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Optimization of Required Power for an Electric Vehicle

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Abstract — *With an increase in pollution in the past decade, there has been a need for an alternative (EVs) to the conventional gasoline powered vehicles. Keeping in mind to reduce the vehicle mass, an optimal design is developed for the powertrain of electric vehicles (EVs) to reduce the power consumption while providing constant efficient performance. Based on a prototype EV, the paper takes minimum gross vehicle weight as design principle. The superiority of the design is proved by comparing of the optimization results with the original values.*

***Keywords* —** Electric vehicle, Brushless DC motor, Optimal design, Power consumption

1. INTRODUCTION

India is currently the fourth largest emitter of greenhouse gases in the world. Opportunities exist to mitigate greenhouse gases emissions and make India's transport growth more sustainable and climate compatible by aligning development and climate change agendas. The National Electric Mobility Mission Plan was announced recently to incentivize use and production of electric vehicles in India with a view to mitigate adverse environmental impacts of vehicles and to enhance energy security. In this context EV's are expected to play a significant role in low carbon transition of India. Electric Vehicles are defined as vehicles which use an electric motor for propulsion. The electric vehicle has many components like charging module, converters, controllers, batteries, electric motor [1]. The electric motor selected for driving a vehicle must have the ability to provide sufficient power and torque to overcome the force due to load and other opposing forces acting on the vehicle.

2. CALCULATIONS

2.1 The Design Constraints

This paper will aim to develop an optimal design of power system to realize energy saving while ensuring dynamic performance. BLDC (Brushless DC) motor has been selected as the driving motor because of its qualities of high efficiency and varied range of speed. We have selected the Lithium Ion battery as the power supply for its high energy density. Based on a prototype EV's power system, the design should keep accordance with original basic parameters. [2]

Parameters	Value
Gross Vehicle Weight	500kg
Windward Area	1.92m
Co-efficient of Friction (f)	0.03
Drag Co-efficient (c)	0.3
Wheel Radius	280mm
Maximum Speed	35km/h

Table -1: Basic parameters required for an electric vehicle

We took dynamic index as the breakthrough point, and the constraints include the single charge-driving mileage and whole life cycle driving mileage of battery pack, which respectively represent the economy and cost constraints. The performance requirements are shown as follows.

2.2 The Prototype Vehicle's Needs of Peak Power

The motor's peak power should satisfy vehicle's dynamic needs. As vehicle works at a constant speed, the main resistance comes from air and friction. Based on the vehicle dynamic equation, the power demand is calculated as follows. [3]- [6]:

1. Air Resistance (R_a)

Whenever a body is moving it has certain amount of resistance due to air. The resistance offered by the air to the movement of vehicle is called air resistance. It depends on following.

1. Density of air
2. Size and shape of vehicle body (area)
3. Aerodynamic drag coefficient (Cd)
4. Velocity of vehicle
5. Acceleration due to gravity

$R_a = \frac{c\rho A V^2}{2g}$ N

A = Windward Area
V = Vehicle Speed
c = Drag coefficient
ρ = Density of Air

Windward Area

A = (H-C)*L
Where,
H = Height
L = Width
C = Ground clearance

For passenger cars A = 1.7 to 2.0 m^2

2. Rolling Resistance (R_r)

To resistance offered by the road surfaces to move the vehicle is called as road resistance or rolling resistance. It depends on the following.

1. Nature of road surface
2. Type of tire (pneumatic or solid rubber)
3. Weight of vehicle
4. Vehicle speed

R_r = W*f*g N
Where,
W = Gross vehicle weight
f = Co-efficient of friction

3. Gradient Resistance (R_g)

The resistance offered by a grade to move up of a vehicle is called as a gradient resistance. It depends on grade slope.

$R_g = W*\sin\theta$ N
Where,
θ = Angle of slope
W = Gross vehicle weight

4. Total Resistance

Total resistance is the sum of all resistance, like air resistance, gradient resistance and rolling resistance.

