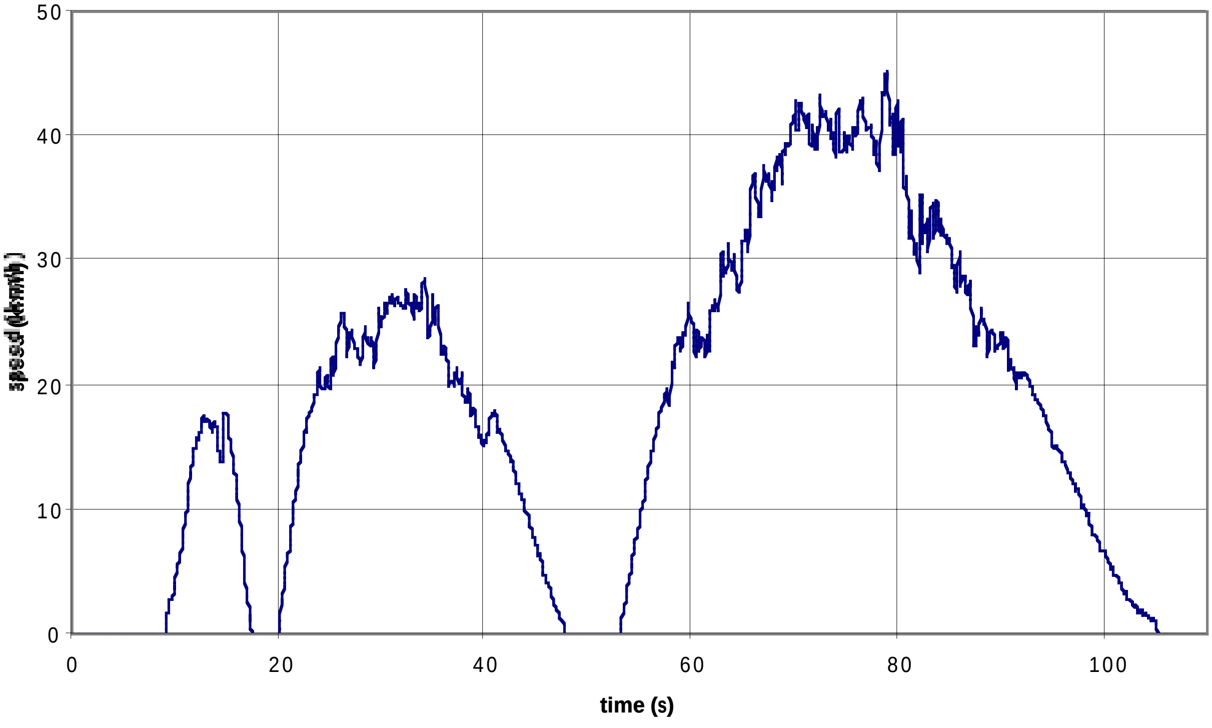

Figure 13: Pseudo-ECE cycle on snow

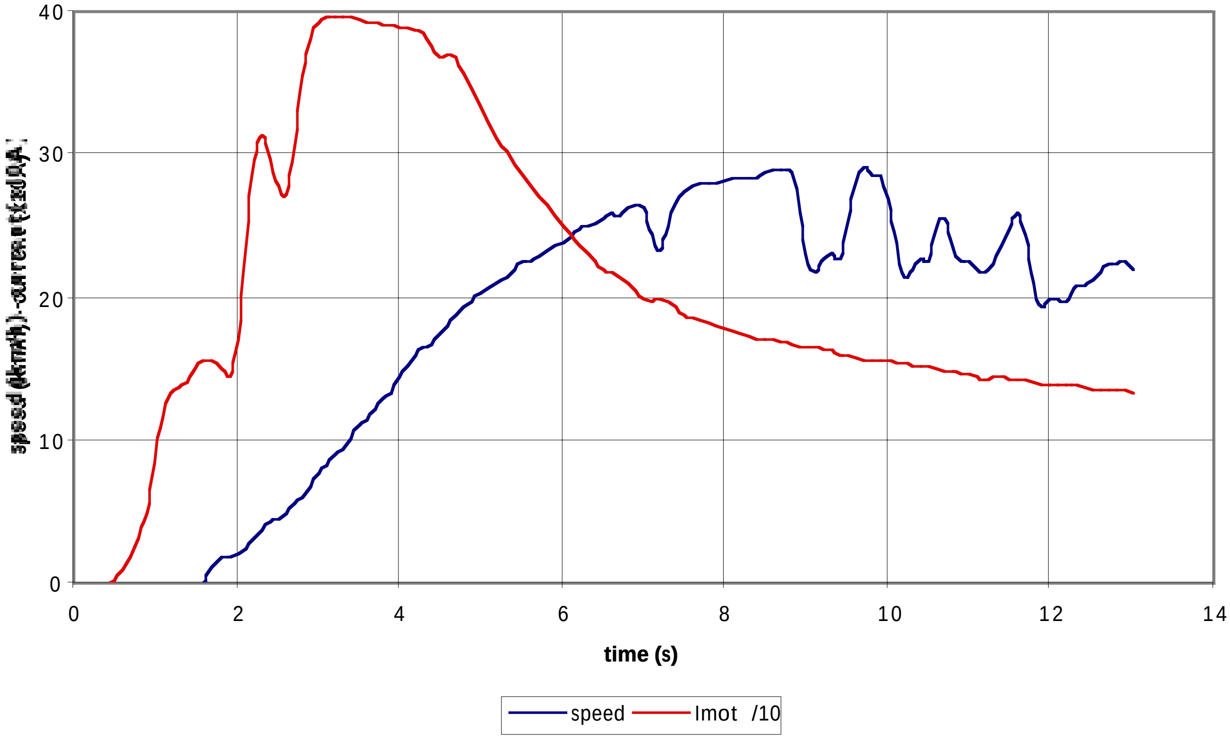

Figure 14: Acceleration on snow

This figure gives an overview of the phenomena during an acceleration on snow. It should be compared with figure 11.
One can see the following:

- During acceleration, there are instances where the motor current suddenly drops (like at second 2,5). This is not due to gear change (the acceleration was done in the same gear), but is an illustration of the wheel slipping phenomenon: the wheels spin loose, motor speed increases, and current decreases as can be expected with a series motor.
- During the "constant speed" phase, vehicle speed is fluctuating due to the variations in tyre grip on the snow, while the wheels are turning at a more or less constant speed as can be determined from the smoothness of the motor current curve.
- Instantaneous energy consumption in these snow tests was 4,50 Ah/km (average value), which is considerably higher than the same types of trajects on de-iced roads.

9. The traction battery

The ELCAT comes with a battery pack consisting of 12 tubular plate vented lead-acid batteries of 6 V each. These give a system voltage of 72 V and a total capacity of 180 Ah (5h). Each battery weighs 31 kg, giving a total weight of 372 kg. This corresponds to an energy density of 34,8 Wh / kg.

The battery pack is located centrally in the vehicle. Access can be gained by removing the cover; this makes all batteries readily available for watering, control,…
The batteries needs watering approximately every 1000 km.
The batteries are fixed to the vehicle floor by means of safety belts. These belts are also used to remove the whole battery pack with a workshop crane or fork truck. This allows an easy changing of the battery pack.

The vehicle is also fitted with a battery heater, supplied from the mains during charging. The heating element consists of a resistor cable located under the batteries. It is activated when the battery temperature is under a pre-set value (typically 32°C). On the other hand, a battery-cooling fan is activated when battery temperature is above another pre-set value (typically 37°C).
