Fundamentals of Hybrid and Electric Vehicles

Principles of Operation, Standards and Maintenance

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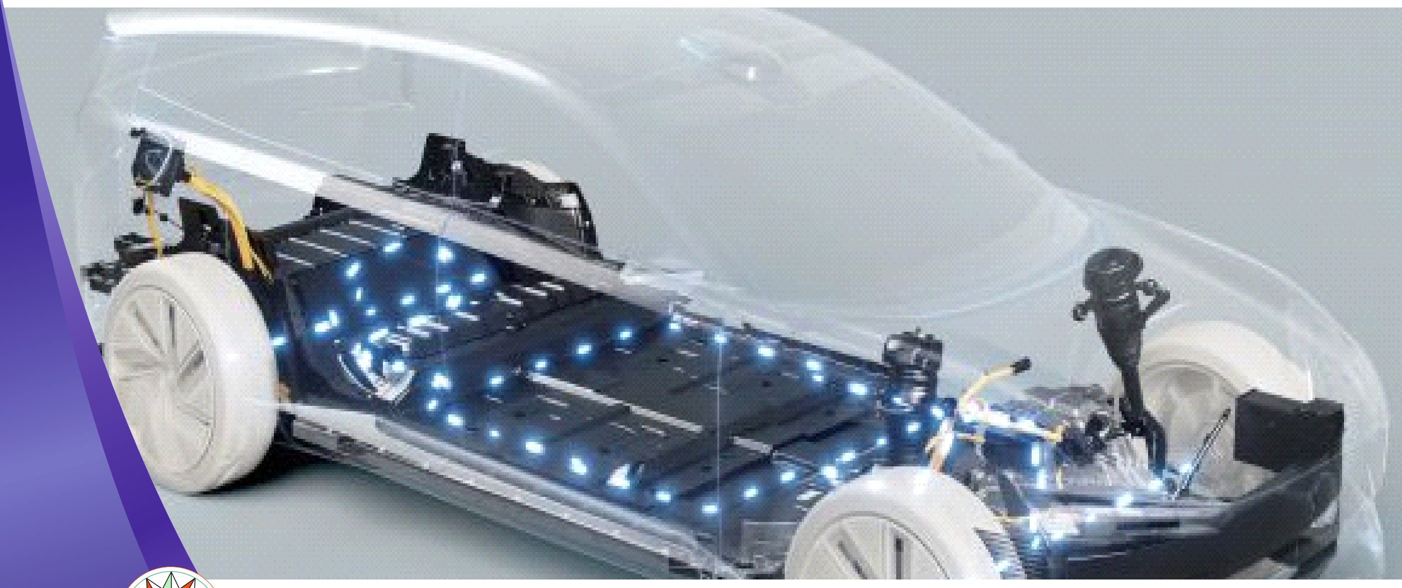
Amit R. Patil
Arvind J. Bhosale
S.S. Raghuwanshi



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Principles of Operation, Standards and Maintenance

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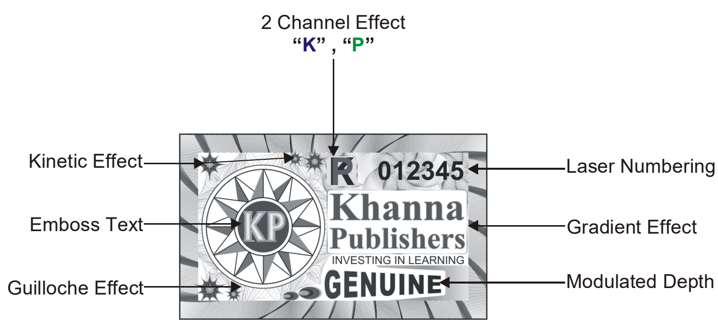

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Preface

This book is presented with an objective to meet the requirement of the students of Indian universities securing graduate program especially in "electric mobility". Inevitably, India being the largest or 2nd largest population in the world, is under impelling pressure to adopt alternative means of transportation that is clean and doesn't depend on fossil fuel. Indian government economic policy to become energy self-sustain may prevail this country to adopt electric vehicle as alternative mobility means for transport. Reduction in CO_2 emission has to be reduced as commitment to world order. Few days absentee of truck and motor on road has significant effect on air quality. The message has been widely presented in print media giving enough indication for adoption of HEV and EV in this county has not been so widespread compared with other developed countries. This delay can't be avoided for long time. With this objective we four authors decided to present a comprehensive book on this subject titled "Fundamentals of HEV and EVs".

