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Development of a next generation Electric Car for World markets

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ABSTRACT

There are over 3000 ‘Reva’ Battery electric cars in over 20 different countries. This has given Reva Electric Car Company (REVA) a unique understanding of the customer requirements in various geographies.

The experience of running these cars has also given REVA an insight into the performance parameters required of an electric city car in different geographies and climates.

This paper describes the development of the next generation electric city car for the world market based on these insights combined with a systematic assimilation of market and in house knowledge base.

The development effort involved formation of an in house knowledge management system to capture the essence of the company’s experience in sourcing, manufacturing and field operation. Feedback was collected from present users of EVs. The new car design incorporates learning’s from these as also inputs from technological advances in several related areas.

While the first generation Reva car is a 2 door hatchback with 80 km range primarily designed for gentle city use, the new generation car marks the transition into larger, higher performance vehicle that can operate in a mixed city-highway environment.

The exercise has also resulted in several other areas like higher life expectancy, better all weather performance, fast recharge capabilities, improved aesthetics and improved user guidance and information systems.

Keywords:

Reva, Electric Car, Knowledge management, Lithium ion, fast charge, iEMS™, Data collection

1. Introduction:

Reva Electric Car Company (REVA) has pioneered development of Battery electric Cars in India. REVA has also successfully introduced these cars in several markets in Asia and Europe.

Following are the basic characteristics of the 'current' model of Reva being sold in the markets

- 2 door hatchback; 2 + 2 (children) seating
- Driving range 80 kms based on lead acid batteries, upgradeable to Lithium Ion Batteries
- Top speed – 80 kmph
- Registered as 'quadricycle' in Europe

Over 3000 of these cars are running in several countries resulting in an 'on the road' experience of over 60 million kilometers. This has resulted in the generation of a knowledge base on

- In house experience of manufacturing 2 generations of EVs
- Experiences at supply chain partners
- Usage conditions in different territories (EU, Asia and South America)
- Performance of drive systems/ batteries in different climate conditions. (Norway to Delhi)
- Specific user preferences and technical feedback from servicing

RECC has developed a new generation electric car putting to use this knowledge generated from the experiences.

The broad process of this development can be depicted by figure 1

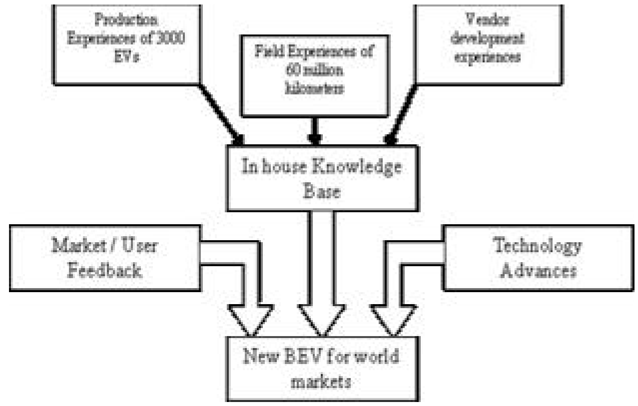

Fig1: Broad process of development

2. Knowledge Management

2.1 Knowledge base consolidation

An extensive in–house knowledge management program was launched to gather and process all the knowledge gained from experience. The knowledge management exercise, focused on total involvement of the entire work force from different disciplines inside the company as also partners such as part vendors and service partners.

The knowledge management exercise consisted of five initiatives:

i. Collation of existing databases
   a. From incoming parts quality libraries
   b. From production quality database
   c. Customer quality feedback

ii. Collection of voices
   a. Voices from production line operators and technicians
   b. Voices from testing and engineering personnel
   c. Voices from field personnel – sales and service.
   d. Voices from supply chain partners

iii. Commissioned studies
   a. Time and motion studies on production and assembly.
   b. Time and motion studies in service

iv. Brainstorming sessions

a. With key manufacturing personnel

b. With key service personnel

c. With key engineering personnel.

The processes i to iv can be depicted by the diagram Fig 2.

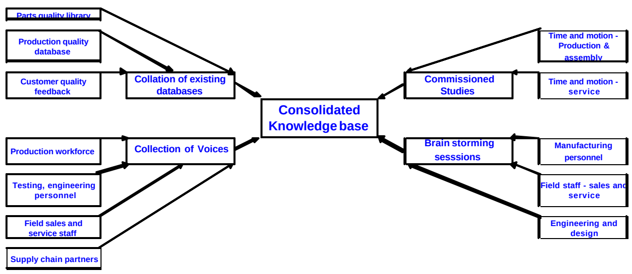

Fig 2: Formation of consolidated knowledge base.

