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Essential Analysis of Modeling Parameters for the Design of an Electric Vehicle

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ABSTRACT: Electric vehicles possibly ascend as a substitution of internal combustion engine vehicles shortly as they are efficient, produce nearly zero pollution, have the sustainable scope of energy source, quiet, and can be utilized in bidirectional power transfer in V2G configuration. To design and implement an electric vehicle, estimation and computation of modeling parameters are pivotal. Designing and implementing of the electric vehicle are perplexing with the goal that every parameter must be inspected independently. Every parameter ought to be examined independently to maintain a strategic distance from off base ends which will adversely influence the output.The designing of the rating of each particular section is an arduous assignment since the input and output of each module are mutually depended. This shared dependence raises the danger of undesirable cost and mistakes during assembling and implementation. This paper centers around the modeling parameters for an electric vehicle which is relatable to the pragmatic values. The model is structured considering the vehicle type, driveline, engine, power transformation, battery, charging and the extension for the future turn of events.

KEYWORDS: Bidirectional power transfer, driveline

I.INTRODUCTION

Transportation and commercial territory have grown very surprisingly with the pushing forward of the mechanical industry. Car is the most extensively utilized four wheelers all around the globe. It can be classified fundamentally into the IC engine (ICE) type and the electric type. Presently fuel vehicles are not yet replaced by electric vehicles. ICE vehicles have various disadvantages. While looking at the expense of fuel, adaptability and speed, they stand much behind electric vehicles.A generally utilized ICE vehicle has thousands of parts which make it complicated. Innovations are expected to meet the expanding fuel cost and emission standards. Simultaneously, makers should meet the desire for clients without diminishing or meddling economic factors. Electric vehicles can satisfy both client and maker since they can address all the issues that a typical fuel vehicle can't do. It is expected that 500 million electric vehicles (EVs) will be on the roads by 2030 [1]. This paper focuses on analyzing design parameters like driving needs (km everyday), driving behavior (city streets or expressways), charging facilities demanded, etc. Ideally, individuals need a vehicle that utilizes little energy, drives long on a solitary charge, can charge rapidly, can utilize power from renewable sources of energy and obviously, has a low cost. Following the introduction, Section II describes the modeling parameters. Section III presents the calculations for the computation of the proposed model. Section X gives full chart of the system.

II. MODELLING PARAMETERS

- **Car type –** Car type has to be choosen before starting with vehicle parameters. Car can be domestic, commercial, sports e.t.c.
- **Driveline –** The car can be HEV, PHEV, BEV or FCEV. Car type must be identified.
- **Motor –** The type of electric motor we use is an influential factor. They can be induction, permanent magnet, synchronous reluctance etc.
- **Power conversion:** Efficiency of the EV depends on the efficiency of power conversion. For ac charging, both AC/DC (rectification) and DC/DC (buck and boost) conversion are used.
- **Energy source** – Battery selection is a Key factor in modeling. That type (Li-ion, Ni-Mh, other) and size (kWh/AH), the nominal voltage of battery pack etc have to be pre-planned for modeling.
- **Charging:** Charging of the vehicle can be done by inductive/conductive/battery swapping technologies etc. If we choose conductive charging. Again we have options for level 1, level 2, DC supercharging etc. Type of the charger (on-board/off-board) has also to be selected.
- **Future scope –** What all alterations can be adapted in the future and how can we design to guarantee it?

III.SELECTION OF CAR

Determination of the correct vehicle is a persuasive piece of the modeling. There is a variety of alternatives available, which can be intended for various design plans to suit performance, range etc. The first activity is to select the most suitable vehicle. For this contextual analysis, we will pick a household reason four-wheeler. This class is chosen to analyse the commercial and technical feasibility once it is implemented.At the point when a vehicle is chosen, all the detail about it ought to be known. For calculation, the weight of car, acceleration, top speed required, wheel diameter, gear ratio, grade angle, frontal area, rolling resistance coefficient, aerodynamic drag coefficient etc ought to be known for calculation purposes. Battery capacity can be decided clearly with these figuring's. Conditions for estimation is clarified in section 3.

TABLE 1 - SPECIFICATION OF THE VEHICLE

Specification	Quantity
Weight of car (kg)	1400
Acceleration (m/s^2)	2.778
Average speed (m/s)	15
Wheel diameter (m)	0.64
Gear ratio	9
Gradeability	30% (16.7°)
Frontal area(m^2)	1.8
Rolling resistance coefficient	0.011
Aerodynamic drag coefficient	0.2
Air density (kg/m^3)	1.2
Weight of car (kg)	1400
Acceleration (m/s^2)	2.778
Average speed (m/s)	15
Wheel diameter (m)	0.64
Gear ratio	9

IV.DRIVELINE

The force from the engine and transmission to the wheel is conveyed by the driveline. The sort of vehicle must be recognized first. An electric vehicle can be BEV, HEV, PHEV, FCEV etc. BEV or battery electric vehicle will work entirely on battery. The battery pack can be energized through an outside power source.AC or DC charging can be utilized for this.HEV stands for the hybrid electric vehicle. It represents the half breed electric vehicle. It will have the qualities of both the ordinary vehicle and EV. It is overwhelmingly an inward ignition motor vehicle where the battery helps in improving performance and in low speeds.In HEV battery will be recharged from regenerative braking and through the IC engine (ICE). PHEV is the abbreviation of the plug-in hybrid vehicle. As the name suggests we can plug-in PHEV for reviving the battery. It has a lot greater battery capacity contrasted with HEV. It can run as either BEV or ICEV or both. FCEV or fuel cell EV runs on power produced by the response between compacted fluid hydrogen and air inside the power module stack. For this contextual analysis, we are picking BEV**.**

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V. MOTOR

EV will have an electric motor instead of an internal combustion engine. A large battery pack will be used to power the electric motor. This battery pack can be recharged through electrical outlets and charging stations. We can use different motors like PMSM, Induction motor, Synchronous reluctance motor e.t.c. for the operation. Specifications of the motor chosen for the case study is given below.

TABLE 2 - SPECIFICATION OF THE MOTOR

Specification	Quantity
Motor Type	Permanent Magnet Synchronous Motor(PMSM)
Motor Torque	276 N-m
Motor Power	95 kW

VI. POWER CONVERSION

We are assuming the nominal voltage of the battery pack as 320 V. That is we should require a voltage more than 320 V to charge the battery. Assuming we are utilizing a level 2 charger, input voltage is 230V AC. That is, we will get 325 V DC around, which isn't sufficient. So after amendment, we need to help that. Here a rectifier (AC-DC), and boost converter (DC-DC) is utilized. To turn on the motor which is AC, we need to change over the DC from the battery to AC. For this inverters are utilized.Hence practically all converters are used in an electric vehicle particularly for battery charging. We can choose different charging topologies to design a battery charger which might be On-board or off-board type. Rectifiers, for example, PWM rectifiers with IGBT/MOSFET can be utilized to convert AC to DC.V2G configuration has bi-directional power transfer contrasting with the ordinary electric vehicle. For the contextual analysis, we are utilizing a level 2 AC single-phase charger with an on-board charging setup. So we will have a rectifier to convert AC-DC charging. Power conversion in electrical engineering is converting electrical energy from one form to another. There are 4 basic power conversions. AC-AC, AC-DC, DC-DC and DC-AC.

TABLE 3. POWER CONVERSION

Conversion	Circuit
AC-DC	Rectifier
DC-DC	Chopper
DC-AC	Inverter
AC-AC	Cycloconverters

VII.ENERGY STORAGE

Battery or battery pack in EV is a gathering of cells or battery modules managed to create a required voltage. Tesla Model S have 7104 cells directed in 6 gatherings of 74 cell every which is part into 16 modules. Every cell may have a voltage of volts. Huge variety of battery types is accessible. Specification of the battery for the analysis is given in table 4

TABLE 4. Specification of battery pack

Specification	Value
Battery Type	Li-ion Type
Battery capacity(AH)	95 AH
Nominal Battery Voltage	320 V
Battery Capacity(kWh)	30 kWh
Average Current demanded by EV	23.1 A

VIII.CHARGING OF BATTERY

Charging should be possible through conductive, Inductive or Battery swapping approach. Conductive is the typical way where we charge batteries utilizing electric wires. In inductive charging, we are utilizing the rule of electromagnetic induction to charge it. Battery swapping is done at charging stations. Emptied batteries out of EV will be replaced by a completely energized battery pack in the charging station.

Conductive charging is a broadly utilized strategy. Electric vehicle charging should be possible by utilizing either the On-Board charger (OBC) or OFF board charger. In On-board charger, charging hardware will be in the vehicle itself. We can legitimately plug it into the power socket. An off-board charger, the circuitry will be outside the vehicle. The charger will be fixed in-home or charging stations. Electric vehicle charging station/Electronic charging station (ECS)/Electric vehicle flexibly equipment (EVSE) is the framework that deals with the power supply to all off-board charging EV. Off-board charging EV can be charged only through these particular outlets. Battery management system (BMS) will communicate with the charging station for proficient and safe charging of batteries.

Charging of EVs using a cable can be done today with AC or DC charging [2].Large penetration of EV can lead to increase in the peak demand on the grid and possible overloading of distribution network assets [3], [4]. Measures have to be taken for balance the distribution system. For charging at home or work, some EV will have an on-board charger. The simplest way to charge EVs is to use the onboard AC charger, which is an AC/DC converter with isolation [5]–[8]. The converters will be inside the vehicle itself. We can legitimately plug EV to the socket. The converters inside the vehicle will convert the power to appropriate measure through BMS standards. Level 1 and level 2 charging should be possible straightforwardly from the household electrical plug. It works with 120 V AC and 230 V AC.DC supercharging is done at a higher force level (>50 kW). It was introduced in order to facilitate faster charging of EVs (up to 350kW) and to overcome the weight and size limitation of an onboard charger [5], [9]. For the case study, we are picking Level 2 AC charger for an On-board charging EV.

Table 5 – AC/DC charging plugs, power levels in Europe and USA [5]-[8]

Plug	Number of pins	Charging level	V,I,P
Type 1 SAE J1772 USA	3 Power pin –L1,N,E 2 Control Pins –CP,PP (PWM over CP)	AC Level 1	≤ 1φ 120v 16A, 1.9 kW
		AC Level 2	≤ 1φ 240v 80A, 19.2 kW
Type 2 Mennekes Europe	4 Power pins –Ll.L2,L3,N,E 2 Control pins - CP,PP (PWM over CP)	AC Level 1	≤ 1φ 240V 32A, 7.4 kW
		AC Level 2	≤ 3φ 400v 63A , 43kW

Type 4 Chademo	3 Power – DC+, DC-, E 7 Control pins – CAN communication	DC Level 3	≤ 200-500V 400A,200kW
SAE CCS Combo	3 Power – DC+, DC-, E 2 Control pins - CP,PP (PLC over CE,PE)	DC Level 3	≤ 200-1000V 350A,350kW
Tesla US	3 Power – DC+, DC-, E (or) L1,N,E 2 Control pins - CP,PP	DC Level 3	≤ Model S 400V 300A, 120kW

TABLE 6 - EV WITH BATTERY TYPE, RANGE AND CHARGE TIME

MODEL	**BATTERY**	**Charge Times**
Toyota Prius PHEV	4.4kWh Li-ion	3h at 115VAC 15A; 1.5h at 230VAC 15A
Chevy Volt PHEV	16kWh, Li-manganese/NMC, liquid cooled, electric range 64km	10h at 115VAC, 15A; 4h at 230VAC, 15A
Mitsubishi iMiEV	16kWh, Range 128km	13h at 115VAC 15A; 7h at 230VAC 15A
Smart Fortwo ED	16.5kWh – Range 136km	8h at 115VAC, 15A; 3.5h at 230VAC, 15A
BMW i3	42kWh, LMO/NMC, Range 154, 215, 178 miles	11kW on-board AC charger; ~4h charge; 50kW DC charge; 30 min charge.
Nissan Leaf*	30kWh; Li-manganese, Range 250km	8h at 230VAC, 15A; 4h at 230VAC, 30A
Tesla S*	70kWh and 90kWh, Range 424 Km	9h with 10kW charger 120kW Supercharger 80% charge in 30 min
Tesla 3	75kWh battery, Range 496km	11.5kW on-board AC charger; DC charge 30 min
Chevy Bolt	60kWh, Range 383 km	40h at 115VAC, 15A; 10h at 230VAC, 30A 1h with 50kWh

IX. FUTURE SCOPE

Electric vehicles will supplant IC motor vehicles within few years.Wireless power transfer, Battery swapping technology and Energy from renewable sources are the hot spots in the topic.An inductive power transfer(IPT) framework can be utilized to transfer power remotely from a primary source to secondary at agreeable distances. Inductive charging heads over conductive since it can use when vehicle is static, dynamic and in all weather conditions.

The possibility of electric arc and shock can be prevented through inductive charging. Dynamic charging is generally accomplished by having rehashed charge pads on the road. Initial expense is high for IPT contrasted with conductive mode.

The battery swap works on the basis of switching out the depleted battery and replacing the same with a full battery. Once the car went to the battering swapping bay, automated systems will replace depleted battery with fully charged battery pack. The depleted batteries will be later charged at the station.We can use renewable sources to power our car. Major source of energy are wind and solar. The Wind energy from the wind farms have to transported to the charging stations which then will be used for charging EV. The Megawatt rating solar have to be converted to the standards of EV. Wind production will be maximum in night time.

Solar panels can be installed in rooftops which s much close to charging point. Energy produced from solar panels will be maximum during day time.A fully functional EV which is powered only from solar panels is possible to design. EVs can likewise lessen the outflows that add to environmental change and exhaust cloud, improving general wellbeing and diminishing biological harm. Charging your EV on the sustainable power source, for example, sun based or wind limits these discharges significantly more.

X.CALCULATIONS

A. Total Tractive Effort

$F_{total} = F_{rr} + F_{g} + F_{aero} + F_{accel}$

Table 7. Calculation of Force

Quantity	**Formula**	**Value**
C_{rr}	0.01(1+V/147)	0.011
F_{rr}	$MgC_{rr}\sin\theta$	43.412 N
F_g	$Mg\sin\theta$	3946.609 N
F_{aero}	$½\rho C_d AV^2$	48.6 N
F_{accel}	1.05Ma	4083 N
F_{total}	$F_{rr} + F_{g} + F_{aero} + F_{accel}$	8121.621 N
C_{rr}	0.01(1 + V/147)	0.011
F_{rr}	$MgC_{rr}\sin\theta$	43.412 N
F_g	$Mg\sin\theta$	3946.609 N
F_{aero}	$½\rho C_d AV^2$	48.6 N

F_{rr} – Rolling Resistance Force
F_g – Grade Resistance Force
F_{aero} – Aerodynamic Drag
F_{accel} – Accelerating Force
P – Air Density
C_{rr} – Coefficient Of Rolling Friction
C_d – Coefficient of Aerodynamic Drag
V – Velocity assumed

B. Motor Torque and Power

Table 8. Motor power and calculation

Quantity	Formula	Value
T_{motor}	$(0.5d_{wheel}\ F_{total})/G$	288.76 N
ω_{wheel}	$vG/(0.5d_{wheel})$	421.875 rad/s
T_{power}	$\omega_{wheel}\ T_{motor}$	121.82 kW

T_{motor} – Motor Torque
ω_{wheel} – Motor Speed
T_{power} – Motor Power

C. Determination of top speed

Nominal DC batter voltage =250 V
Specific load motor speed = 28 RPM/1 V at full load
Maximal motor RPM = 250×28 = 7000 RPM
Maximal wheel rotating at full load = 7000÷9= 777.77 RPM
Wheel circumference = 2×3.14×0.32 = 2.0096 = 2.001
V_{max} = (778×60×2.001)÷1000 = 93.40 kmph

D. Battery capacity

Let energy efficiency in ambient conditions = 260 Wh/mile
Required Range = 200 km = 124.27 mile
Wh per mile / pack voltage = 1.04 Ah/mile
Battery capacity required = 1.04×124.27 ×1.2(To get 20% charge left on battery) = 155.088 AH
Battery capacity in kWh = Battery capacity in Ah × Nominal battery pack voltage

Battery capacity (kWh) = 250 × 115.088 = 38.772 kWh

XI. FULL CHART

Weight of car	1400 kg
Acceleration(0-100 km)	10 second
Top speed	93.4 km/hr
Wheel diameter	64 cm
Gear ratio	9:1
Gradeability	30%
Frontal Area	1.8 m^2
Average rolling resistance force	43.412 N
Average aerodynamic drag	48.6 N
Motor Type	Permanent Magnet Synchronous Motor(PMSM)

Motor Torque	290 N-m
Motor Power	122 kW
Battery Type	Li-ion Type
Battery capacity(AH)	155 Ah
Nominal Battery Voltage	250V
Battery Capacity(kWh)	38 kWh
Range	300 km

XII.CONCLUSION

The electric vehicle will supplant ICE vehicles in the coming future. BEV, HEV, PHEV and FCEV work distinctively and can be utilized in various situations. By modeling the design parameters, we will have the option to implement a profoundly productive EV. We have considered vehicle type, driveline, motor, power conversion, battery, charging and the future scope for analysis. Calculations considering the modeling parameters is explained in the paper. The future extent of electric vehicles incorporates using renewable sources of energy and execution of inductive charging.