This device has proven very useful: even in the harsh winter conditions of Kajaani, with outside temperatures as low as –25°C, the battery temperature will never go below 30°C; this way the full battery capacity remains available and the use of lead-acid batteries, which are normally sensitive to low temperatures, does not interfere with the practical operation of the vehicle.

When the vehicle is used in an intensive way, the battery heating is done by the charging and discharging current inside the battery itself and the heating does not have to intervene. When the vehicle is parked for a prolonged time however, the battery cools down, and here the heating becomes essential.

10. The battery charger

Connection of the charger

The Elcat is fitted with an on-board, high frequency charger located in the electronic control box on top of the motor. Connection of the charger is done through a spiralled cable located in a swing-out box in the front bumper. This cable is fitted with a Schuko side-earthed plug.
For a demanding application like electric vehicle battery charging however, this type of plug, and more in particular the corresponding current outlet, may not be fully suitable and are prone to early failures, as shown by the 15-year long experience of Brussels University. The use of more robust, industrial-type, connectors is recommended.

Charger characteristics

The charger has an I-U characteristic, as can be seen in the figures 10 and 11. The charger stops automatically after about four hours of final charge (constant-voltage). One can see that the constant-voltage is 83 V; this voltage is under the gassing voltage of 2,4 V per cell (86,4 V for 36 cells).
This will limit water consumption, but also will raise the need for a thorough equalising charge to be applied in due time.
The output power of the charger is only about 2 kW, allowing use of a 10A outlet.