The book contain total twenty one chapters divided into seven units. The first unit starts with "Introduction to hybrid and electric vehicle" which contain four chapters which introduce learner to history of e-mobility, basic terminology, classification of EV and environmental aspect of this technology. This unit also cover chapter on basics of vehicle dynamics which are prerequisite for understanding the working of EV and HEV.

The second unit "Vehicle architecture" cover two chapters which focused on architectural aspect to help learner to understand different layout of HEV and EV and its classification based on it. The arrangement of different components like battery pack, motor, DC-DC converter etc. play a critical role during design of layout of electric vehicle and explain in this unit.

The next three units, third, fourth and fifth unit deals with explanation of working and control of important component of EV. The third unit "Electric propulsion system" contain three chapters which cover introduction to powertrain technology in EV, its classification followed by chapter which explain design and different control methodologies of powertrains. This unit help reader to understand electric to mechanical power conversion process. The fourth unit contain two chapters which deals with energy storage system and explain different types of Energy storage system and their selection criteria for use in EV.

Unit six contain three chapters and discuss energy management system of EV. Energy management is very important aspect in electric vehicle as it carried entire power source within itself. Energy transfer from source to wheel and conversion in mechanical form is very complex and slight mismanagement may lead to fire hazard. The various energy management systems along with its classification, performance and evaluation are explained in Chapter 15 followed by next Chapter 16 on Thermal Management of Battery Pack. Chapter 17th contain sample case studies on design aspects of hybrid and pure electric vehicles.

The last seventh unit deals with introduction to Indian automobile standards, different charging techniques for EVs. 20th chapter explains safety and maintenance procedure for HEV and EVs. This book conclude with last 21th chapter on future technology to give glimpse of upcoming technological advancement in EVs. The researcher around world working very aggressively to give EV longer range, safety and life so many new technology are evolving daily than authors included in this chapters.

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UNIT I: INTRODUCTION TO HYBRID AND ELECTRIC VEHICLE

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Historical Review: Evolution of HEVs and EVs

1.1. INTRODUCTION: FOSSIL FUELS AND THE GREEN HOUSE EFFECT

1.1.1. Carbon Emission and Environment

The excitement about the Hybrid and Electric vehicles has recently taken a centre stage in automobile industry as well as the government of India. The extreme interest in such HEVs and EVs is exhibited by the countries who were the largest emitters of green house gases for about a century. Most notably USA and countries of Europe which grew their economies by burning fossil fuels are now making the maximum noise for reducing carbon emissions and thrusting for the same on developing nations to follow the legislative resolutions. The riches or most developed economies in the world often blame for the catastrophe of global green-house effect and climate change but the poorest countries suffer the most from this.

The rich nations such as USA and Europe, burning maximum fossil fuel and spewing carbon from factories, homes and cars. Today they still emit carbon and other greenhouse gasses disproportionately into the environment, although other big countries such as China and India have attempted to check.

The wealthy nations drive the world towards ecological disasters. It is the poor nations that face the gravest consequences and face sufferings in coping up with the problems. Low-lying Bangladesh already battered by increasingly powerful cyclones and might lose 10% of its land to the ocean, within a few decades displacing 18 million people that may be attributed to climate change only.

