Electric Commercial Vehicles ECV / eBus

eBus Executive summary

Summary

A major question which arose at the beginning of the project concerned the feasibility of electric buses. It can already be seen that an answer has been found for this question, and the question has been already redefined to be: when electric city buses are introduced, what form will their implementation take? The project arose from the clear need to ascertain whether electric buses could compete with conventional technologies. Although environmental sanctions were in place, the prospects for economic profitability were unclear. No comparison was yet possible between different types of electric buses; an environment in which research on electric buses could be conducted was required. Since Veolia already had relatively long experience of testing electric buses, the eBus project can be regarded as arising from the mutual desire of the bus operator and research centre to develop such a research environment. With the involvement of Helsinki Regional Transport (HSL) and the City of Espoo, collaboration expanded to include key parties with an interest in the issue. The issue also seemed to interest a large number of the relevant Finnish stake holders and it was easy to find parties interested in co-operation, since the time was ripe for such a venture. With respect to their products, component manufacturers were well placed to become involved. While a research environment was needed in order to study commercial buses, for component development purposes a platform was required as a research environment for generating references.

The current document serves as a description of the events that occurred in the first two years of the eBus sub-project of the ECV ’Electrical Commercial Vehicles’ programme. The project as a whole will last for four years, which have been divided into two halves. It is being implemented in line with the original four-year plan, whereby the research environment and faculty are being developed during the first half of the project. The project's achievements thus far can be divided into three parts; 1. the development of a prototype to function as a testing platform for the components of an electric bus; 2. the creation of a research environment for commercial electric buses and 3. the creation of co-operation links between public and private sector actors whilst offering them information in support of decision-making.

The prototype bus, the "Test Mule", developed under the project enables the testing and development of the components of an electric powertrain within an independent research environment. Such a testing platform for components for this heavy vehicle can serve as a reference for manufacturers of energy-efficient products, without being limited solely to powertrain components. However, maximisation of overall energy efficiency entails the control of all energy flows and it is with respect to this aspect that a key role is being played by the utilisation of waste heat energy and use of high-efficiency auxiliary equipment.

The testing of commercial electric buses consists of long-term testing and studying the distribution of the bus's energy consumption. In long-term testing, vehicles equipped with special instruments are being run on a bus route for a period of three years, during which time data is being continuously collected on the vehicle's year-round operation. In addition to the electric buses, two diesel buses, serving as references for the period, are being subjected to an identical driving regime. Initial measurements are being conducted, during which the distribution of energy consumption between each vehicle's various components is being determined. The driving regime's impact on performance is being ascertained through annual laboratory measurements. In this context, any change in the component efficiency can be discerned. For the bus manufacturer, this provides an opportunity to ascertain the sources of unnecessary energy consumption, thus providing an excellent basis for bus production development. Field testing, on the other hand, provides an opportunity for co-operation through which the manufacturer obtains information on the performance of its bus in an actual operation environment. In this way, the manufacturer receives direct product development support aimed at improving the operational reliability and performance of the bus. This enables the discovery and rectification of teething troubles of a bus in the initial stages of long-term testing, which ensures that the optimum vehicle can be obtained for the test.

During the project, a database is being formed based on the electric buses subjected to measurement. Using this database, the energy efficiency of the average electric city bus can be obtained based on the average value for the measured buses. This reference database will also serve as a benchmark for buses to be measured in the future and for diesel and gas buses already being measured at VTT Technical Research Centre of Finland.

However, while the initiation of co-operation between actors and the information provided to decision-makers has already answered a number of questions, it has also raised some new ones. In order to answer questions relating to the charging of electric buses in particular and to provide information and solutions within the sub-areas in question, new projects have been established under the ECV programme. The eBus project has strong connections to these new projects, making use of their results as well as functioning as their starting point.

