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An overview of the development of lead/acid traction batteries for electric vehicles in India

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Abstract

Electric vehicles (EVs) made an entry into the Indian scene quite recently in the area of passenger transportation, milk floats and other similar applications. The industrial EV market, with various models of fork-lift trucks and platform trucks already in wide use all over India, is a better understood application of EV batteries. The lead/acid traction batteries available in India are not of high-energy density. The best available indigenous lead/acid traction battery has an energy density (*C*/5 rate) of 30 W h kg^{-1} as against 39 W h kg^{-1} available abroad. This paper reviews the developmental efforts relating to lead/acid traction batteries for electric vehicle applications in India, such as prototype road vehicles, commercial vehicles, rail cars, and locomotives. Due to the need for environmental protection and recognition of exhaustible, finite supplies of petroleum fuel, the Indian government is presently taking active interest in EV projects.

Introduction

The most successful battery system that has been widely used for electric traction is the well-known workhorse – the lead/acid battery. This system has a wide range of applications and has been developed in different designs by manufacturers. Improvements to the lead/acid battery are being sought in energy density, service life, rechargeability, manufacturing process, and cost. The industrial electric-vehicle (EV) market, with various models of fork-lift trucks and platform trucks already in wide use all over India, is a better understood application of EV batteries.

As the main power source, the battery is the single most important component of an EV. The performance of the vehicle depends mainly on the performance, efficiency and reliable operation of the battery. At present, almost all commercial battery-powered vehicles use lead/acid batteries. These batteries are quite heavy and have inherent constraints that affect their popularity as well as the large-scale introduction of EVs. The batteries available in India do not have a high-energy density. The best available indigenous lead/acid battery has an energy density (*C*/5 rate) of 30 W h kg^{-1} as against 39 W h kg^{-1} available abroad.

An overview of the development of lead/acid traction batteries for EVs in India is presented in this paper.

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Motive-power batteries for materials' handling equipment

Different types of industrial vehicles are used in various factories for several applications in India. The simplest is the platform truck that can work with, or without, pallets for transferring semi-finished products; these transfers are mainly on ground level. Depending on the special requirements of a particular operation in specific industries, the following are some of the varieties of materials' handling equipment:

- electric truck for use in steel plant soaking pit;
- electric truck for frame and channel handling and mounting stud planter and stud puller in aluminium industries;
- fork-lift truck for bale handling;
- electric truck for batch trolleys in textile industries;
- electric truck for die handling and for use as an order picker;
- electric truck for inter-bay movements;
- electric locomotive for mines;
- electric tow truck for handling passenger luggage at airports;
- electric vehicle for passenger movement at airports.

The general requirements of battery packs in India are 48, 96 or 120 V with capacity ranging from 100 to 1200 A h or more ($C/10$ rate) as demanded by the duty application. The voltage ranges are not restricted to these values only. It is difficult to assess the total requirement of motive-power batteries for materials' handling and other localized applications. There were more than 60% battery-operated trucks in the total range during the year 1984. The need for vehicles for materials' handling has since then registered a growth rate of 7% per annum.

Developmental efforts for battery-powered road vehicles in India

The first attempt in India at the development of EVs started in 1973 in the Vehicles Research & Development Establishment (VRDE), Ahmednagar, when the Department of Science & Technology sponsored a project for the development of battery-powered road vehicles. Design of the total system, development of vehicle chassis, transmission, body and cab, as well as the overall coordination of the complete project, were vested with VRDE. Bharat Heavy Electricals Ltd. (BHEL), Bhopal, was responsible for the development of the power controller for the electric drive system; Central Electrochemical Research Institute (CECRI), Karaikudi, for the development of high-energy density lead/acid batteries; and Research, Designs & Standards Organization (RDSO), Lucknow, for the selection of the traction motor. The project team developed three prototypes of half-ton battery powered pick-up vans, i.e., BPV-I, BPV-II and BPV-III. The technical specifications of these vehicles are given in Table 1.

