Electric vehicle technology: The transformation of conventional vehicle-based travel to an electric mobility in urban India

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Abstract: The recent changes in the environment made the researchers to ideate new alternatives in all walks of life to reduce the effect of global warming and pollution. Transportation is one of the key factors for the day-day increase in the depletion of ozone layer. The conventional vehicles increase the air pollution by the emission of harmful gases, governments and people are now moving towards electrical mobility which is green and safe alternative. The drastic demand of electric vehicles inspired the researchers to bring new concepts into market which are user friendly and sustainable in nature. This paper deals with the comparison of various motor and battery technologies used by current automobile Electric Vehicle industry. The paper also presents the modelling and simulation of an electric car and recommends the common people to shift from conventional to electric vehicles.

Keywords: Electric Vehicle, Electric Propulsion, Motors, Battery, and Power Converters.

1. Introduction

The ascent of enthusiasm for the electric mobility might be especially very much followed by looking to the web. This should be possible by considering first the quantity of search requests of web clients over a period range and second by breaking down the quantity of hits showed via web crawlers over a period for electric cars title. We have first examined distinctive as often as possible utilized keywords with Google Insight for Search. As of late, Electric Vehicles (EV) are picking up prevalence, and the reasons for this are many. The most famous one is their commitment in diminishing ozone depleting
substance (Green House Gas GHG) outflows [1-3]. In 2009, the transportation part radiated 25% of the GHGs delivered by vitality related areas. EVs, an extremely old and once dead idea, this time raised as a financially practical and accessible item. As a vehicle, an EV hushes up, simple to work, and does not have the fuel cost compared with regular vehicles [4-5]. As a metropolitan vehicle mode, it is exceptionally valuable. Driving Car companies such as Honda, Ford, Toyota, and others drew out their specific EVs too. Toyota's profoundly effective Prius, the principal business hybrid electric vehicle (HEV), was initiated in Japan in the year 1997, along with 18,000 units marketed in the same year of manufacturing. At present, almost no one of those 20th century EVs available; an exclusion can be Toyota Prius, even now going robust in a better and developed form. Current market is led by Nissan Leaf, Tesla Model S and Chevrolet Volt.

2. Electric vehicle configuration
The basic components present in the EV system are presented here. The EV comprises of three key subsystems:

- Electric propulsion
- Power supply
- Ancillary system

The electric propulsion module includes:
- Electronic control device
- Power Electronic converter
- Motors
- Power transmission
- Wheels of the vehicle

The Power supply module comprises:
- The Energy storage devices (battery, ultra-capacitor.)
- Energy controlling unit
- Energy replenishing component

The Ancillary module entails:
- Power driving component
- Back-up power supply
- Temperature regulatory unit

3. Electric propulsion system
In the Figure.1, a twofold line, an electric connection shown as a thick line and a command interface by a slight line speaks to a mechanical connection. The bolt on every line signifies the heading of electrical drive stream or monitor data correspondence [6].

In light of the control contributions regarding the brake and quickening agent pedals, the modern electronic regulator gives legitimate control signs to turn on or turn off the primary gadgets of the power converter, which capacities to manage power stream amid the electric engine and vitality source. The retrogressive force stream is because of regenerative type of slowing down of the EV and this type of
regenerative energy can be put away or stored as the energy source is chargeable. Note that most accessible EV batteries just as capacitors and flywheels promptly acknowledge regenerative vitality.

The vitality the executive’s unit helps the electronic regulator to regulate regenerative type of slowing down and its vitality recuperation. It likewise coordinates with the vitality replenishing unit to regulate re-fuelling & to screen ease of use of the vitality source. The assistant force flexibly gives the essential force distinctive levels of voltage for all EV helpers, particularly the temperature monitoring and force directing units. Other than brake and quickening agent, the directing car wheel is one more prime control contribution of EV. Considering its rakish stance, the force guiding module can decide how pointedly the car should run.