A recent study from Stanford university found that climate change is aggravating global income inequality between wealthy nations in cooler regions, and poor nations in hotter parts of the world. This is due, at least in part, to the relative inability of poorer countries to pay for the projects necessary to mitigate the effects of climate change, including more extreme weather events and the deterioration of agricultural land in subsistence economies. Whatsoever the case may be, the responsibility for this climate change belongs to all of us. Then it is a global problem and therefore requires a global solution, hence we must change our attitude.

But the effect must be led by the nations that reaped so many of the benefits of economic development and increased wealth through industrialization for so long. The poorest countries in the world need help finding the money, resources and technology to move towards a sustainable future without plunging themselves further into crushing poverty and inequality.

The richer countries, though they will have enormous costs of their own, have a moral obligation to step up.

Call for justice on climate change started in 2010 and then again in 2015, with the Paris agreement on climate change, wealthier nations *pledged to donate* to the so-called Green Climate Fund, building up to $100 billion per year by 2020. The fund was created under the auspices of the United Nations to help developing countries reduce the emissions that lead to climate change and adapt to the inevitable effects of it that are already underway. The goal of the fund is to use "public investment to stimulate private finance" for climate-related projects. It is governed by a board of representatives from 24 nations.

But in 2018, Oxfam found that the donor nations had fallen behind in meeting their pledge. The organization's senior climate change policy advisor called the money moving from rich countries to the least developed and most vulnerable "sadly inadequate". We would say: shameful. While the world burns, the politicians and bureaucrats fiddle.

As such, there is no goal programming solution for determining how much to be contributed by different nations in accordance to their carbon emissions or something else. This fund seems to be based on an honour system or status of the country on GDP or something else. However, the World Resources Institute noted, the initial $ 10.3 billion in commitment was a "good beginning", but it appears to be of a more accidental outcome rather than a planned and a transparent logical design.

Even if rich nations change their energy policies, they must help developing countries to create sustainable energy grids. We must oppose China's counterproductive practice of building coal-fired power plants in developing nations to carry political influence. We must offer aid and policies to reverse deforestation in the Amazon, Indonesia and other vital forests that remove carbon from the atmosphere.

1.1.2. Countries for Zero Emissions Policy

By 2020 more than 110 countries committed to a net zero emissions target by 2050, and China, the largest emitter by 2060. *Carbon neutrality* means some emissions are still being generated but will be offset somewhere else, concluding in net zero emissions. What the Paris Agreement attempts to uphold is making sure global temperatures stay within 2C by 2100, but preferably closer to 1.5C. The energy innovation of the past two decades have given us a chance to use fossil fuels, which National Geographic says, supplies 80% of the world's energy. By *understanding our carbon footprints*, we can start *reducing emissions*. Monitoring your carbon dioxide emissions in real-time and accurately *offsetting remaining emissions*. The countries with legacy binding agreements so far are Sweden, the U.K., France, Denmark, New Zealand, and Hungary. Countries with proposed legalisation include Canada, South Korea, Spain, Chile, Fiji and the EU Member States. There are many countries with in-policy documents including but not limited to the United States, China, Japan, and Germany (*see* Fig. 1.1).

1.1.3. Countries with Negative Green House Gas Emissions

1.1.3.1. *Bhutan*

Bhutan receives more greenhouse gases from the world than it emits making it a carbon negative country. Since it is a country that is mostly forested with 750,000 people, they mostly work in agriculture and forestry. Because they are largely Buddhist and prioritize health and happiness, they have done their best to protect the environment and have been effective at tackling climate change. Although they work in forestry, they had banned logging exports in 1999. Legally, Bhutan must stay 60% covered in the forest at all times making it more eco-friendly for the world. They also use hydropower as their electricity source.

