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Electric Traction Motor Peak Power Estimation Strategies for Electric Vehicle Application

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Abstract
The electrified automotive vehicles are pollution free mobility and those are referred as eco-friendly mobility. In the electric vehicle, different subsystem of motor, Controller and battery are included. During the design electric vehicle, the important subsystem part to be chosen is an electric motor as because as it plays major role in an electrified vehicle. The electric motor used in an electrified vehicle need to create vehicle demanded traction power and torque that are necessary for vehicle traction requirement. The key role is to calculate an appropriate power of motor based on the dynamic load to be pulled. This paper explains the strategies for calculation of power of electric motor with an examples of Brushless Direct Current motor for an electric vehicle. The vehicle dynamics is derived for selecting the appropriate proper electric motor subsystem that would provide necessary power, torque for the traction demanded. In addition to that, proper calculation of power rating required also involves in finalizing Motor characteristics towards torque and speed, Power and speed curves. Hence, to meet all the tractive characteristics of the motor performance, the Dynamic load of the vehicle is derived and considered for the BLDC Motor power calculation.

Key words: Electrified Vehicle, Vehicle dynamics, Traction effort, BLDC, Motor specification.

Introduction

The electrical vehicle has the multiple subsystems called Power source, Motor, Controller and Vehicle controller. The power source is the energy supply system which is used to supply the required energy to drive the motor for driving the vehicle. Motor is the electromechanical device which is used to draw the electrical energy and produce the mechanical power to the vehicle. Different type of motors available for various applications. Automotive application used Motors are few types such as Brushless permanent magnet, permanent magnet synchronous motor, switched reluctance motors, Induction motor, these are the type of motors available with various sizingand layouts. An automotive industry is looking for the optimized motor which will be suitable for the vehicle drive application aspects[2]. The performance of the vehicle is directly depending on the motor performance and its long run requirements. The electric propulsion system has multiple subcomponents start from wheel to Motor controller[3] as shown the Fig. 1. Electric propulsion subsystem.

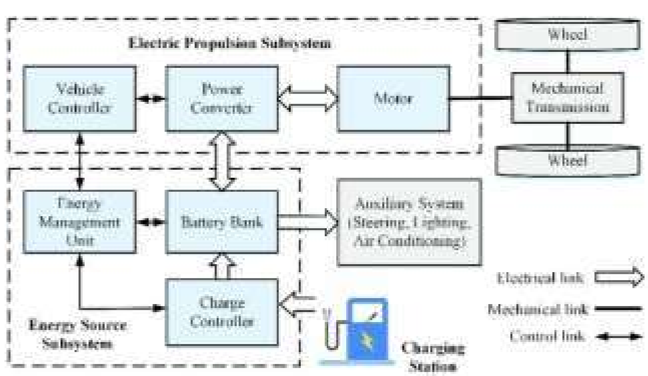


Fig. 1. Electric propulsion subsystem.

The requirements of the motor is fully depends on the vehicle demands for the various drive situations. The vehicle run under many load conditions which are taken care by the motor performance to meet the load requirements. The contest of motor design depends on the various strategies in which the strategies are as follows.

Vehicle Behavior: The parameters of the vehicle like Package, mass, GVW and aerodynamics are the critical vehicle characteristics which will narrow down to determine Power, speed, torque demand of the electrified vehicle motor. This parameter will support to understand the influence of the operating scenario of the vehicle. This are key for the selection of the optimized powertrain.

Vehicle drive cycles: The various use case of vehicle being used for long run to meet the reliability

requirements and that will be driven in an urban area and city route which includes or few stops. These use case define the vehicle configuration and other sub system like battery pack which influence Motor design.

Vehicle Arrangement: Vehicle configuration has the different architecture of parallel and Series or Hybrid which the vehicle construction arrangement influence the Motor design based on the drive route. The vehicle when the route is not predictable or driven for long period of run time mostly preferred for the hybrid concept[2]. The complete electrified configuration is most chosen for in city driving where the travel route is not too far between stopping points, the speed of the vehicle is less and the number of stops is more. The different architecture for the vehicle concepts is shown below Fig.2 Vehicle
arrangement.