$R = R_a + R_r + R_g$ N (Gradient Road)
$R = R_a + R_r$ N (Level Road)

5. Vehicle Acceleration

Assume maximum acceleration from vehicle data it is 0.9 to 1.05 m/s^2 for the vehicle which is having maximum vehicle speed 35 km/h. The maximum acceleration always occurs at 1/3 of maximum vehicle speed. The acceleration of the vehicle at maximum speed is zero.

The Excess Driving Force

$$EDF = \frac{W}{g} * \frac{a}{Ka_{cc}} \quad N$$

Where,

W = Gross vehicle weight

a = Acceleration

Ka_{cc} = Acceleration constant

g = Acceleration due to gravity

6. Driving Force

$$DF = EDF + R_T \quad N$$

Where,

EDF = Excess driving force

R_T = Total resistance

7. Power Required By the Vehicle

A driving horsepower at road vehicle is proportional to the total resistance and the EDF to give the required acceleration.

$$P = \frac{DF * V * 1000}{3600} \quad kW$$

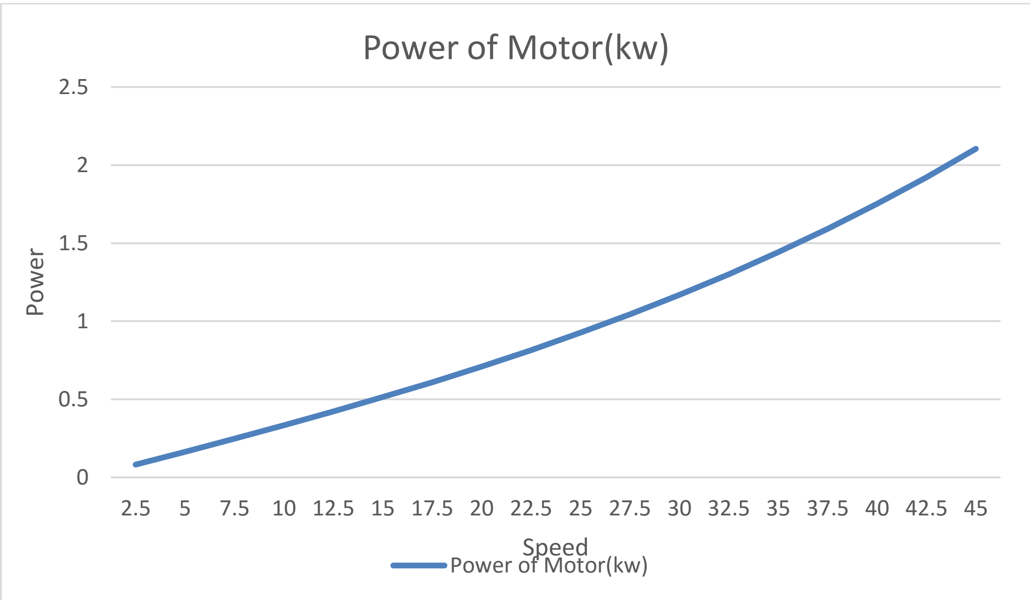

Figure -1: Graph representing power of motor

3. RESULTS AND CONCLUSIONS

3.1 Optimization results of economic characteristic

Taking minimum gross vehicle weight as the integrated design principle, we carried on the optimal design. After a series of calculation and verification, we chose 3000rmp as the base speed, and the comparison of the optimized results with the original are shown in Table 2.

Parameters	Prototype EV	Mass minimum	Difference
Top speed (km/h)	35	35	0
Gross vehicle weight (kg)	500	400	-100

Peak power (kW)	2.5	2	-0.5
Rated speed (rpm)	3000	3000	0
Peak torque of motor (N.m)	24	19	-5
Motor mass (kg)	11	9	-2

Table -2: Comparison of the optimized results with the prototype vehicle

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