Field testing

Commercial electric buses are being run along the route of their actual operation environment for a period of three years. Any potential deterioration in the performance of a bus along the operation is identified in annual monitoring, based on which the buses are subjected to performance measurements in laboratory conditions. Above all, there is a question mark concerning the ageing of the vehicle's battery in the actual operation environment. Finland's winter conditions, in which the temperature of a battery can vary considerably, can deplete a battery more rapidly than estimated. Conditions of this kind require the heating and management of the battery. The Battery Management System (BMS) does, in fact, play a key role in ensuring optimal functioning of the battery in cold as well as hot weather. In addition to the battery cells, the quality of the BMS has a major effect on reliability, but the BMS cannot be tested until an electric bus has been acquired. On the other hand, at least some attempt can be made to estimate the quality of battery cells on the basis of the manufacturer.

Besides electric buses, two diesel buses are being driven along the route, to serve as a reference for the electric buses; for the purposes of comparison, the results are thereby being related to standard diesel vehicles operating in the same operation environment.

Caetano was the first commercial electric bus to arrive for testing.

<u>Commercial buses</u>

In practice, no research information has been established on the general standard of technology in electric city buses, and development has only begun in earnest over the last few years. In fact, the objective of the eBus project is to generate such information on the current standard of commercial buses. For this reason, the search for buses suitable for the project had to be conducted by visiting the manufacturers on site. As the bus operator, Veolia is the body that procures buses under a leasing principle, while VTT provides support with selection. The manufacturers were offered access to the research results on the performance of their buses compared with the average results for other buses, in return for a reduction in the purchasing price of their buses.

Veolia began searching for suitable buses in the autumn of 2011, by identifying and meeting with manufacturers. Finding suitable buses for the three-year field test proved challenging in what was variable and challenging environment. In principle, the aim was to find full electric buses, but plug-in series hybrids capable of at least 50 km on all-electric power were deemed acceptable. However, many of the manufacturers were unable to deliver the vehicle during 2012. Ultimately, there were delivery problems with some manufacturers despite the fact that delivery should have been possible within the given time frame. Despite the existence of several manufacturers of such vehicles, all of their buses are pre-production vehicles, with intensive development still under way or having just begun. Two manufacturers that seemed promising, and with whom discussions had reached the contract stage, went bankrupt and exited the project. Veolia and VTT actively endeavoured to bring vehicle body and powertrain component manufacturers together with a view to testing high-quality buses. In particular, during the initial stage of the project it proved difficult to obtain a bus suitable for cold climates. However, considerable development has taken place among electric bus manufacturers compared to the situation two years ago.

On account of delivery problems, only two buses arrived for the field test. On the other hand two buses have yet to be tested: the Chinese BYD and the Dutch VDL. The first arrival was the Portuguese Caetano, which made its entrance at the end of 2012. This airport bus-based vehicle was still clearly a prototype. The Chinese-Dutch Ebusco, which arrived a year later, was a considerably more refined solution. During the first year, the Caetano experienced a large number of problems, particularly due to its inability to withstand low temperatures. The vehicle was upgraded and repaired by the manufacturer several times. It was dispatched to

Portugal to be refitted last summer. Ultimately, the manufacturer managed to get it working fairly well in time for the following winter. No major problems were encountered with the Ebusco, although it should be borne in mind that the second winter was very mild. Both buses performed well during a week-long period of almost 20 degrees of frost. In early June, owing to various problems and the need for adjustments, the Caetano was once again returned to Portugal. However, by the end of June the project was supplemented by two buses upon the arrival in Finland of the BYD and the VDL, which began operating in the summer.

Caetano and Ebusco (pictured on the left) were joined in field testing by BYD (centre) and VDL (right) in the summer of 2014.