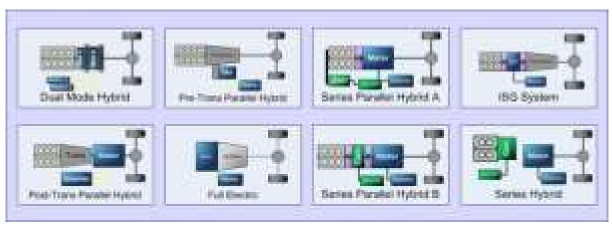


Fig.2 Vehicle arrangement.

Maximum Speed: The expected maximum speed of the vehicle will be decided based on the continuous run with drive mode or sport application[5]. The gearbox ratios, differential ratio and the rolling radius of the tire wheel define the estimate the maximum speed the electric motor for application.

Maximum Torque: The peak torque creates the vehicle to support for the drive cycle and the highest slop the vehicle will travel to claim. Using that slop, peak torque is to be calculated of the required torque for the electric motor in combination with the differential or gearbox. These are explained as shown
the Fig.3 Force diagram.

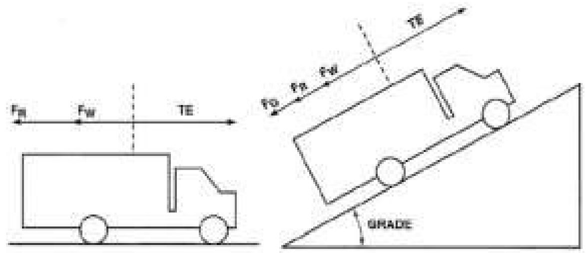


Fig.3 Force diagram.

Maximum power: The slope needs to be achieved by climbing force at a minimum speed required. The maximum power is calculated at maximum speed where the vehicle has a wider frontal area at highest speed. This situation to be more suitable for powerful motor for all the different drive cycle conditions.

The maximum power creates the vehicle to attain and maintain a constant speed under steep slope and speed conditions. The calculation of the maximum power depends on the aerodynamic drag parameter and friction coefficients parameters that are needed for the slope travel climbed.

Battery Voltage and Capacity: The battery voltage is directly proportional to the capacity of the vehicle sizing. As the battery voltage rises, the current release is less. This is the situation where the vehicle continuous power is demanded more in the larger vehicles, that to maintain the size of the cable at a manageable level by maximizing the the battery voltage. The battery capacity is significantly calculated using a simulation to standard specified drive cycle for the drive pattern of the vehicle. The simulation can help in predetermine the power consumed economy of the vehicle in kWh/km.

II. VEHICLE DYNAMICS AND STRATEGIES:

Motor power calculation is very critical for the electric vehicles which supplying the power and torque for the vehicle to perform on the road. Vehicle running on the road has the multiple load which must be overcome the various loads. The following flow chart is the strategies for design the electric motor for the vehicles.

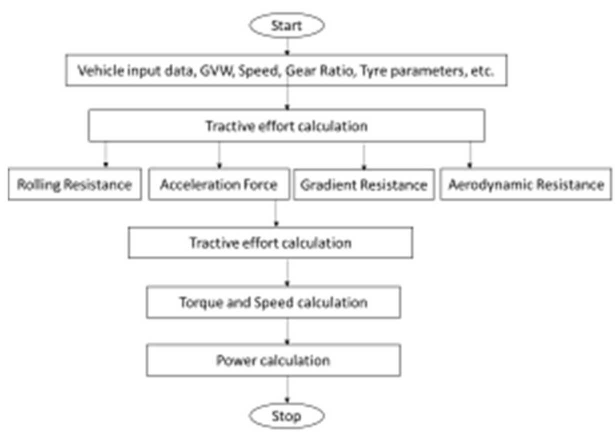


Fig.4 Flow chart

Asper the vehicle dynamics, the force acting on the body of the vehicle are start from the wheel resistance which give wheel to tire resistance force. The vehicle receives the Aerodynamic drag force due to the speed of the vehicle. When the vehicle goes in the climbing or slop then the body receives the gradient force[1]. These forces are being considered for the calculation of motor power of the electric vehicles which plays the key role in choosing the maximum power and torque of the vehicles. The force acting on the body explained as shown the Fig Vehicle force diagram.