Commercial EV development in India

About 95% of city transportation in India covers a distance of less than 60 km with a speed of less than 50 km h^{-1}—a range and speed within the capacity of electric vehicles. Realizing this, the government decided, in 1982, to support commercial EV development in India. One firm in the private sector (M/s Chatelec Vehicles India Ltd.) was sanctioned a project to produce 12 000 EVs per annum with British

TABLE 1

Specifications of battery-powered pick-up vans

Parameter	BPV-1	BPV-II	BPV-III
Battery			
Type	Pb/acid	Pb/acid	Pb/acid
Make	Chloride (I)	CECRI	CECRI
Voltage	8×12 V, 235 A h batteries in series	32×12 V, 60 A h batteries connected in series-parallel	2×48 V batteries in series
Capacity (A h)	235	240	300
Weight (kg)	860	750	1037
Energy density (W h kg^{-1})	26.2	30.72	28.8
Motor			
Type	d.c. series	d.c. series	d.c. separately excited
Max. rated power (kW at 2000 rpm)	10.73	18.6	18.6
rpm (max.)	4660	5000	5000
Controller	thyristor chopper	thyristor chopper	transistorized chopper
Vehicle			
GVW (kg)	2300	2450	2730
Pay Load (kg)	230	500	500
Motor (kg)	80	170	190
Controller (kg)	80	80	30
Vehicle weight (kg)	1050	950	973
Performance			
Av. range per charge (km)	47	45	60
Maximum speed (km h^{-1})	60	60	60
Acceleration, 0–30 km h^{-1} (s)	15	14	15

collaboration. The range of industrial EVs included tow tractors, platform trucks and station wagons. The company has proposed to manufacture passenger buses also.

In the Public Sector, BHEL was assigned, around the same time, the task of developing 1-ton payload EVs with a targetted production of 5000 vehicles/annum after prototype testing and commercialization. At present, some 150 EVs (mini-vans) developed by BHEL are operating in Dehli, Hyderabad and Bhopal. The battery characteristics for each vehicle are: lead/acid storage battery pack 96 V, 300 A h; in the form of 16 modules of 6 V each or 48 cells of 2 V each. The projected battery requirement for the targetted production and operation (of 5000 vehicles) will be 500 000 cells. The commercial running of battery buses during the last five or six years has revealed that the system can function in an economically viable pattern provided that some innovations are made to the traction batteries.

Electric road vehicle battery development

BHEL pioneered the development of electric vehicles in India. Due to the non-availability of advanced high-energy density batteries in India, BHEL adopted existing traction lead/acid batteries for use in electric vehicles. The batteries used in the first few vehicles had 6 V iron-clad traction battery units whose energy density was 25 W h kg^{-1}. BHEL took up, with the country's leading battery manufacturers, the development of 12 V tubular positive-plate lead/acid traction battery units with fibre reinforced plastic casing. This development was completed in 1984 by the three major manufacturers, namely Chloride, Amco and Standard.

In the next stage, BHEL modified the design of battery bank to incorporate 6 V monoblocks. These were again developed by the manufacturers and gave an energy density of 27 W h kg^{-1} (*C*/5 rate). UB-MEC Batteries Ltd., Bangalore, also developed such a battery in 1986 and supplied a few to BHEL for trials. Details of these blocks are given in Table 2.

The majority of the traction-cell packaging in India has been traditionally in hard rubber containers and covers. The gain in specific energy by changing the material to polypropylene would be close to 10%. Further improvement of energy density to the value of 30 W h kg^{-1} was achieved by implementation of the following measures:

- plastic/PVC cell containers in the initial stages, followed by polypropylene containers;
- optimized design of cell connectors;
- improved design of 6 V monobloc FRP.

The introduction of FRP casings in place of MS encasings—which are used for normal traction batteries—and LDPE rotomoulded containers in place of hard-rubber containers has resulted in a 7% reduction in weight. Details of these batteries are given in Table 3.

