

***Low weight electric bus with multiple energy supply-
The project on hybrid buses reduces emissions, exhaust as well as noise
from the public transport vehicles***

Uppsalabuss AB, Sweden

Summary

The project aimed at showing a city bus design for the beginning of this century including an environmentally friendly technique. The aim must be expressed as follows: “public transport without noticeable negative impact on the environment”. The project gives an opportunity to develop environmentally friendly prototype buses together with a bus manufacturer. Buses that further on may come into serial production. In the project a new type of bus with the following properties is demonstrated:

- ❑ Average energy savings and reduction of CO₂-emission of 30 % compared to present day city buses;
- ❑ Zero emission operation in limited restriction areas;
- ❑ Average reduction of the pollution to approximately half compared to conventional buses; comfortable, quiet low floor buses;
- ❑ Economically attractive as a series product.

End-user area	Target Audience	Technical
<input type="checkbox"/> New buildings	<input type="checkbox"/> Citizens	<input type="checkbox"/> Energy efficiency
<input type="checkbox"/> Refurbishment of buildings	<input type="checkbox"/> Households	<input type="checkbox"/> Heating
<input checked="" type="checkbox"/> Transport and mobility	<input type="checkbox"/> Property owners	<input type="checkbox"/> Cooling
<input type="checkbox"/> Financial instruments	<input type="checkbox"/> Schools and universities	<input type="checkbox"/> Appliances
<input type="checkbox"/> Industry	<input type="checkbox"/> Decision makers	<input type="checkbox"/> Lighting
<input type="checkbox"/> Legal initiatives (municipal regulations, directives, etc)	<input checked="" type="checkbox"/> Local and regional authorities	<input type="checkbox"/> CHP
<input type="checkbox"/> Planning issues	<input checked="" type="checkbox"/> Transport companies	<input type="checkbox"/> District Heating
<input type="checkbox"/> Sustainable communities	<input type="checkbox"/> Utilities	<input type="checkbox"/> Solar energy
<input type="checkbox"/> User behaviour	<input type="checkbox"/> ESCOs	<input type="checkbox"/> Biomass
<input type="checkbox"/> Education	<input type="checkbox"/> Architects and engineers	<input type="checkbox"/> Wind
<input type="checkbox"/> Other	<input type="checkbox"/> Financial institutions	<input type="checkbox"/> Geothermal
	<input type="checkbox"/> Other	<input type="checkbox"/> Hydro power
		<input type="checkbox"/> Other

Context

Uppsala is situated just north of Stockholm and has a population of about 190,000 (Sweden’s fourth largest city). Malmö is Sweden’s third largest city and the commercial center of southern Sweden, with a population of 255,000 inhabitants. The Province of Bolzano is situated in Northern Italy in the heart of the Alps bordering to Austria in the north and Switzerland in the west. It covers an area of 7,400 km² and it is divided into 116 municipalities. It has a population amounting to approximately 457,000.

Objectives

The project aimed to show a city bus design for the beginning of this century including an environmentally friendly technique. In the project a new type of bus with the following properties was to be demonstrated, with the aim to achieve:

- Average energy savings and reduction of CO₂-emission of 30 % compared to present-day city buses;
- Zero emission operation in restriction areas;
- Average reduction of the pollution to approximately a half compared to conventional buses;
- Comfortable, quiet low floor buses;
- Economically attractive in serial production.

Process

The demonstration project was performed in the cities of Uppsala, Malmö and Bolzano.

The LOW FLOOR BUS, Neoplan Metroliner MIC 8012 GE for Urban Service without steps at entry and exit doors were used in the project. The bus was a monocoque cell completely manufactured from glass and carbon fibers. At the end of 1998 five vehicles were completed for the project. To make the vehicles light and corrosion free, the bodies were made of glass-and carbon fiber composite material. The result is a body 30% lighter than that of a normal bus.

The basic elements of the Magnet-Motor (MM) drive systems were the MM electric motors mounted directly on individual wheels, thus constituting a compact rear wheel drive unit.

The braking energy, normally converted to heat, was efficiently used for generating electric energy. During the braking phase, the motors run as generators and feed energy into the batteries (Varta NiMH). The braking energy charges the batteries. When the vehicle accelerates the batteries feed the stored energy back into the drive motors. To obtain synergy effects the power of the batteries and the MM generator work together during this phase.

The specification for the Swedish and the Italian buses became relatively different. The bus for Bolzano remained equipped with a diesel engine. An absolute condition for Skånetrafiken and Uppsalabuss for participating in the project was that special environmental considerations had to be accounted. This ended in four of the buses being equipped with biogas-powered engines.