Laboratory measurements of electric buses

A tailored measurement technique was required in order to gather data on the electric buses. Measurements carried out using the chassis dynamometer at VTT's vehicle laboratory enabled the database containing information on the city buses to be expanded with data collected on the electric buses. This unique database can be used to compare the performance of buses with different propulsion systems and to evaluate their energy efficiency. With respect to the electric buses, the database can also be used for reference purposes when comparing commercial electric buses to each other. The method developed for measuring overall energy consumption can be used to perform comparable cycle-specific measurements on any commercial electric bus. Thanks to such comparability, a unique testing environment for electric buses has been created in Finland. With respect to laboratory measurements, this includes determination of the distribution of energy consumption, which is of particular interest to vehicle manufacturers. VTT can thereby provide manufacturers of commercial city buses with data on their vehicles, based on measurements at general and more specific level on the distribution of energy consumption in the customer's bus with respect to different load cycles. For the customer, this provides e.g. a starting point for modifying the vehicle for the desired operating environment.

Testing environment for components – Testing Mule

The starting point for creating a prototype bus lay in the need to test the components of an electric heavy vehicle in an independent testing environment. The components to be tested are not restricted to the components of the electric powertrain, since the aim is to study energy efficiency on a broader basis than this would entail. In an electric vehicle, this means more precise control of auxiliary equipment and energy flows compared to diesel buses. In order to assess these aspects reliably, an actual prototype needs to be tested. The parties involved in planning are at the top of their field, which has enabled the reliable evaluation of various scenarios. A simulation model for the bus was used to provide support in decision-making. In addition to energy efficiency, an electric bus must be able to compete with diesel buses in terms of its reliability; this requires components that last several years in varying conditions. Experience has yet to be accrued on the durability of the components, and the impact of a cold climate in particular still needs to be assessed. Compared to commercial buses, the prototype bus could be equipped with more instruments designed to generate data on the status of the components while the vehicle was travelling along the route. In the future, Test Mule will be increasingly used to study the optimal control of energy flows -– heating and cooling of the passenger compartment play an integral part in this. Maintaining the battery at an optimum temperature is also essential from the perspective of energy efficiency and battery life.

Test Mule being tested with VTT's heavy vehicle dynamometer

Simulations

A simulation model was created of the Test Mule to be constructed for the project, enabling the evaluation of energy consumption and an investigation of the effect on performance of the powertrain components. The simulation model was used to conduct a number of simulations relating to the dimensioning of the Test Mule. With respect to the powertrain components, the performance requirements focused on the electric motor, the inverter and the differential. The requirements for the electric motor, particularly the requirement for torque, were determined by means of various simulated driving cycles. From previous projects Aalto University, which was responsible for the simulations, had experience of the simulation environment to be used. The results of the simulation could therefore be regarded as a reliable source. When the Test Mule was completed, additional certainty was obtained by comparing the simulated results to those resulting from the measurements. In the comparisons, the powertrain energy losses corresponded well with one another. In the future, the simulation model will be updated to include heat management, which is essential to controlling overall energy efficiency. This will enable the identification of optimal solutions for scenarios in various operating environments.

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Driving style study

The purpose of the driving style study is to ascertain how driving style affects electric bus energy consumption and to compare the driving style identified as optimal for low consumption with the diesel buses used as a point of reference. To identify the optimal driving style, the mileages involving the lowest possible consumption are sought and their speed profiles are then analysed. When the optimum driving style has been found for a particular route, a recommended speed can be communicated to the driver through a driver advisory system. The basis of the study is the driver advisory device developed for use on diesel buses by VTT. This device is a real-time driver advisory system for bus drivers. The goal and the objective of the study is to clarify an energy saving, high quality driving style that keeps the bus on time. The driver advisory system monitors the vehicle's movements and locations, comparing the data to the timetable and collecting data on the journey. During the project, functionality enabling the partial comparison of driving events was added to the software, allowing the analysis to focus on optimally driven stretches between bus stops or, according to need, on even shorter stretches in order to identify the optimum overall speed profiles. The result of the analysis can be generalised later for adaptation to other routes, by categorising the partial speed profiles related to each driving-stretch. Since the driving style study is based on data gathered over a long period of time, the actual analyses will be obtained during the second half of the project.