Brain storming and feasibility evaluations of the knowledge base were undertaken to arrive at actions required in various areas like component requirements, product specifications, process definitions and communication package design.

The actions can be summarized by the following picture.

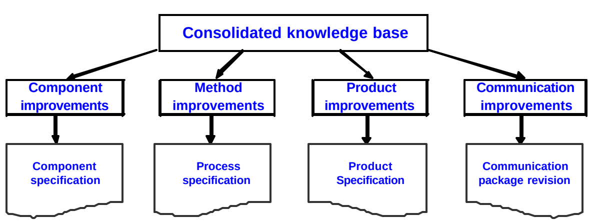

Fig 3: Action points from knowledge base.

2.2 Car data analysis and consolidation

The present Reva car has an on board computer system (EMS) which maintains a historical record of charge and drive cycles.

Databases at the Reva technical center maintain a full record of this 'historical data of each car on the road.

A typical record of the data is as shown in picture Fig 4

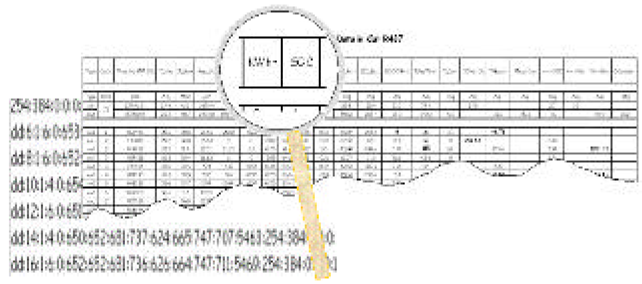

Fig 4: Typical data format

In addition to the above, an exercise was undertaken to map usage patterns and life time behavior patterns of the BEV under different conditions.

Fig 4 shows a typical format of data stored in the on board system.

The data is analysed to arrive at information on

- Car performance patterns in different climates and usage conditions
- Usage patterns in different geographies
- Subsystem behavior patterns in different climatic conditions
- Lifetime behavior patterns of batteries and other subsystems.

This analysis is used to determine drive power requirements and battery requirements under different conditions.

3. Market / User Feedback:

A systematic methodology was adapted to collect feedback from users of EVs on the features required for the next generation of BEVs.

The feedback collection process involved

- Informal chats with users
- Focus groups
- Open house sessions with marketers and users
- Collation of opinions expressed in discussion forums.
- Conjoint analysis carried out on specific target audiences

The result of these analyses were used to generate a wish list specification document that reflected market expectations.

Some of the important requirements that emerged from this exercise are:

- Need for more passenger space
- Freeway capability – higher power and speed
- Greater availability – fast charge requirement
- Consistent all weather performance
- Directions on aesthetics
- Friendly user interfaces

4. Technology advances

A number of limitations of early EVs can be attributed to the limitations of technologies available at those times.

A lot of research on EVs today is focused on overcoming these weaknesses.

Reva has been continuously involved in keeping abreast with these developments and actively pursuing joint technology development programs in all areas.

Some of the technology areas addressed in the current development are as follows:

Battery Technology

Reva has continuously been evaluating Battery technologies by means of simulated bench tests and actual on car tests. Some of the Batteries that have been evaluated include

- Variants of lead acid batteries – flooded, AGM, Gel, and advanced grid constructions
- Nickel Metal Hydride
- Sodium Nickel Chloride
- Nickel Zinc
- Lithium Ion

With increasing activity all over the world on Lithium Ion Batteries, Reva has maintained a special focus on Lithium Batteries for the obvious reasons of higher energy density. The knowledge management exercise also pointed to a need to increase the driving range of the vehicle. Lithium Ion chemistries offer the best possibility of offering a choice of driving ranges without increasing the size and weight significantly.

Several alternate Lithium chemistry options and constructions have been evaluated.

After initial evaluation of several battery types, a detailed evaluation program was launched to gather actual field experience with 2 different chemistries and constructions of Lithium Batteries.

12 cars and 6 test benches have been put together to carry out 24 hour running of batteries and gather complete data.

