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eTRUCK – Electric truck innovation platform operating in daily use in Finland

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Executive Summary

Electrification of trucks will enable low noise and low emission delivery and collection of freight in population centers and city areas. Nevertheless, in all cases electric trucks must fulfill the reliability and performance demands arising from logistics operations and wider from commercial needs.

The eTRUCK project collects experiences from 16 ton electric delivery truck technologies and their real-life operation capabilities in northern circumstances in Finland. The project is carried out by Tampere University of Applied Sciences together with public-privet partners like municipalities, line operators, technology companies and research institute. The eTRUCK project is financed by European Regional Development Fund (ERDF). The eTRUCK has been operating since autumn 2015 in harsh climate conditions from commercial bases at Tampere region.

The eTRUCK has been equipped with present-day monitoring and communication instrumentation enabling to remote follow-up of its operations like: location, operation phase, speed, electric parameters, energy consumption and charging. The data collected will be compared to those produced with computational tools in order to have accurate enough match between measured real-life data and calculations. In future the computational tools will support route and operation planning, charging and driving cycle optimization for electrical delivery trucks in demanding operational and environmental conditions.

The project will establish a truck operation database which can be used in future as a comparison reference for other type and size of trucks. The task is to enable more accurate estimations and planning of electric truck operations. At a later stage the results accumulated from the eTRUCK experiences will be analyzed from energy consumption, emission and economical perspective.

1 Introduction

In autumn 2015 the first fully electric 16 ton truck, eTRUCK, started to operate in commercial use in Tampere region. The eTRUCK until now is the only electric truck registered in Finland. So far eTRUCK has driven in one shift some 58 000 km, typical daily drive distance being 110 – 150 km.

Figure 1: eTRUCK 16 ton electric truck in its present form connected to grid at terminal.

The truck is owned by Niinivirta Ltd which is a transport company operating in Finland and Italy. Material arriving to Tampere region from Europe will be distributed by a fleet of covered trucks. eTRUCK is one of those operating in same manner as the rest of the fleet powered by diesel engines. Material distributed are clothing, food products, beverages, household products and construction materials. Distribution is done between terminal and companies. Private or consumer deliveries has not been performed so far. In practice it means that the daily operation routs and time schedules are repetitive in nature and well known. Accordingly the optimization of routings and delivery stops can be made easily.

In regional use the eTRUCK is operating in highways, local streets in semi-urban areas and in city centers. The maximum speed limit of eTRUCK is 87 km/h. In figure 2 is a map of drive route of a typical day in March 2017, total length 114 km.

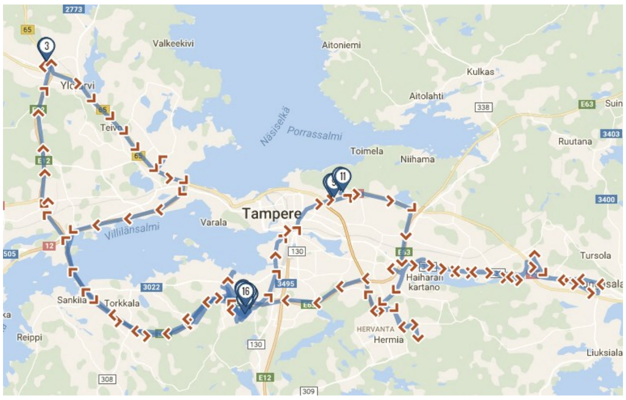


Figure 2: eTRUCK drive route in one day in March 2017.

In typical routing eTRUCK will start at early morning form the terminal. At morning hours eTRUCK deliveries material to some 3 – 5 clients and drives some 30 – 50 km. After that it returns to terminal for reloading material for afternoon deliveries. The second rout is somewhat longer, some 40 – 70 km and consists of 5 – 7 delivery stops. Final stage is to return to terminal for unloading empty cages and reloading material for the next day. All driving is done by one driver in one long day and in one working shift. Some of the major customer stops and unloading of material may take even more than one hour of time. A typical stop is some 10 – 20 min long. From operation point of view a longer stops could be used for charging the batteries if a plug-in connection for charging would be available. However this is not the case. The only charging point is available in the terminal. During the time when eTRUCK is at terminal it is connected to charging connection. This happens at day time stop and during the night time the battery will be charged to its full capacity.

2 eTRUCK innovative platform

eTRUCK is a 16 ton electric truck type EMOSS CM1616 powered by 235 kW PM motor. The energy capacity of the batteries are 160 kWh. In figure 3 is an illustration of the truck provided by the manufacturer and in figure 4 the main circuit diagram of the electric power system.

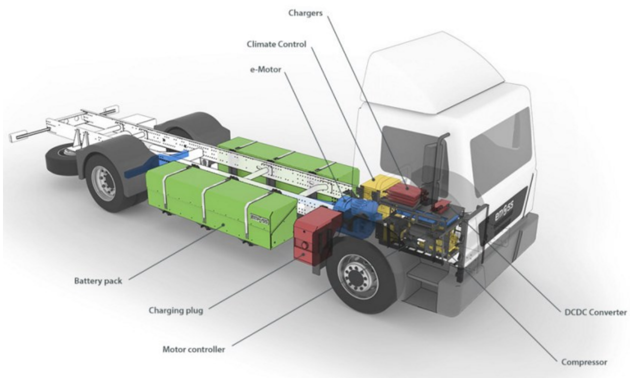


Figure 3: eTRUCK 16 ton electric truck structure.

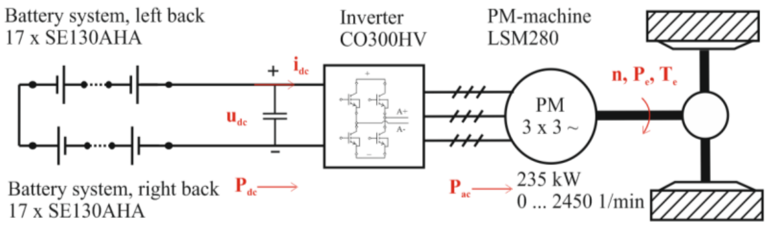


Figure 4: Main circuit diagram of the eTRUCK power system.

The technical data and main parameters of the eTRUCK are listed in table 1. The data is based on the information provided by the manufacturer.

Table 1: eTRUCK technical parameters

	Values
Weight (kg)	16 000
Payload (kg)	9 466
Energy storage pack (LiFePo4, kWh)	160
Number of two parallel units in series	192
Range (NEDC, 80 % payload, km)	210
Top speed (km/h)	80
Electric motor type	PM
Power, cont. (kW)	235
Power, max (kW)	250
Torque, cont. (Nm)	1600

Torque, max (Nm)	3400
Operation range (1/min)	0 - 2450
Operating battery voltage (V)	300 – 750
Maximum efficiency (%)	94,5
Cabinet heating	oil heater

Because the eTRUCK is a commercial truck and operating in real use there has been limited access to the electric drive train structure. All main components are sealed in their own cowers which has not been opened or examined by the research group. Also the control systems and drive parameters are not able to modified. From research group point of view the eTRUCK has been monitored as it has been delivered by the manufacturer and as it is in practice. This means that all observations will be focused to the instrument called eTRUCK and it capability to perform in operation use. The eTRUCK has been equipped by the research group with present-day monitoring and communication instrumentation enabling to remote follow-up of its operations. The focus has been in following parameters: location, operation phase, speed, electric parameters that are available, energy consumption and charging. The data collected will be compared to those produced with computational tools in order to have accurate enough match between measured real-life data and calculations. Equipment used in monitoring is based on IoT-TICKET platform which is a complete Internet of Things (IoT) service covering data acquisition, reporting, dashboard and analytics. The system is delivered by company called Wapice Ltd. Measurements from the eTRUCK has been collected by WRM 247+ device which is a robust device for remote management, measurement and control [2].

Figure 4: WRM 247+ device for remote management, measurement and control.

3 System components of the eTRUCK simulation model

The eTRUCK model is based on the component models combined together in modular principle. The most important model components are: the model of the dynamics of the eTRUCK, the traction drive, electric motor, power electronic converter and the energy storage. The connection of the components is based on an action-reaction principle according to the physical causality. Simulations has been performed in Matlab/Simulink environment.