TABLE 2

Characteristics of batteries used in BHEL's mini-transport bus

Capacity at *C*/5 rate (A h)	300
Dimensions (mm) of 6 V unit	length 505–443
	width 175–166
	weight 395–367
Weight of 6 V filled unit (kg)	66–69
Energy density (W h kg^{-1})	26–27
Cycle life to 80% DOD	1000

TABLE 3

Characteristics of improved batteries for BHEL mini-transport bus

Capacity at *C*/5 rate (A h)	300
Dimensions (mm) of 6 V filled unit	length 445–437
	width 180–166
	weight 385–367
Weight of 6 V filled unit (kg)	60
Energy density (W h kg^{-1})	30
Cycle life	1000

BHEL and the Department of Non-Conventional Energy Sources (DNES), together with four major lead/acid traction battery manufacturers initiated efforts for the development of high energy-density batteries. A further improvement in energy density to 35 W h kg^{-1} ($C/5$ rate) has been planned and lead/acid traction batteries with this energy density are expected to be available in about 3 years.

Battery-driven rail cars

There is one area of application in railways where battery power would be economically attractive. Battery-powered rail cars are ideal for short-range multi-stop and/or inaccessible location rail routes, where the cost of installing power lines may be uneconomical in comparison with the cost of batteries. The lead/acid battery, which has long performed well on the rails, would be the ideal choice for battery-powered rail cars.

Battery-powered locomotives

The Indian Railways has been working on the development of battery-powered locomotives for shunting and other relatively less demanding services. The battery is made in FRP-covered steel trays since the locomotive is designed to run on tracks. Here again, BHEL have developed locomotives for goods train (narrow gauge) to be eventually used by the Indian Railways, or perhaps in mining applications. The battery for locomotive applications was developed during 1986–1987. The 25-t engine is rated to pull a load of 110 t at a maximum speed of 35 km h^{-1}. The technical features of the battery are given in Table 4.

In 1989, battery-powered locomotives were also produced for the Metro Railway in Calcutta. Three such locomotives were manufactured by the Integral Coach Factory. The locomotives utilize electric and brake equipment supplied by BHEL and are essentially required for work-cum-maintenance inside the tunnels. The total weight of the locomotive, including battery and 16 passengers, is 64 t with a battery weight alone of 17.2 t. The lead/acid battery capacity is 1200 A h at a voltage of 384 V. Each locomotive is equipped with 4 motors connected in series with a motor terminal voltage of 96 V. The battery had an energy density of 26.8 W h kg^{-1}. The speed control is conventional with resistance notching and a cam shaft controller. The

TABLE 4

Technical parameters of batteries for locomotives

Battery voltage (V)	224 (nominal)
Battery capacity at $C/1$ rate (A h)	2050 (30 °C)
Energy density (W h kg^{-1})	29
Cells/voltage per unit	28/56
Units per battery	8 (series-parallel)
Weight of each unit without electrolyte (kg)	1530
Weight of electrolyte per unit (kg)	437
Total weight of 8 units (tons)	15.735 (with electrolyte)

locomotive is capable of starting and hauling a trailing load of 107 t at a speed of about 15 km h^{-1}.

Conclusions

Electric vehicles have made an entry into the Indian scene quite recently in the area of passenger transportation, milk floats and other similar applications. Hitherto, the battery industry was mainly catering to the materials' handling market, primarily for applications such as platform trucks and fork-lift trucks. EVs do have a potential for deployment as postal pick-ups, milk delivery vans, paper delivery vans, school pick-ups, etc. Nevertheless, their use as off-highway vehicles is doubtful.

Battery vehicles have a bright future due to efforts to protect the environment and to extend the exhaustible and finite supply petroleum fuel. Efforts are needed, however, to improve existing batteries and to develop new types with good matching to battery chargers. In particular, traction lead/acid batteries should preferably be of the maintenance-free type.

With the Indian government taking active interest in EV projects, a promising period is forecast for battery-powered vehicles.

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