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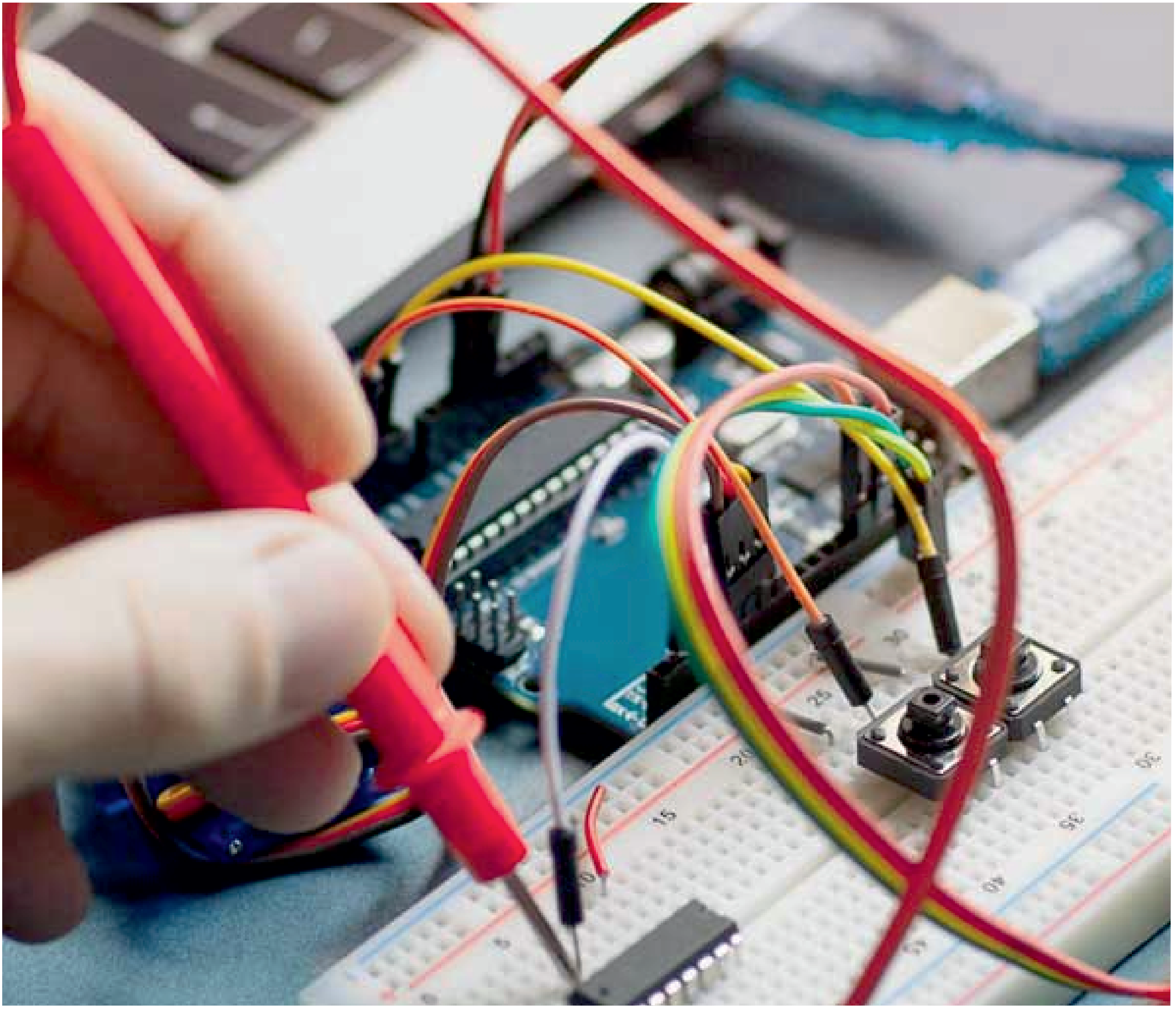
BIOGRAPHY

Vaisakh Mohan is currently pursuing his B Tech degree in Electrical and Electronics Engineering at Government Engineering College Thrissur. His current project is "Symmetrical multi-level inverter with minimum switches for motoring and regeneration of induction motor for EV"



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