The storage tanks, lightweight aluminum/glass fiber/carbon fiber composite tanks, were made by Raufoss Composite AS, Norway. The three tanks each had a volume of 203 liters and a working pressure of 200 bars.

The buses produced in the project were of the second-generation prototypes. Further on it will be necessary to produce a 0-series before going into commercial production.

The partnership was chosen due to the fact that different experiences were needed to carry out the project. The lessons learned about the partnership were that it is crucial for the different staffs to work together and to make it possible to enhance the networking.

The problems that had to be solved during the project were items concerning the responsibility from the different technologies. New innovative technologies were mixed with old and time was spent to clarify borderlines for the differences, as well as who was to be responsible for the total product. This also resulted discussions between the constructors and the producers.

The new technology demanded a design specification in two parts. One considering conventional bus components and one with all the new parts.

Financial resources and partners

The project was supported by the Thermie programme, funded under the 5th FP.

The project was coordinated by AB Uppsalabuss in Sweden, other contractors were Gottlob Auwärter GmbH in Germany, Skånetrafiken in Sweden and SAD- Transporto Locale s.p.a. in Italy.

Results

The intention was from the beginning that two experimental hybrid buses should be able to replace one standard bus. In Malmö only one hybrid bus was available. In Uppsala both hybrid buses were in normal operation, but with accessibility less than 50 %. The expectation that a hybrid bus could have an accessibility of 50 % was initially not fulfilled. All buses had several system faults and even “normal” mechanical faults in the conventional bus components. At this initial stage the accessibility was below 20 %. During the later part of the “monitoring phase” the accessibility has been increased considerably for the buses, both in Malmö and in Uppsala, and today it exceeds the stipulated 50 % level.

All innovative parts performed well in their mechanical parts, such as electric wheel motors, engine-generator and drive battery. The electronic management systems, however, had to be regarded as prototypes and functioned accordingly.

The Thermie Project cleared the way for technical and commercial knowledge about the electric drive. Since the electric drive is a basis for future development of emission free energy efficient vehicles, the project was both a test and an important milestone in the development of public transport vehicles.

From the first test results it was shown that the emissions were unusually high. This was, however, not representative for gas engines generally but should be seen as a result of an incorrectly tuned engine. Despite the lack of catalyst and incorrectly tuned engine, the emission figures were not higher than what is normal for a diesel engine. Furthermore, the engine was not completely adjusted to electric hybrid propulsion. The conclusion was that a correctly adjusted engine, optimized for a complete and total electric hybrid system gave considerably better results.

At hybrid mode with combined battery- and combustion engine drive it is possible to reach large decrease in the emissions from the engine. Measurements have shown:

- CO₂-emissions can be reduced with ca 30%,
- CO-emissions can be reduced with ca 60%,
- NO_x-emissions can be reduced with ca 50%.

During two weekdays in March 2000, 119 passenger questionnaires were distributed and collected on board the Electric Hybrid buses. 80% of the respondents were frequent passengers, i.e. travel at least once a week or more. The overall impression can be summarized as follows: two thirds of the respondents graded the bus as good or very good. Most positive were the young and the +60 groups

where 80% in both groups said the bus was good or very good. None of the respondents graded the bus as very bad. Only 2% totally thought the bus was bad.

Lessons learned and repeatability

Since most systems do include microprocessors it should be possible to use computer based software systems as a complement or alternative to traditional paper manuals. Nevertheless the training of the service staff is crucial.

Maintenance matter should be part of the offer procedures, i.e. when vehicle specifications are formulated.

If the matter of emissions is to be properly esteemed by the public, the use and operation of the engine should be combined with information inside the vehicle.

In addition, in order to optimise the economy the investment must include operating as well as maintenance costs for the whole vehicle life span.

The problem attached to electrically powered vehicles was due to the energy pack which had to accompany the vehicle in order to reach a reasonable distance covered. The alternatives at hand are mainly of an electrochemical storage type, (the battery), of an electro-magnetic kind (the fly wheel) and of an electro-statically stored energy kind (the supercondensator). No bus equipped with this type of energy supply will ever come close to the energy content a pure diesel bus can carry. One way of solving the energy-storing problem of an electrically powered vehicle was to place a combustion powered generator onboard the vehicle to assist the electrochemical energy storages. From a mileage-point-of-view such a vehicle has the same advantage as the high-energy fuel combustion engine powered vehicle.

Bottlenecks were:

- Borderlines for areas of responsibility
- Involvement of the different partner's staffs
- Documentation and specification of technologies
- Keeping project management within the expected budgets

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