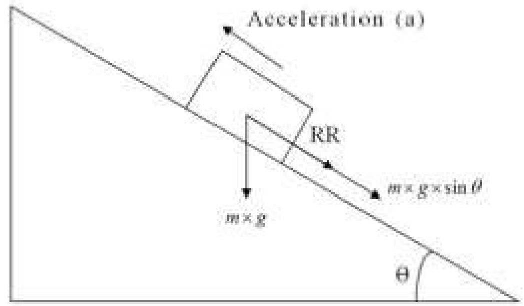


Fig.5 Vehicle force Diagram

1. **Rolling Resistance**

The Rolling Resistance is the resistance force that the vehicle has to overcome due to the motion of the vehicle between the vehicle wheel tire and the road surface. The rolling resistance force is proportional to the co-efficient of rolling friction which varies with respect to the material of wheel tires and theroughness of the surface of motion as shown the Table 1 . co-efficient of rolling friction. The Rolling resistance can be calculated as below equation (1).

Contact Surface	C_{rr}
Concrete(good/fair/poor)	0.010/0.015/0.020
Asphalt(good/fair/poor)	0.012/0.017/0.022
Macadam(good/fair/poor)	0.015/0.022/0.037
Snow(2 inch/4 inch)	0.025/0.037
Dirt(smooth/sandy)	0.025/0.037
Mud(firm/medium/soft)	0.037/0.090/0.150
Grass(firm/soft)	0.055/0.075
Sand(firm/soft/dune)	0.060/0.150/0.300

Table.1 Co-efficient of rolling friction

2. **Gradient resistance force**

Grade Resistance force is the force required to move a vehicle on the slope in uphill direction and some time it is known as Gradeability[4]. This calculation must be made using the peak or maximum angle or grade the vehicle will be expected to climb in normal operation. This is calculated as below equation (2).

3. **Acceleration force**

Acceleration force is the force which support the vehicle to reach a targeted speed from the starting of the postion in a specified period. The motor torque has a directly proportional with the acceleration force. Optimized torque is support for the lesser the time required by the vehicle to reach a given speed. The acceleration force is a function of the mass and the its own specific acceleration of the vehicle. This is calculated as:

4. **Aerodynamic resistance force**

5. **Total Tractive force:**

Total tractive force is the force required to move the vehicle at various load conditions that the vehicle undergo different road conditions with vehicle speed [8]. This can be written as follows.

Aerodynamic drag force is the resistance force offered due to viscous force acting on a vehicle. It is determined by the shape of vehicle. Drag coefficient is the factor which is depends on the Vehicle body surface friction and Velocity. Fontal area of the vehicle is defined by the area hitting the air resistance during the vehicle in movements as hsown the **table**
2. Coefficient of Drag and Frontal area. The formula for calculating aerodynamic drag is given by below equation (4).

Vehicle	C_D	A_f
Motorcycle with rider	0.5-0.7	0.7-0.9
Open convertible	0.5-0.7	1.7-0.9
Limousine	0.22-0.4	1.7-2.0
Coach	0.4-0.8	6-10
Truck without trailer	0.45-0.8	6.0-10.0
Truck with trailer	0.55-1.0	6.0-10.0
Articulated vehicle	0.5-0.9	6.0-10.0

Table.2 Coefficient of Drag and Frontal area

6. Wheel torque derivation:

Torque of the vehicle is derived from the tractive effort and wheel radius. The tractive force is the force required to pull the vehicle and the radius of the wheel support to improve the effort for the Torque advantages.
The vehicle dynamics parameters calculations for wheel torque are using the wheel radius as parameter. Vehicle tire markings is the reference for the calculation of radius[9]. With use of the size marking of the tire, the calculation can be done for the free static wheel radius. When there is no load applied on the wheel is free and when there is a wheel is stationary means static. The reference size marking of a tire is defined as:

Width of the Tire [mm] / Aspect Ratio [%] – Type of the Construction - Diameter of the Rim [in]

The aspect ratio (AR) is defined in percentage, as the ratio between tire sidewall height and tire width.

where: AR–aspect ratio

H – Wall height of the tire side W – Width of the tire

D – Diameter of the Rim

The deformation of the tire, a coefficient of 0.95, which means that the free static radius will decrease with approx. 5% under load of vehicle weight is referred for the calculating the Radius of the wheel. As referred, static radius of the wheel be:

ELECTRIC MOTOR POWER SIZING

Permanent magnet BLDC motors uses permanent magnets without the rotor windings wires as shown the Fig 6. (a) Electric motor. Since Permanent magnet BLDC is not include rotor losses in efficiency is more than other motors. Permanent magnet BLDC motors have a small constant power operation region because of their permanent magnet field weakened by a stator field as shown the Fig 7. Electric traction- Characteristics. Since EVs requires a wider constant power region, this can be extended by using advance angle control where the speed range may reach two to to four times the base speed of the Motor characteristics [6].