3.1 Motors used in EVs

Electric propulsion schemes are acting as heart of Electric Vehicles and Hybrid Electric Vehicles. EVs constitute DC/AC motors, solid state converters, and controlling devices. The motor alters electric form of energy to mechanical form to drive a car and opposite action to permit regenerative type of braking and/or to produce electricity for the resolve of battery charging using the on-panel energy storage. The solid-state converter is utilized to provide the available motor with required voltage and required current. The controlling device instructs the power electronic converter by offering regulatory indicators to it, and then regulates the action of the available motor to develop appropriate torque and required speed, as per the instruction given by the driver [7].

![Electric propulsion system.](image)

Figure 1. Electric propulsion system.
### Table 1. Comparison of Motors used in EVs

| Motor type                        | Advantage                                                                 | Disadvantage                                                                 | Vehicles Used In                                                                 |
|----------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Brushed DC motor                 | ● Maximum torque at low speed                                             | ● Bulky structure                                                            | ● First Panda Elettra (Series DC motor)                                        |
|                                  |                                                                           | ● Low efficiency                                                             | ● Conceptor G-van (Separately excited DC motor)                                |
|                                  |                                                                           | ● Heat generation                                                            |                                                                               |
| Permanent Magnet Brushless DC Motor (BLDC) | ● No rotor copper loss                                                  | ● Short constant power range                                                | ● Toyota Prius (2005)                                                          |
|                                  | ● More efficiency than induction motors                                  | ● Decreased torque with increase in speed                                   |                                                                               |
|                                  | ● Lighter                                                                | ● High cost because of PM                                                   |                                                                               |
|                                  | ● Smaller                                                                |                                                                               |                                                                               |
|                                  | ● Better heat dissipation                                                |                                                                               |                                                                               |
|                                  | ● More reliability                                                      |                                                                               |                                                                               |
|                                  | ● More torque density                                                   |                                                                               |                                                                               |
|                                  | ● More specific power                                                  |                                                                               |                                                                               |
| Induction motor                  | ● The most mature commutator less motor drive system                     |                                                                               | ● Tesla Model S,                                                              |
|                                  | ● Can be operated like a separately excited DC motor by employing field-oriented control |                                                                               | ● Tesla Model X,                                                              |
|                                  |                                                                           |                                                                               | ● Toyota RAV4,                                                               |
|                                  |                                                                           |                                                                               | ● GM EV1                                                                      |
| Synchronous Reluctance Motor (SRM) | ● Simple and robust construction                                         | ● Very noisy                                                                 | ● Chloride Lucas                                                              |
|                                  | ● Low cost                                                              | ● Low efficiency                                                             |                                                                               |
|                                  | ● High speed                                                            | ● Larger and heavier than PM machines                                        |                                                                               |
|                                  | ● Less chance of hazard                                                | ● Complex design and control                                                |                                                                               |
|                                  | ● Long constant power range                                            | ● Problems in controllability and manufacturing                             |                                                                               |
|                                  | ● Fault tolerant                                                       |                                                                               |                                                                               |
|                                  | ● Efficient                                                             |                                                                               |                                                                               |
|                                  | ● Small                                                                |                                                                               |                                                                               |

#### 3.1. Power converters in EV

The power converter is a muster of current solid-state semiconductor technology. Converters are utilized to regulate the flow of power among the basic energy resource, the alternate power supply, and the
drives. The process modules of drive block are applied by regulating the solid-state converter. The maneuver modules of the drive block basically incorporates generator-only power-driven action, batteries-only powered action, combination of generator and energy storage batteries driven hybrid action, regenerative type of braking action, and batteries charging action [8-10] are the different architectures of the power electronic converter.

![Figure 2. Architecture of Power Converters.](image)

The following steps to followed for selection of converters

- Find the available source
- Find the individual component range
- Convert Available to required

3.2. Battery system

The essential component of every battery is the electrochemical cell. An association of various cells in arrangement shapes a battery. The perspective of electric vehicle manufacturer’s is the battery can be considered as ‘black box’ with performance benchmarks. These benchmarks will consist of [11-13]:

- specific energy
- specific power
- standard voltages
- amp hour ratings
- energy efficiency
- self-discharge rates
- recharge rates

The controllers and algorithms used for the optimization of battery management systems of the FACTS devices are discussed in detail [14-23].

| S. No | Performance parameters | Lead Acid (Wh/Kg) | Nickel cadmium (Wh/L) | Nickel metal hydride (Wh/L) | Lithium ion (Wh/L) |
|-------|-------------------------|-------------------|-----------------------|-----------------------------|--------------------|
| 1     | Specific energy         | 30-40             | 40-60                 | 40-80                       | 130-200            |
| 2     | Energy density (Wh/L)   | 60-90             | 80-140                | 90-160                      | 180-320            |
| 3     | Specific power (W/kg)   | 250-600           | 300-800               | 900-1600                    | 1200-4000          |
| 4     | Cycles                  | 500-800           | 800-1200              | 800-1200                    | 1500-2000          |
3.3. Charging time calculation

The batteries used in electric vehicles are like updated editions of the battery in a mobile phone. Batteries carry direct current (DC) power and distribute to the load demand. The basic aspect is what electric vehicle drivers have command over. There are different “levels” of charging; indicating the amount of power they will deliver battery. When we plug an electric vehicle into a standard 120-Volt domestic wall outlet, we get Level 1 charging.

Assume a Level 1 charging station with load power $P_L$. Say $P_L = VI \Rightarrow 230\text{V} \times 16\text{A} \approx 3680\text{W}$.

Now, Let the car’s total battery power $P_C = 24\text{KW}$.

$P_C/P_L \Rightarrow 24000/3700 \Rightarrow 6.5\text{Hrs.}$

4. Problem formulation

As the concern rises about the emissions of ICEs and shortage of petrol and diesel, Electric vehicles are on their path to be the market leader in the automobile industry in the upcoming years. In this case, it eventually leads to more companies which implies to more employment in various sectors.

There are so many parameters involved in making an electric vehicle. There are other things, such as, charging stations which must be adequate for the consumer usage. To adapt to the future technology of road transportation and know how it works is essential in both employment wise and consumer wise.

4.1 Calculations

For E.g.: - $M = 1000\text{kg};$ Speed = 60km/h (16.66 m/s); $\text{Acc}(a) = 2.77 \text{ m/s}^2$

Aerodynamic drag: - $\frac{1}{2}\rho AV^2C_d$: - $(0.5) \times (1.2) \times (2.2) \times (277.55) \times (0.3) = 110\text{N}$

Rolling resistance: - $\mu Mg$: - $(0.015) \times (1000) \times (9.8) = 147\text{N}$

Gradient resistance: - $Mgsin\theta$: - $(1000) \times (9.8) \times (\sin (0)) = 0\text{N}$

Acceleration resistance: - $(M/g) \times a$: - $(1000/9.8) \times (2.77) = 282.6\text{N}$

Total Tractive Force = 110+147+282.6 = 539.6 $\approx 540\text{N}$

To find out the required motor power.

Power = TTF * Speed = 540*16.66 = 8996.4 $\equiv 9000\text{W}$

To find out the required motor torque.

Torque = $(9.554 \times P)/N = (9.554\times9000)/480 = 179\text{Nm}$

To find out the required battery capacity

We know, $P = V/I$

$9000 = 48/I \Rightarrow 188\text{Ah}$

$1.2 \times 9000 = 10800\text{W} \Rightarrow 10800/48 = 225\text{Ah}$

5. Simulation and results of EV

The objective is to provide detailed information about the working and the parts used in making an electric vehicle and provide the necessary calculations required and a simulation model which shows the 3D model of the working of an electric vehicle.
The objective of this design is to bring everyone closer to the electric vehicles. How do they select a motor for it, how do they select right battery with correct specifications for it and what are the mechanics involved in it.

In this paper, we provide all the basic necessary calculations involved which helps make an electric vehicle. CAD model is shown in figures 3.1 and 3.2 to show the internal arrangement of battery and motor of an electric car which helps for better understanding. We also include a MATLAB simulation model for basic electric vehicle which gives battery usage and drive cycle results.

The Figure 4 is a MATLAB simulation of simple working of an Electric vehicle. It consists of a brushed DC motor, PWM controller, Battery, and a Vehicle body. The objective of this simulation is to find out the difference between drive cycle speed and vehicle speed and the continuous change in battery capacity.
The voltage characteristics of the battery used in EVs is shown in the figure 5. A battery used in EVs is every so often self-possessed of multiple small, distinct cells placed in a format of series/parallel to obtain the required voltage in the ultimate module. A common module is compiled of blocks of 15-30
cells in parallel connected in series to obtain a required voltage. For example, a 400V module will be having approximately 96 series cells (Tesla Model 3).

![Current Characteristics of a Battery](image1)

**Figure 6.** Current characteristics of a Battery.

The increase in the current demand may be because of the additional electrical loads such as headlamps, wipers, as well as internal heating and cooling. Belligerent driving in a mountainous landscape decreases the driving limit more.

![State of Charge of a Battery](image2)

**Figure 7.** State of charge of a battery

The state of charge versus time shown in the figure 7. State-of-Charge (SoC) is the available capacity of a battery articulated as a measurement of the fully charged capability. An alternative way of the same measurement is the depth of discharge (DoD), the flip side of SoC.
The above curve has two lines in it. The one rising is the drive cycle which is requesting for high speed whereas the other line is the vehicle speed. Where X-axis represents time and Y-axis represents drive cycle.

6. Conclusion
Makers are offering more than 40 models of EVs, a number expected to develop to more than 200 throughout the following two years. An examination by the J.P. Morgan speculation firm observes customary inner burning motor vehicles tumbling from a 70% portion of the market in 2025 to only 40% by 2030. The EV Technology is the combination of vehicle technology and electric technology. Thus, structure amalgamation & optimization are critical factors for the accomplishment of good performance at reasonable cost. Compared to the conventional vehicles EVs are of high primary cost and short driving range. To maximize the consumption of on-board energy storage, a smart energy management needs to be implemented. To enhance the driving limit, numerous energy resources may be integrated for advanced EVs. The conforming hybridizing process should be augmented based on vehicle efficiency and cost.

7. References
[1] Susan Anenberg, George and Joshua Miller 2019 Health impacts of air pollution from transportation sources in Delhi, FACT Sheet: *India, International Counsel of Clean transportation* 5 1-5
[2] Kalpana Balakrishnan, Sagnik Dey and Tarun Gupta, India state-level disease burden initiative air pollution collaborators 2019 The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: The Global Burden of Disease Study 2017 *THE LANCET Planetary Health* 3(1) 1-7
[3] Rachana Vidhi and Prasanna Shrivastava 2018 A review of electric vehicle lifecycle emissions and policy recommendations to increase EV penetration in India *MPDI Energies* 5 1-10
[4] Gelmanova Z, Zhbablova G, Sivyakova, Galina, Lelikova O, Onishchenko O, Smailova A and Kamarova S. 2018 Electric cars. Advantages and disadvantages. *Journal of Physics: Conference Series* 5 1-10
[5] Mitchell L House and David J Wright 2019 Using the health benefits of electric vehicles to justify charging infrastructure incentives *International Journal of Electric and Hybrid Vehicles* 11(2) 1-8
[6] Akhtar Md, Behera, Ranjan and Parida S.K. 2015 Propulsion system design of electric vehicle 10.1109/PESA.2015.7398900 1-5

[7] Zarma, Tahir, Galadima, Ahmadu, Maruf and Aminu 2019 Review of Motors for Electrical Vehicles Journal of Scientific Research and Reports 1-6.

[8] Mudi J, Shiva C K, Vedik B and Mukherjee V 2020 Frequency stabilization of solar thermal-photovoltaic hybrid renewable power generation using energy storage devices Iran J Sci Technol. Trans. Electr Eng. https://doi.org/10.1007/s40998-020-00374-w

[9] Vedik B, Naveen P and Shiva C K 2020 A novel disruption based symbiotic organisms search to solve economic dispatch Evol. Intel. https://doi.org/10.1007/s12065-020-00506-5

[10] Sudhakar A V, B Sathyavani and D Raja Babu 2019 Development of technology for high-power industry converters International Journal of Innovative Technology and Exploring Engineering 8(10) 3130-32

[11] Vidyanandanan, K V 2019 Batteries for electric vehicles Project Report by NTPC

[12] Jung Won, Ismail, Azianti, Ariffin, Mohd Faris and Noor S 2011 Study of electric vehicle battery reliability improvement International Journal of Reliability and Applications 12 123-129

[13] Sudhakar A V, Rajababu D and Sathyavani B 2019 Analysis of the power losses in both DC side and AC side cascaded converters International Journal of Recent Technology and Engineering 8 897-899

[14] Nandi M, Shiva C K and Mukherjee V 2019 Moth-flame algorithm for TCSC and SMES Based controller design in automatic generation control of a two-area multi-unit hydro-power system Iranian Journal of Science and Technology, Transactions of Electrical Engineering 1-24 https://doi.org/10.1007/s40998-019-00297-1

[15] Mudi J, Shiva C K and Mukherjee V 2019 Multi-verse optimization algorithm for LFC of power system with imposed nonlinearities using three-degree-of-freedom PID controller Iranian Journal of Science and Technology, Transactions of Electrical Engineering 43(4) 837-856

[16] Vedik B, Shiva C K and Harish P 2020 Reverse harmonic load flow analysis using an evolutionary technique SN Appl. Sci. 2, 1584 https://doi.org/10.1007/s42452-020-03408-4

[17] Vedik B, Ritesh K, Deshmukh R and Shiva C K 2020 Renewable energy based load frequency stabilization of interconnected power systems using quasi-oppositional dragonfly algorithm J Control Autom Electr Syst. https://doi.org/10.1007/s40313-020-00643-3

[18] Kumar R, Sahu B, Shiva C K and Rajender B 2020 A control topology for frequency regulation capability in a grid integrated PV system Archives of Electrical Engineering 69(2) 389–401

[19] Basetti V, Chandel A K and Subramanyam K B 2018 Power system static state estimation using JADE-adaptive differential evolution technique Soft Computing 22(21) 7157-76 https://doi.org/10.1007/s00500-017-2715-3

[20] Swathi N, Padmaja Ch and Navya Joyothi G 2020 Audio assistive for blind people to identify the cloth patterns and colors Journal of Critical Reviews 7(17) 154-158 10.31838/jcr.07.17.23

[21] Prakash TC, Mamatha M and Samala S 2020 An IoT based under weather monitoring system Journal of Critical Reviews 7(17) 148-153 10.31838/jcr.07.17.22

[22] Kumar CN and Satyanarayana N 2015 Hybrid loss recovery technique for multipath load balancing in MANETs 2nd International Conference on Electronics and Communication Systems ICECS 2015 1294-1301 10.1109/ECS.2015.7124793

[23] Sekhar VM Rao, KVG Rao NS and Chand MG 2016 Comparing the capacity NCC and fidelity of various quantization intervals on DWT Advances in Intelligent Systems and Computing 413 45-55 10.1007/978-981-10-0419-3_6