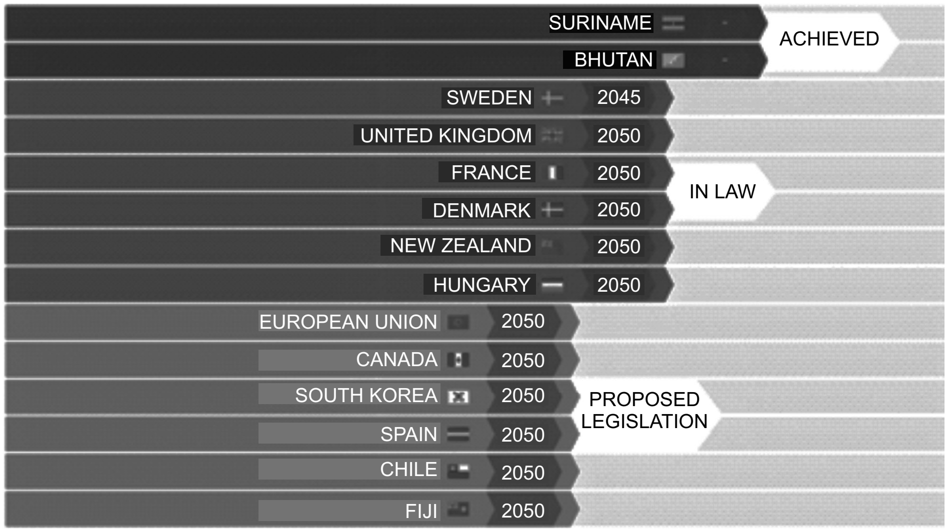

Fig. 1.1. Comparison of countries progress toward legal binding for net zero emissions.

By 2025, Bhutan's hydroelectric exports are projected to offset CO_2 emissions by 22.4 million tons. With the melting Himalayas and landslides due to global warming, however, their hydropower could be badly affected.

1.1.3.2. *Suriname*

The United Nations reports Suriname is 93% covered in the forest so it absorbs more greenhouse gases than it emits. It is also the second country to have made updated plans to fight climate change. The Marshall Islands was the first. Despite they are a small countries, they are committed and enthusiastic about global warming prevention and doing their part. Countries like these are also susceptible to climate change worse than most though they are the least contributers. This will cost Suriname $969 million USD to keep greenhouse gas emissions down. Their plan is to commit to 93% forest cover in their country and keep renewable energy sources over 35% by 2030. Agriculture contributes to 40% of their emissions hence they are dedicated to climate and cultivate smart farming like converting biomass into energy, promoting sustainable land management, and water resource management. Furthermore, public transportation will become more sustainable too.

1.2. HISTORICAL REVIEW EVOLUTION: HEVs AND EVs

1.2.1. History of Hybrid Cars

The advent of the thought of a sustainable future life on this planet gave birth to the hybrid cars. A sense of recognising as a most sensible mobility solution. Well one might think that the buzz around the automobile industry for an alternative transportation method is a recent technological trend, however, the hybrid technology for automobiles existed a century ago and has evolved radically since then.

Jacob Lohner and Ferdinand Porsche developed the first functional hybrid car way back in 1900 in Vienna. The hybrid car was christened "Semper Vivus", which means "always alive". The car made its debut at the Paris Auto Exhibition in 1900. Well, the fact is that the initial efforts were made to build an utterly electric vehicle; however, due to lack of infrastructure and range, anxiety put the plan on hold. In 1901, a production-ready version made its mark as the Lohner-Porsche "Mixte".

The first hybrid car that Jacob Lohner and Ferdinand Porsche developed used to run on a single-cylinder gasoline engine to drive a generator that supplies electrical energy to the hub motors mounted on the front wheels. According to reports, it was able to achieve a top speed of 56 km/h. Mass-market manufacturing was a big challenge back then, and only 300 units were being sold.

This development was shadowed by the Henry Ford, when he started the first assembly line in 1904. Ford's capabilities to manufacture low-cost, light-weighted petrol combustion engine cars caused the biggest hurdle for the advancement in Hybrid technology. And according to reports,by the mid-1920s, hybrid cars went extinct.