Put together, an equivalent of a cumulative running of 800,000 km of on road testing has been completed

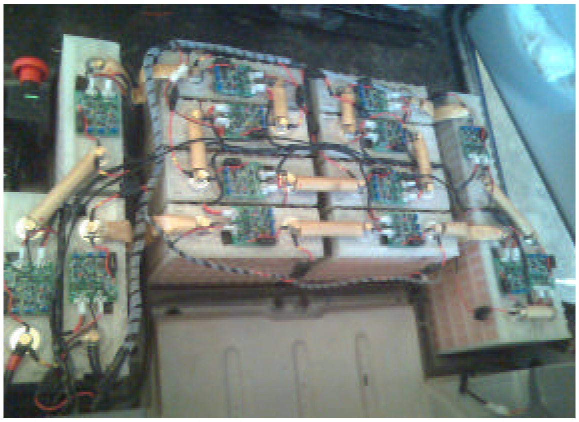

Fig 5. Lithium Battery pack with local monitoring

The Lithium Battery evaluation program has given a complete insight into the working of different chemistries under

- Different duty cycles
- Different modes of charging and drive
- Different environmental conditions

The exercise has also given unique insights into variations of battery characteristics with ageing.

These learning's are translated into specific requirements for battery management system.

One of the significant issues to be addressed in Lithium chemistries relates to safety.

Reva has worked closely battery manufacturers to evolve safe chemistries and constructions of the cells.

In addition to the construction, a series of protections have been built into the system.

Detailed failure mode analysis have been carried out, possible modes identified, experimental validations conducted and countermeasures instituted.

Fig 6 shows a glimpse of the review of possible failure modes and back protection mechanisms.

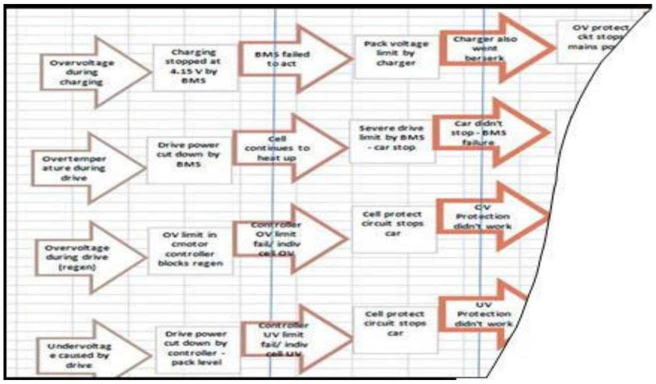

Fig 6: A glimpse of failure/ protection mechanisms

The protection mechanisms consist of multiple stages of back up devices at cell, module and pack levels.

The assemblies have also been subjected to abuse tests like overcharge, over temperature, nail penetration and possible failure of front end protection mechanisms.

This has resulted in the evolution of a completely safe and reliable battery system.

Advanced *Intelligent Energy Management System* - iEMS™

One of the most important technology components of the new generation vehicle is its advanced energy management system.

This is an on board computer incorporating all functions of battery management, diagnostics, user information generation and body electronics management functions.

The salient function of the iEMS include:

i. Battery Management
   a. Multiple chemistry capability
   b. Charge profile management
   c. Equalisation / cell balancing
   d. Parameter limit monitoring and protection
   e. SOC, SOH calculation
   f. Thermal management
   g. Lifetime information records
   h. Fast charge management
   i. Idle mode management

ii. Diagnostics
   a. Fault detection
   b. Generation and logging of error codes
   c. System enable/ disable functions
   d. Drive system fault monitoring

iii. User information generation
   a. Dashboard indicators
   b. Fuel gauge
   c. Messaging
   d. User guidance (efficiency, distance to empty, time to charge)

iv. Body electronics management
   a. Climate control
   b. Immobiliser functions

Each of these areas consists of a large body of work involving algorithms developed with help of inputs from the knowledge management exercise.