Switched Reluctance Motors is a type of variable reluctance motor with dual saliency as shown the fig 6 (b) Electric motor. Switched Reluctance motors are very easy in construction and but robust. The rotor of the SRM is a piece of laminated steel without windings or permanent magnets on it. This makes the inertia of the rotor less which helps in high rotational speed. This is the reason that SRM is well suit for the highspeed application. SRM also not limited to high power density which are most required characteristics of Electrified Vehicles. Since the heat generated is critical and it mostly generated in the stator, it is easier to cool the motor. The biggest drawback of the SRM is the complexity in control and increase in the switching circuit [6]. It also has some noise issues.

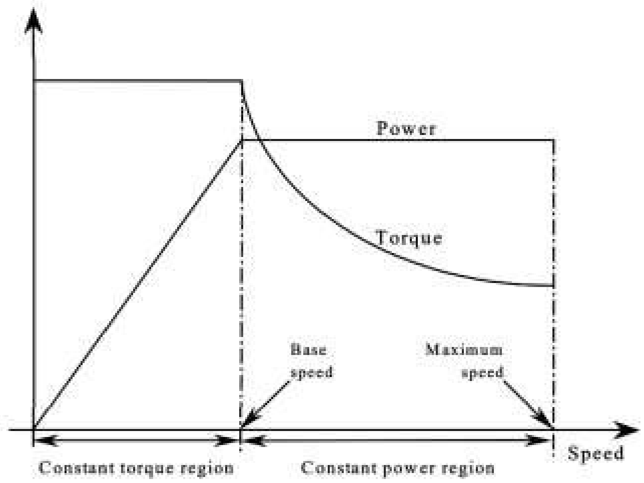


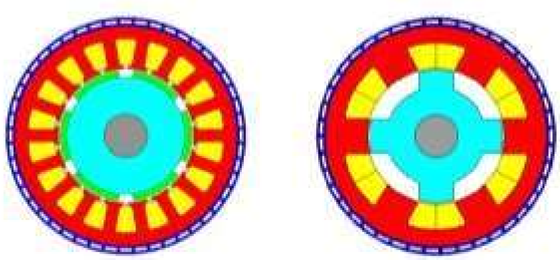
Fig 7. Electric traction- Characteristics.

Drive case for the Maximum power and Torque calculation:

When the vehicle run at flat road, the gradient is zero then the Gradient force become zero in the drive case. The other forces of rolling resistance, Aerodynamic and Acceleration forces are existing in the drive case[6]. So the traction force becomes

The above equation is forming the Peak torque or power of the Vehicle requirements.

Let us consider the typical specification for 2- wheeler, 3-wheeler, and 4-wheeler vehicle requirement for sizing the power of the traction motor.



(c) PM brushless motor. (d) Switched reluctance motor.

Sr.No	Parameters	Units	Specification	Specification	Specification
	Vehicle segment		2W	3W	4W
Input data	Gross Vehicle Weight	Kg	248	650	1750
	Max Speed	Km/h	80	50	120
	Speed to Max acceleration	Km/h	60	40	100
	Acceleration in seconds to reach Max Speed	Sec	10	10	9
	Grad angle	Degree	8	8	10
	Aspect Ratio	%	90	90	215
	Section width	mm	90	90	60
	Rim Diameter	Inch	12	12	16
	Transmission Gear Ratio	[-]	3.3	10	9.1
	Frontal area Effective Height	mm	1.14	1.6	1.4
	Frontal area Effective Width	mm	0.6	1.2	1.81
	Frontal Projected Area	m^2	0.684	1.92	2.534
	Tire Rolling Resistance Coefficient	[-]	0.02	0.02	0.02
	Aerodynamic Drag Coefficient	[-]	0.48	0.48	0.82
	Tire Dynamic Rolling Radius	m	0.229	0.229	0.328
	Air density	Kg/m3	1.225	1.225	1.225

Table 3. Electric traction- Characteristics.