Various initiatives were carried out to keep pollution in check, thus advancing technology in hybrid vehicles also. However, Honda and Toyota stirred the growth of Hybrid cars in the late 1990s and early 2000s. In 1995, the Toyota Prius was first introduced to the public as a concept car in the Tokyo Motor Show and soon went into full-scale production in 1997. Honda also gave birth to the Honda Insight, a two-door sedan capable of achieving 61 mpg of combined mileage. The evolution and demand emerged when these Japanese manufacturers entered the American market. With the subsequent success of Honda Insight and Totota Prius, the major auto manufacturers also developed their versions of hybrid cars. Today, as we are on the cusp of a mobility transformation, hybrid technology is quite recognized and prevalent. Recently, Honda has launched its Hybrid Honda City e:HEV.

1.2.2. History of Electric Cars in USA (Period of 1890–1930)

The electric vehicle is not a recent development. In fact, the electric vehicle has been around for over 100 years and has an interesting history of development that continues to the present.

France and England were the first nations to develop the electric vehicle in the late 1800s. It was not until 1895 that Americans began to devote attention to electric vehicles. Many innovations followed and interest in motor vehicles increased greatly in the late 1890s and early 1900s. In 1897, the first commercial application was established with a fleet of New York City taxis.

Early electric vehicles, such as the 1902 Wood's Phaeton, were little more than electrified horseless carriages and surreys. The Phaeton had a range of 18 miles, a top speed of 14 mph, and cost $2,000.

Fig. 1.2. Woods Electrified Horseless carriage.

By the turn of the century, America was prosperous and the motor vehicle, now available in steam, electric, or gasoline versions, was becoming more popular. The years 1899 and 1900 were the high point of electric vehicles in America, when they outsold all other types of cars. Electric vehicles had many advantages over their competitors in the early 1900s. They did not have the vibration, smell, and noise associated with gasoline cars. Changing gears on gasoline cars was the most difficult part of driving, in contrast, electric vehicles did not require gear changes. Steam-powered cars also had no gear shifting, but they suffered from long start-up times of up to 45 minutes on cold mornings. Steam cars had less range before needing water than an electric car's range on a single charge. The only good roads of the time period were in towns, which caused most travel to be local, a perfect situation for electric vehicles, because their range was limited. The electric vehicle was the preferred choice of many because it did not require a manual effort to start, as with the hand crank on gasoline vehicles, and there was no wrestling with a gear shifter.

While basic electric cars cost under $1,000, most early electric vehicles were ornate, massive carriages designed for the upper class. They had fancy interiors, with expensive materials, and averaged $3,000 by 1910. Electric vehicles enjoyed success into the 1920s with production peaking in 1912.

Fig. 1.3. Electric car with Fashioned interior on Detroit city roads.

The cost factor lead to the decline of electric vehicle, however, following were the major reasons for its discontinuation:

1. By the 1920s, America had a better system of roads connecting cities, and bringing with it the need for longer-range vehicles.
2. The discovery of Texas crude oil reduced the price of gasoline, making it affordable to the average consumer.
3. The invention of the electric starter by Charles Kettering in 1912 eliminated the need for the hand crank to start internal combustion engines. Initiation of mass production of internal combustion engine vehicles by Henry Ford made these vehicles widely available and affordable in the $500 to $1,000 price range. By contrast, the price of the less efficiently produced electric vehicle continued to rise. In 1912, an electric roadster sold for $1,750, while a gasoline car sold for $650.

1.2.3. Disappearance of Electric Cars

By 1935, electric cars disappeared and remained out of market till 1960, particularly for use as personal transportation means. However, during 1960 to 1970, the problems of CO_2 emission from the burning of fossil fuels as well as the depending on imported crude oil. These reasons for compelling to develop practical electric vehicles by 1960.

1.2.4. Re-appearance of Electric Cars

During the early 1960s, the Boyertown Auto Body Works jointly formed the Baltronic Truck Company with Smith Delivery Vehicles Ltd., of England, and the Exide Division of the Electric Battery Company. The first Baltronic electric truck was delivered to the Potomac Edison Company in 1964. This truck was capable of speeds of 25 mph, a range of 62 miles and a payload of 2,500 pounds. Baltronic worked with General Electric from 1973 to 1983 to produce 175 utility vans for use in the utility industry and to demonstrate the capabilities of battery powered vehicles. Baltronic also developed and produced about 20 passenger buses in the mid-1970s.

Fig. 1.4. Baltonic Electric Van developed in 1978.

With advancing time new designs continued to come in the market and Jet Industries of Austin, Texas were successful in converting vehicles in electric propulsion. Most of the Jet Industries electric cars were based on a Ford Escort and Mercury—Lynx chassis purchased now from Ford as "gliders" (body and chassis without engines). To convert the Escort to electric, Jet mated a Prestolite 96 volt traction motor to the original Ford transaxle, fabricated battery boxes front and rear, filled them with 6 volt flooded lead-acid batteries, and added a motor controller and an on-board battery charger using 120 volt alternating current power.

During this time, Sebring-Vanguard produced over 2.000 "CitiCars". These cars had a top speed of 44 mph, a normal cruise speed of 38 mph, and a range of 50 to 60 miles. Another company was Elcar Corporation, which produced the "Elcar". The Elcar had a top speed of 45 mph, a range of 60 miles, and cost between $4.000 and $4,500 (*see* Fig. 1.5).

In 1975, the United States Postal Service purchased 350 electric delivery jeeps from the American Motor Company to be used in a test program. These jeeps had a top speed of 50 mph and a range of 40 miles at a speed of 40 mph. Heating and defrosting were accomplished with a gas heater and the recharge time was 10 hours.

Electric vehicle manufacturers continued demonstrating the capabilities of these cars, such a trip was organised by Arizona Public Service in a MARS II electric car built by Electric

Fuel Propulsion Inc. of Detroit, Michigan. The trip started in Detroit on September 20, 1967, and ended in Phoenix on October 5, 1967, with 37 stops along the way for fast charging of the car's lead cobalt batteries. Arizona Public Service purchased the MARS II and a 50 kW fast charger built by Electric Fuel Propulsion Inc. for this historic 2,226 mile trip.

Fig. 1.5. City cars developed by Elcar and Vanguard.

Fig. 1.6. Classic 1968 Mars II Electric Vehicle.

Development of efficient and improved propulsion continued, and EVcort, an experimental electric car was developed from 1981 to 1994 by Electric Vehicle Associates of Cleveland, Ohio and later by Soleq Corporation of Chicago, Illinois. The car consisted of a stock body and transmission from the Ford Escort, retrofit with an electric propulsion system, and every component was engineered and manufactured specifically for the car. It incorporated features such as regenerative braking and a multistep charging algorithm that are common on modern electric vehicles, but were quite innovative at the time. The intent was to produce a practical alternative-fueled vehicle with performance comparable to gasoline-powered cars. The EVcort was used extensively by a variety of institutions for electric vehicle demonstration and testing programs, including the U.S. Department of Energy's Site Operator Program.

Fig. 1.7. EVcort Electric car that had multistep charging algorithm.

1.2.5. Modern Generations Electric Cars (1990–2010)

Several legislative and regulatory actions renewed electric vehicle development efforts. Primary among these actions are the 1990 Clean Air Act Amendment, the 1992 Energy Policy Act, and regulations issued by the California Air Resources Board. In addition to more stringent air emission Vehicle requirements and regulations requiring reductions in use of fossil fuels, several states issued Zero Emission Vehicle requirements.

The "Big Three" automobile manufacturers (*i.e.*, Chrysler, Ford, and General Motors) and the U.S. Department of Energy, as well as a number of vehicle conversion companies, were actively involved in electric vehicle development through the Partnership for a New Generation of Vehicles. Electric conversions of familiar gasoline-powered vehicles, as well as electric vehicles designed from the ground up, were available that reached highway speeds with ranges of 50 to 150 miles between recharging.

One example of these vehicles was the Chevrolet S-10 pickup truck, converted by U.S. Electrical. It was powered by dual alternating current motors and lead acid batteries. It had a range of about 60 miles and could be recharged in less than 7 hours.

Fig. 1.8. Ecostar 1992 pick-up van model.

Another example was the Geo Metro, converted by Solectria Corp., which was an electric-powered four-passenger sedan powered by an alternating current motor and lead-acid batteries. It had a range of 50 miles and could be recharged in less than 8 hours. During the 1994 American Tour de Sol from New York City to Philadelphia, a 1994 Solectria Geo Metro cruised over 200 miles on a single charge using Ovonic nickel metal hydride batteries.

Fig. 1.9. 1997 Electric Pick-up Truck model S-10.

Fig. 1.10. Geo Metro car manufactured by Solectria Corporation.

The 'Big Three' automobile manufacturers were also making electric vehicles, however, none of them brought out any popular model on the roads as early as 1990, when Ford Motor developed Ford Ecostar a utility van with a speed of 70 mph and range of 80 to 100 miles. It was never offered commercially. Other EVs offered by Toyota RAV4 sport utility and Honda EV plus Sedan were equipped with NiMH packs. Whereas Nissan came out with Altra EV stations wagons equipped with lithium-ion battery pack.

The Toyota RAV4 was a five-passenger sport utility vehicle with a range of about 95 miles, a 1,000-pound NiMH batteries, a top speed of 79 mpg, acceleration from 0 to 50 mph in 13 seconds, and a payload of 785 pounds.

Fig. 1.11.

Fig. 1.12. Dodge EPIC electric 1999 model.

Fig. 1.13.

BMW also came out with the Mini E in a limited numbers of states. The Mini E was a two-passenger hatchback with a range of about 120 miles with its 575-pound lithium ion batteries, a top speed of 81 mpg, acceleration from 0 to 50 mph in 8 seconds, and a payload of 354 pounds.

Fig. 1.14. BMW Mini E.

However, Ford did offer an electric version of its Ford Ranger pickup. It had a range of about 65 miles with its lead acid batteries, a top speed of 75 mph, it accelerated from 0 to 50 mph in 12 seconds, and the payload was 700 pounds. Ford later came out with a Ranger version equipped with a nickel metal hydride (NiMH) battery that weighed 1,100 pounds. Depending on how it was driven, the range was about 85 miles.

Fig. 1.15. Ford Ranger Electric pickup.

General Motors designed and developed an electric car from the ground up instead of modifying an existing vehicle. This vehicle, called the EV1, was a two-passenger sports car. The lead acid EV1 had a top speed of 80 mph, a range of about 80 miles, and it could accelerate from 0 to 50 mph in 6.3 seconds. The battery pack in the lead acid EV1 weighed 2,600 pounds.

Fig. 1.16. General Motors EV1.

Not long after the lead acid version, General Motors introduced a NiMH battery-equipped EV1. The NiMH version had a range of about 150 miles, but under optimal driving conditions it could exceed 200 miles per charge. The NiMH EV1 also had a top speed of 80 mph and an acceleration time from 0 to 50 mph in 6.3 seconds. The battery pack in the NiMH EV1 weighed 1,600 pounds.

In addition to the EV1, General Motors also offered an electric Chevrolet S-10 pickup that initially had lead acid batteries. This vehicle had a range of 40 miles, it accelerated from 5 to 50 mph in 10 seconds, it had a payload of 950 pounds, and the lead acid battery pack weighed 1,270 pounds. Chevrolet later came out with an S-10 pickup equipped with a NiMH battery that weighed 1,100 pounds. Depending on how it was driven, the range was about 95 miles.

Fig. 1.17. Chevrolet electric S-10 pickup.

'Chrysler's first electric vehicle from this generation was an electric conversion of the Dodge Caravan. This vehicle was a five-passenger van. It had a range of about 50 miles with its lead acid batteries, a top speed of 62 mph, it accelerated from 0 to 50 mph in 31 seconds, and the payload was 800 pounds. Chrysler later came out with a Dodge Caravan Epic that was equipped with a NiMH battery that weighed 1,200 pounds (with coolant). It had a range of about 80 miles, a top speed of 78 mph, it accelerated from 0 to 50 mph in 12 seconds, and the payload was 945 pounds.

Ford Motor Company, in 1999 was contracted by the U.S. Portal Service to supply 500 electric carrier route vehicles. These carrier route vehicles were phased into 22 post office locations, in California, New York and Washington D.C. In India, government and particularly ministry of transport, never take such decisions that they start replacing their non-carbon emission vehicles by electric ones and motivate the private public transportation to use electric or hybrid-electric vehicles. Atleast government should start testing the electric vehicles for their own services.

In U.S., 1990 to 2001, several Electric vehicle manufacturers came out with original developments of equipments to be used in electric vehicles, Importantly this was the first period when lighter weight and higher energy density advanced battery chemistries (*i.e.*, NiMH and lithium ion) were introduced into the marketplace in large numbers.

Toward the end of this period, several conversion companies started to convert original equipment manufacturers' hybrid electric vehicles into plug-in hybrid electric vehicles by adding a second lithium ion traction battery pack. The most common hybrid electric vehicle model converted was the Toyota Prius. While there were several conversion companies, A123 Hymotion was the largest of the conversion companies and they used 5-kWh lithium ion batteries from Al23 to convert hundreds of Prius hybrids into plug-in hybrid electric vehicle. In order to recharge this second battery pack, the converted Prius had to be plugged into the electric grid.

1.3. HISTORY OF ELECTRIC VEHICLES IN INDIA

In 1996, the first electric vehicle, a three wheeler named VIKRAM SAFA was developed by Scooters India Pvt. Ltd, Lucknow. Initially 400 vehicles were manufactured and sold. There EVs used 72 volt lead acid battery.

Fig. 1.18. Vikram EV three wheeler, 1996.

In 1999, Mahindra & Mahindra, launched a three wheeler, from their Coimbatore based company. They started selling electric vehicles, named as "Bijlee" from this company from 2001, however, they closed down this company in 2004 due to bad market position. Again in 2006, M&M started their manufacturing base at Haridwar for electric vehicles, as per market-demand.

Fig. 1.19. Three wheeler of Mahindra & Mahindra.

In India, government has made a provision that Subsection (1) of Section 66 of the Motor Vehicles Act, 1988 will not apply to e-carts and e-rickshaws (as defined in Section 2A of the said Act) that are used for carrying goods or passengers with personal luggage This means that vehicles that are registered as e-carts or e-rickshaws will not require any permits. Consequently, more than 5,00,000 e-rickshaws were sold in India in 2016–17. Yet this market is estimated to grow at 30–35% in 2017 to 2020. Most of these e-rickshaws currently ply in

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About the Book

This book is presented with an objective to meet the requirement of the students of Indian universities securing graduate program especially in "Hybrid and Electric Mobility". A hybrid electrical vehicle is a type of hybrid vehicle that combines a conventional I.C. engine system with an electric propulsion system.

This book contain total twenty one chapters divided into seven units. The first unit starts with "Introduction to hybrid and electric vehicle" which contain four chapters which introduce learner to history of *e*-mobility, basic terminology, classification of EV and environmental aspect of this technology. In the second unit "Vehicle architecture" cover two chapters which focused on architectural aspect to help learner to understand different layout of HEV and EV and its classification based on it. In the next three units, third, fourth and fifth units deals with explanation of working and control of important component of EV. In sixth unit contain three chapters and discuss energy management system of EV. Energy management is very important aspect in electric vehicle as it carried entire power source within itself. In the last seventh unit deals with introduction to Indian automobile standards, different charging techniques for EVs.

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