Attitudes of drivers and passengers towards electric buses

The aim is to ascertain the views and expectations of drivers as well as passengers regarding electric buses – and any changes in these while the electric bus is in use. In addition, it will be determined whether interaction between passengers and the electric bus, when in traffic, deviates from that which occurs in the case of a diesel bus. The quietness of electric buses is regarded as the basis for assuming such a change in interaction. This will be done on the basis of driver and passenger interviews, as well as by observing passenger behaviour and any conflicts and dangerous situations during travel. On a more general level, driver interviews will be used to assess drivers' experiences and changes in views as experience of using an electric bus accumulates. The passenger interviews will focus on actual experiences, possible advance expectations and any changes therein.

Visibility and impact

The project received a great deal of media attention from the very beginning. Within Veolia's parent company, Transdev, the eBus project was rated highly during the company's in-house innovation competition. The eBus project's high profile has prompted discussion of electric buses in general. Bodies responsible for public transport in a number of countries have shown interest in the project since, for decision-making purposes, they need precisely the same information as that provided by the eBus project. In Germany, the eBus test platform is considered unique, as it is the only example of electric bus testing in the world to include the buses of five manufacturers. Through the concrete steps it has taken, the project has accelerated the advent of electric buses both in Finland and abroad. Bus manufacturers around the world have been greatly interested in the eBus project. The bus manufacturers that joined the project are seeking information from Finland on how to manage in cold and snowy conditions. They wished to participate in the project in order to obtain research information on their own products, but were also interested in obtaining visibility and references. All of the parties involved have indeed gained visibility in multiple forums. An important role in the eBus project is played by the co-operation arising between the parties. New projects have been launched as a result of such co-operation. Alongside the expansion of the ECV project, the issues that emerged during the eBus project have provided a springboard for the eCharge and eBusSystem projects just under way. At the very outset of the project, it was noted that issues relating to the charging infrastructure and charging in other respects were so extensive and crucial that the eBus project could not address them alone.

Conclusions

The main objective of the eBus project is to assess the potential and feasibility of electric buses in Finland. An answer has clearly been identified to this question, with every indication that electric city buses can operate successfully in Finland. An energy efficient and environmentally friendly electric bus would also appear to be an economically competitive option. A major question at the beginning of the eBus project was whether the realisation of electric city buses was even possible. With the expansion of the ECV, the eCharge and eBusSystem projects now beginning are looking into the introduction of electric buses. These projects have been inspired by the questions that arose during the eBus project relating to the charging system and the infrastructure and operating practices supporting electric bus traffic. On the other hand, the eBus has provided the knowledge which enabled the emergence of these projects.

A concrete achievement of the project is the Test Mule, whose commercial potential is being developed in a separate spin off project. In this context, the company, Linkker, is striving to create a prototype of an electric bus based on the Test Mule. Use of the Test Mule as research environment is continuing, enabling its use as a research tool in commercial assignments as well as for VTT's own research purposes. Use of the Test Mule as a research platform for components is one of the unique services offered by VTT. Another, perhaps even more unique service is the testing environment for electric buses, in which bus manufacturers can be provided with the same testing environment as that used for the commercial buses tested during the eBus project. In addition to testing, the manufacturer can view the performance of its bus in relation to general performance levels, which comprises the average performance of the buses measured by VTT. For the manufacturer, this provides evidence of the bus's energy efficiency. On the basis of distribution of energy consumption, sources of energy losses can be identified and further measures can be planned for rectifying the situation. The bus's simulation model can be used to calculate the savings potential enabled by any changes, and to compare different solutions. Data based on the measurements, simulations and calculations can be used to provide bus operators, cities and municipalities or public decision-makers in general with support in decision-making. Thanks to the eBus project, VTT's comprehensive reference database on buses with different propulsion systems has now been supplemented with data on electric buses, and thereby provides a basis for comparative evaluations. As the bus's powertrain is similar to that of other heavy vehicles, component test results obtained using the Test Mule can be used both in working machinery and in trucks. The powertrain simulation and measuring tools developed can be used effectively in their current condition. Know-how accumulated during the design and construction of the Test Mule is also widely applicable. Thanks to parameterized models, these simulation models can also be applied to passenger cars.