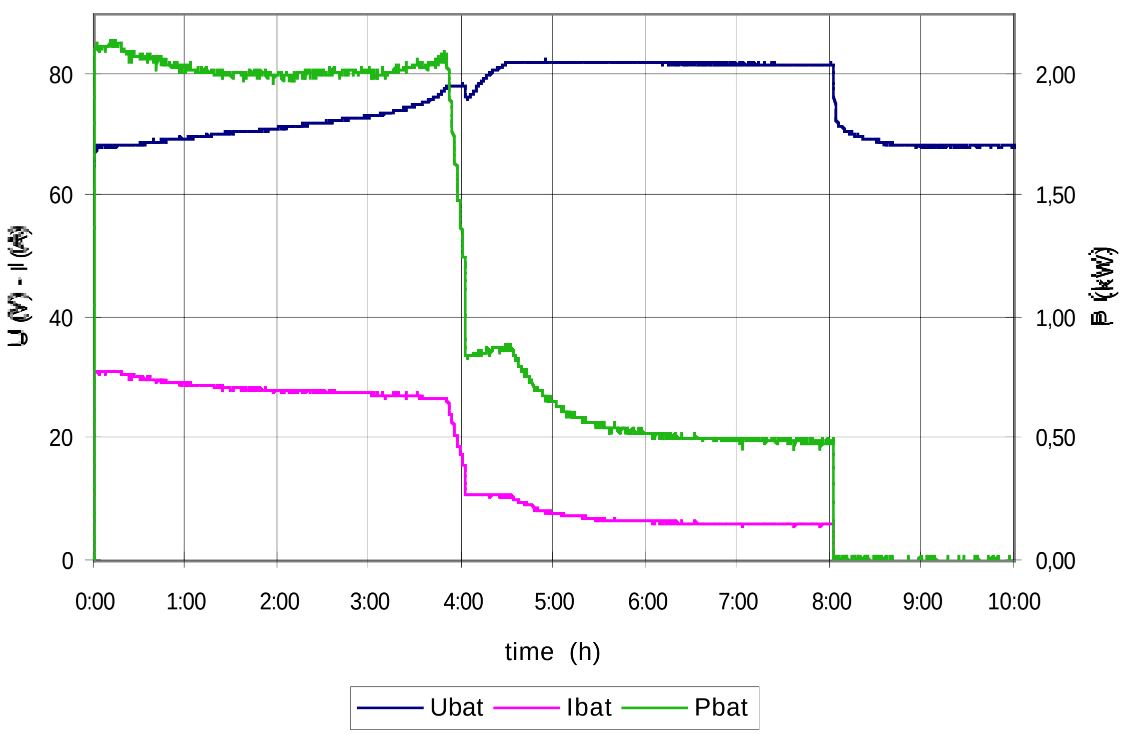

Figure 15: Charger current, voltage and power

11. Safety aspects

Electrical safety

No particular safety problems have been identified.
The traction battery in the tested vehicle is isolated from the vehicle frame, and the DC / DC converter is isolated. This is an essential safety precaution.
The chances of coming into contact with live parts are limited. Live parts are accessible of course inside the battery tray and the electronics box, but these can only be opened with the aid of tools and are in principle only allowed to trained service personnel.

Functional safety

No particular safety problems have been identified.
The functional safety characteristics are satisfactory: the structure of the vehicle permits safe operation of the control system. Some considerations however:

- No indication of the actual motor speed is present, so a vehicle going downhill at excessive speed (too low gear) could overspeed its motor without warning. The same applies when the motor is accelerated in neutral position.
- The vehicle can not be started when charging; this protection is based on the presence of 220 V AC. When the charging cord is inserted in a dead socket, which has been switched off for example, the vehicle can still be driven away, with possible damages as a result.

12. Conclusions

This first measurement campaign performed in the E.V.D. Post project has allowed gaining interesting experiences concerning the use of electric vehicles for postal duties. The determination of the parameters describing the postal delivery rounds in Kajaani will define the methodology to be used in forthcoming measurements in other sites participating in the project.
Furthermore, the measurements performed in near arctic conditions have proved that the electric vehicles are more than able to perform properly in northern countries. Kajaani is in fact the most northern operation theatre for revenue-earning electric vehicles in the world.

13. Acknowledgements

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