The model of the dynamics of the eTRUCK is based on well know dynamic equation of vehicle motion along the longitudinal direction

$$m_v \frac{dv}{dt} = F_t - F_r - F_\omega - F_g \qquad (1)$$

where m_v is the mass of the truck, F_t is the rear tire traction force, F_r is the rolling resistance force, F_ω is the aerodynamic drag force and F_g is the grading resistance [1]. Each of these force components have a detailed physical models based on one-dimensional movement of the truck and number of assumptions regarding different component behavior, losses, dynamic responses and environmental conditions. Special aspects at Tampere region related to the truck dynamics are icy or snowy roads at low temperatures.

Electric drive can be simulated by using dynamic or quasi-static models. In dynamic model the behavior of the motor can be analysed in steady and transient states. While dynamic modelling needs complex models and long simulation time in analyzing large time scales a quasi-static model is used. The quasi-static model is based on first- or second-order time constants and efficiency maps. Figure 5 describes the motor and the inverter efficiency map used in the quasi-static method.

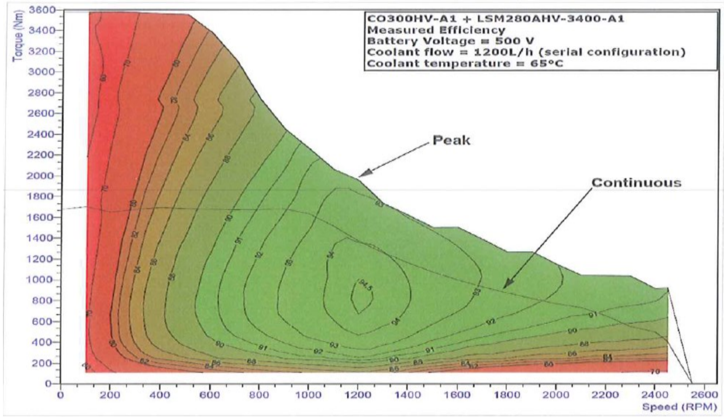


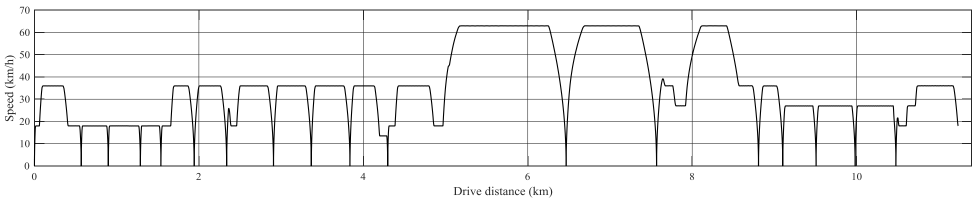
Figure 5: The drive system efficiency map at 500 V provided by the manufacturer.

The energy storage model consists of an internal voltage source V_{batt} and an inner resistance R_{esr}. The inner resistance is not constant but depends on depth-of-discharge, current level, temperature and sign of the current [3]. For example in Tampere region where outdoor temperature can vary between -30 … +35^{o} C, the temperature dependency can be significant from storage operating life point of view. However temperature monitoring is inadequate while the storage temperature sensing arrangement is not known to the research group. Power capability depends on several parameters like state-of-charge level, temperature, age and the time interval of the drawn power.

Capacity modeling of the storage is one of the top issues in eTRUCK project. Often the case is that transport operators are distrustful of the capacity and lifetime of energy storage in general level. As the energy storage is a new and costly component in truck it is not popular to take a technologic risk in transportation business where the competition for market shares is hard. The amount of charge-discharge cycles depend on several conditions like the temperature, current level, age and accepted state-of-charge levels, maximum and minimum.

4 eTRUCK operations and experiences

Data collected from daily operations will be used as a source material for simulations. The main target is to find fitting accurate enough between measurements and simulations. After the fitting is in satisfactory level more wider user based analysis can be done for other applications or circumstances. In figure 6 is an example of one commonly used part of daily delivery route, length of 11.2 km. In figure drive speed, height position and DC link power are shown. In this case the weight of the truck was 10 300 kg. In this part there are both down and uphill part in the route. Total energy consumption is around 6.2 kWh. However, the value is inaccurate while the energy recycling is not detailed monitored.



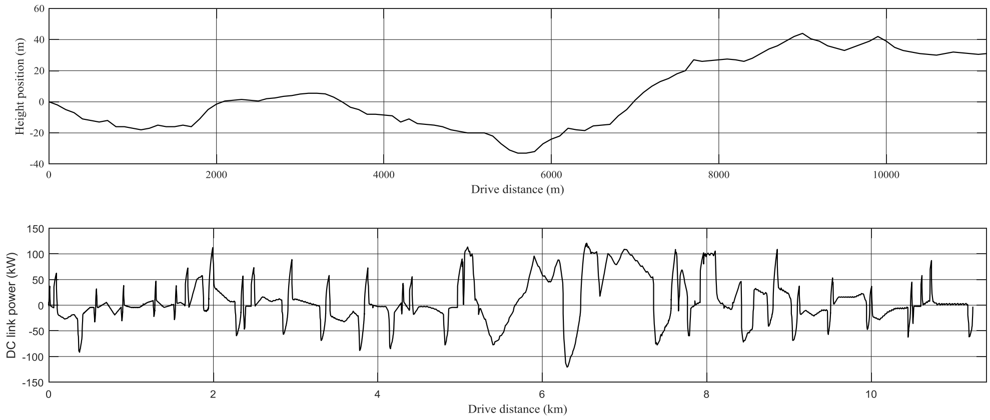


Figure 6: Example of a drive performance total length being 11.2 km.

In system level the focus in the research is in energy consumption, operation cycles, energy storage stresses and performance that are compared to the real life operations done in delivery business. In figure 7 is an example of driving done in September 2016 and energy loaded to the eTRUCK at home terminal. Energy recycling or any drive conditions has not been included while the measurement is based on kWh measurements done at the terminal main switch board.

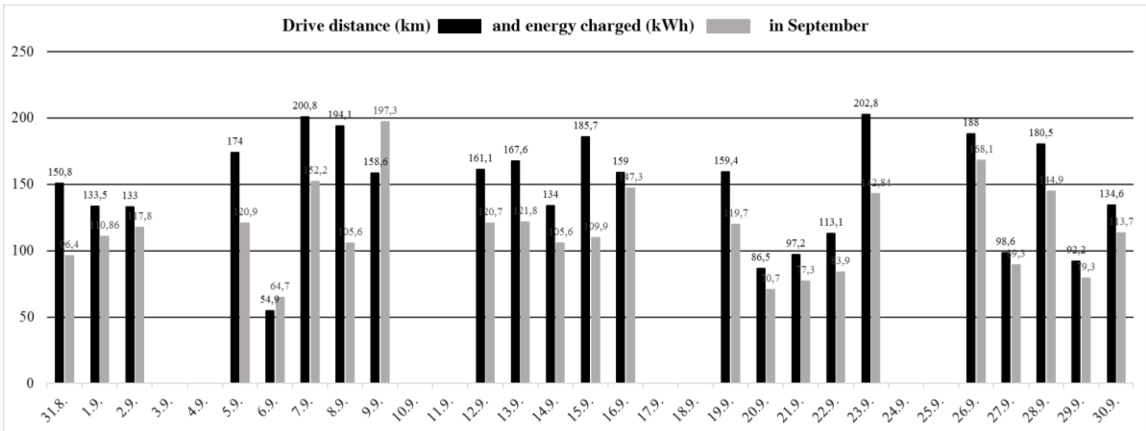


Figure 7: Drive and energy balance sheet at September 2016.

By comparing these results one can find statistical number of energy consumption in one kilometer. In future more sophisticated method and analysis than this straightforward calculation presented here in figure 8 will be done from wider data and detailed information.

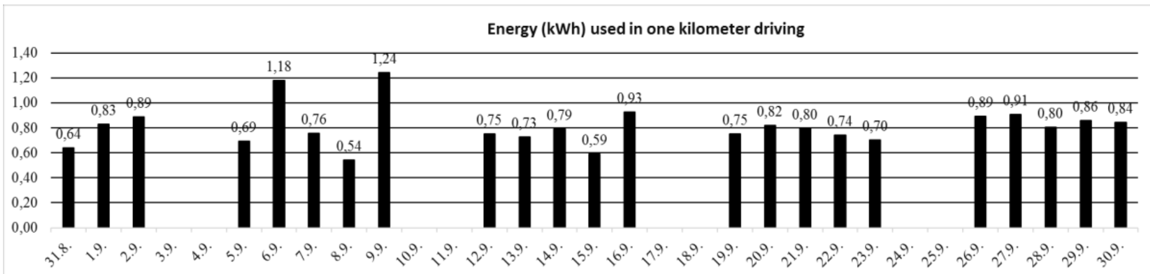


Figure 8: Energy consumption kWh/km at September 2016.

When monitoring more detailed the daily energy charging the change of SOC can roughly estimated. In figure 9 energy charging at terminal is monitored in one hour slots during the first week in September 2016.

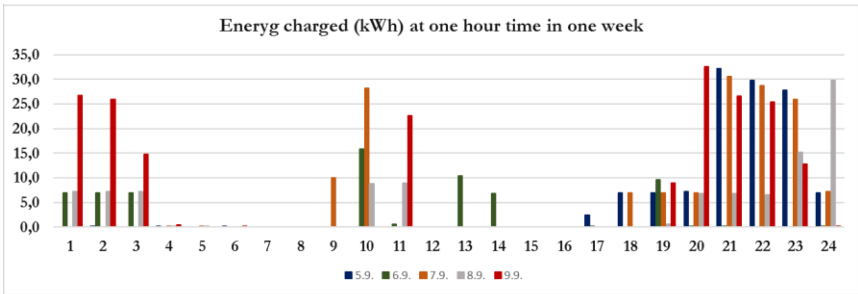


Figure 9: Charged energy at one hour periods on one week at September 2016.

Energy charged is now split in different periods which all have their starting and stopping times. Each of them represents a part of the charge period and driving between discharge period. With this assumption we can then calculate the change in state-of-charge in very rough manner. This is shown in figure 10. In future more sophisticated method and analysis than this straightforward calculation presented here in figure 10 will be done from wider data and detailed information. By using rain-flow-counting method the stress of energy storage could be estimated. This is however for future to be done.

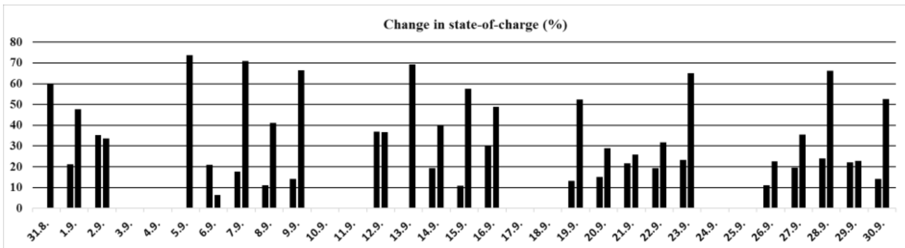


Figure 10: Change in state-of-charge caused by charging at terminal.

5 Conclusions

In eTRUCK project the main focus is to justify the suitability of electric truck in delivery operations at urban or semi-urban area. In practice the typical case is that transport operators are distrustful of the capacity and lifetime of electrical energy storages in general level. As the energy storage is a new and costly component in truck it is not popular to take a technologic risk in transportation business where the competition for market shares and orders is hard. In all cases electric trucks must fulfill the reliability and performance demands arising from logistics operations and wider from commercial needs. It's properties have to be similar or even better than a combustion power truck.

The eTRUCK project collects experiences from 16 ton electric delivery truck technologies and their real-life operation capabilities in northern circumstances in Finland. The eTRUCK has been operating since autumn 2015 in harsh climate conditions from commercial bases at Tampere region.

The eTRUCK has been equipped with present-day monitoring and communication instrumentation enabling to remote follow-up of its operations like: location, operation phase, speed, electric parameters, energy consumption and charging. The data collected will be compared to those produced with computational tools in order to have accurate enough match between measured real-life data and calculations. In future the computational tools will support route and operation planning, charging and driving cycle optimization for electrical delivery trucks in demanding operational and environmental conditions.

The task is to give and ensure more accurate estimations and planning of electric truck operations. Results accumulated from the eTRUCK experiences will be analyzed from energy consumption, emission and economical perspective.

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