For the 2 wheeler, Calculation procedure is explained as below,

Calculated Rolling resistance force
( ) = 49N

Calculated Aerodynamic resistance force
is – ( )

Acceleration force ( )
= 414N

Total force calculated for the given vehicle data of drive Case 1 is 517 N

The vehicle maximum velocity is calculated based on the maximum speed of the vehicle and the acceleration is calculated by dividing the time to reach the maximum speed. Typically for 2-wheeler is
1.67 m/s2 for 60kmph as calculated. Wheel radius is calculated from the above equation (8) is 0.229mm and circumference of the wheel is calculated from the above equation (9) is 1.44mm. these are the input to calculate the Wheel rpm with Vehicle velocity divide by the Circumference of the wheel is 926 rpm as shown the Table 4. Vehicle dynamics results. The tractive force for the two, three and Four wheeler are calculated as per the table inputs considering the Rolling resistance, Aerodynamic resistance and Acceleration force together as shown in Fig 8. Vehicle segments and Forces.

Sr.No.	Parameters	Units	Specification	Specification	Specification
	Vehicle segment		2W	3W	4W
Vehicle Dynamics	Vehicle Maximum Acceleration	m/s^2	1.67	1.11	3.09
	Max Wheel Torque	Nm	139	210	2192
	Max Vehicle speed	m/s	22.22	13.89	27.78
	Max Wheel rpm	rpm	926	579	815
	Tire Rolling Resistance	N	49	127	339
	Gradient Resistance	N	139	888	2981
	Aerodynamic Drag Resistance	N	54	67	983
	Acceleration force	N	414	722	5408
	Tractive Force for Peak Power at Flat road	N	517	916	6730

Table 4. Vehicle dynamics results.

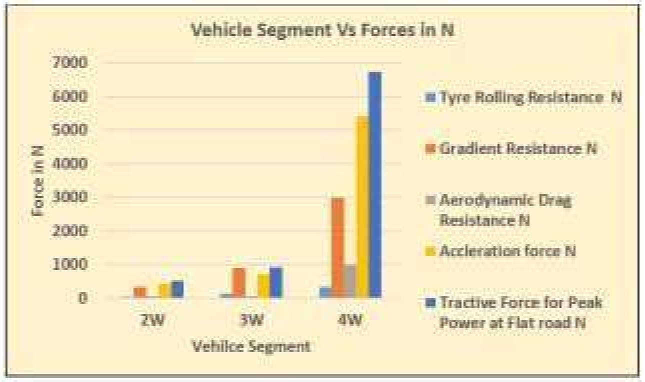


Fig 8. Vehicle segments and Forces.

From the calculated traction force and radius of the tire, the Torque required for the Motor is calculated after the Gera ratio considered for the Motor Maximum torque that is 22Nm for 2 wheeler.
Similarly, for 3 wheeler and 4 wheeler calculated as shown in the Table.4 Motor characteristic results.

Sl. No	Parameters	Units	Specification	Specification	Specification
	Vehicle segment		2W	3W	4W
Motor	Max Motor Torque	Nm	22	21	241
	Max Motor rpm	rpm	5093	5790	7417
	Max Motor Power	KW	5.5	6.1	89

Table 4. Motor characteristic results.

Motor characteristics for the given vehicle input data has been calculated and plotted for the 2 wheeler , 3 wheeler and 4 wheeler respectively as shown the Fig
9. Motor characteristics for 2W, Fig 10. Motor characteristics for 3W and Fig 11. Motor characteristics for 4W. The base speed of the motor is calculated from the plot for all the vehicle segments of 2 wheeler and 3 wheeler and 4 wheeler.