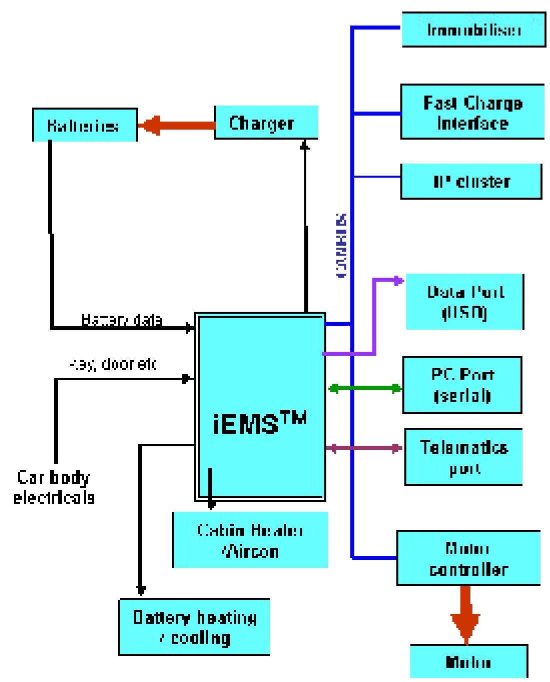

Fig 7. The iEMS

Fig 6 gives a view of the architecture of the iEMS with all the interacting systems.

As can be seen, the iEMS continuously monitors and manages energy flows across subsystems in the car.

The iEMS is also designed for easy upgradeability as most functions are parameterized and built into the software.

The iEMS represents a landmark improvement in the architecture of the energy management for BEVs

Fast Charging

All inputs from customer surveys and knowledge management pointed to a need for increasing the 'availability' of the electric car.

The availability of the car translates to increasing in driving range and ability to cut short the charging time.

A fast charge port has been included in the car to facilitate charging the batteries in on hour.

While the normal charge is carried out using an on board charger, a special off board fast charge station has been designed to facilitate fast charging.

The fast charge station operates from a 3 phase power supply and is designed to deliver 1C charge to the batteries.

Some of the salient features of the Reva fast charge station are

Communication with car over CAN bus

- Charge administration under control of on board iEMS™
- User choice of charge options

The fast charge station is designed for upgradeability for networked operation.

One of the important design philosophies of the fast charge station centers on having the iEMS as the central intelligence. The iEMS controls the charge profile, monitors the energy flow and moderates the same based on the state of the batteries.

This makes sure that all the protection mechanisms are in place and fast charge events are logged into the iEMS database

Data collection and analysis mechanism

The car generates continuous data as it is being used and also logs a lot of data.

A summary information of the happenings is recorded in the on board memory every time the car goes through a charge or a drive cycle.

This data base represents a historical record of the car's usage pattern and behavior of subsystems.

In addition, the iEMS also generates continuous data by measurement and calculation of parameters.

Communication ports on the car provide access to all this data.

A USB port allows use of a standard 'flash' drive to collect all the data at any time.

The summary data is collected periodically and appended to a database at the technical center for further analysis.

The new car design also incorporates a remote data access mechanism by use of GSM / GPRS link. Periodic data collections are scheduled by a central server. In the event of any specific investigation into a particular car, the remote access mechanism can trigger collection of continuous data.

An analysis software has also been developed to convert the 'data' into 'intelligence' and generate meaningful information. The analysis software can be used by front end field engineers as well as factory personnel.

The information so collected would serve as the database for the next knowledge management cycle.

5. Product Upgrade-Reva *Lion*

Prior to launching several of these technologies in a completely new model, REVA has made some of these technologies available in a new variant-the Reva *Lion* that has been recently launched. In addition, its current platform Reva*i*, is upgradeable to accept Li-Ion batteries.

The Reva *Lion* uses a highly safe Li-Ion phosphate battery chemistry. With a total energy of 10 Kwhr, The Reva *Lion* extends the current Reva's range from 80 km to 120 km and also reduces the battery weight by 50%. The vehicle has the newer iEMS and a fully integrated battery heating and ventilation system allowing improved cold weather performance.

The internal charging profiles have been optimized resulting in a reduction of charge time from 8 hrs (for the Reva*i*) to 6 hrs for the Reva *Lion*. It is also equipped with an optional fast charging port that allows the vehicle to be charged to 90% in less than 1 hr.

The Reva Lion is also equipped with a sophisticated GSM/GPRS telematics unit that can be used for remote diagnostics and servicing.

The result of introduction of these technologies, the Reva Lion has a 15% better acceleration, 20% lower

AC energy consumption, 50% improved range and 25% reduced standard charging time.

6. Conclusions

The extensive exercise has resulted in the design of a next generation electric car for world markets with the following features

- Increased range – with possibilities of user options
- Proven Lithium Ion Battery technology – with safety features
- Increased cycle life
- Improved all weather performance
- Fast charge capability – 1 hour
- Futuristic energy management architecture – adaptable to advances in Battery technology
- Improved aesthetics
- Improved power and acceleration

7. References

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