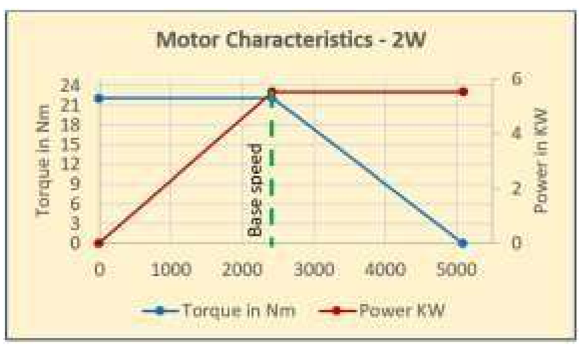


Fig 9. Motor characteristics for 2W.

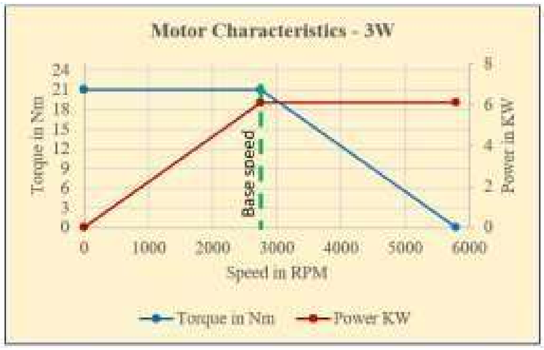


Fig 10. Motor characteristics for 3W.

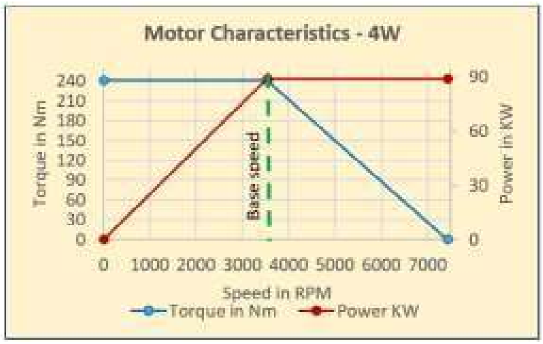


Fig 10. Motor characteristics for 4W.

III. CONCLUSION:

In the electric vehicle, Motor is playing the vital role for moving the vehicle by engaging the drove unit to wheel physically. The design for the traction motor is challengeable when drive cycle is unknown. During this situation the Traction motor is determined by the Vehicle dynamics parameters which include the Resistance force and Acceleration forces according to the nature of vehicle usage. The methodology for calculating the Power and torque of the traction motor is explained and Motor characteristics for 2 wheeler, 3 wheeler and Wheeler is calculated. Constant power and Constant tor region is the characteristics of the traction motor of either BLDC or PMSM motor which has the Base speed in which the operating speed is decided and that has been plotted. The above approach is derived based on the Vehicle dynamic load and Vehicle parameters specific to the Configuration of the vehicle. Hence the Torque and power calculation procedure is established for Electric vehicle and demonstrated

with Vehicle input data for the various configurations.

IV. REFERENCES:

1. Prof. Mahesh S. Khande "Design and Development of Electric scooter", Electrical department, e-ISSN: 2395- 0056.

2. Katic VA, Dumnic B,C orba Z, et al. Electrification of the vehicle propulsion system – an overview. Facta Universit Ser: Electron Energ 2014; 27(2): 299–316.

3. K.W.E Cheng, "Recent Development on Electric Vehicles", Department of Electrical Engineering, The Hong Kong Polytechnic University, Hong Kong. June 2009.

4. Hitesh S, C. Sunanda, "Modeling and Performance Analysis of an Electric Vehicle with MATLAB/Simulink", Electrical department, e-ISSN: 2395-0056.

5. Prof. Rupesh S. Patil, "Analysis of Electric Vehicle Drive Train", Electrical department, p-ISSN: 2395-0072.

6. Aaditya G. Samant1, "The Calculation of Electric Motor and Lithium Battery Capacity of IIRED E-BIKE", Electrical department, ISSN(Online): 2581-7280.

7. Hayrettin Gökozan, "Traction Motors and Motor Drivers Used in Electric Vehicles" European Journal of Science and Technology No. 19, pp. 105-111, August 2020.

8. Bekheira Tabbache, “A Power Presizing Methodology for Electric Vehicle Traction Motors” HAL Id: hal- 00874371, Submitted on 17 Oct 2013.

9. Adeel Saleem1, “Modelling of an Electric Vehicle for Tractive Force Calculation Along With Factors Affecting the Total Tractive Power and Energy Demand” 2020 3rd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET)