OPTIMAL SELECTION, DESIGN AND TESTING OF MOTOR CONTROLLER AND CONVERTER PARAMETERS FOR E-MOTORCYCLE

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ABSTRACT - There is a large requirement for EV across the world mainly due to the depletion of fossil fuels. The next best option to conventional vehicles is the usage of Electric vehicles. The sudden transition from IC engine vehicles to electric vehicle can cause a major hike in sales of electric vehicles but this can also result in dumping of IC engine vehicles on a large scale. Retrofitting of the existing IC engine bike into an E-motor cycle and this is one of the solutions to avoid this disaster from happening. A study says that by 2030, the Indian government aims to convert 50% of the conventional vehicle into electric vehicles. The main purpose and goal of this project is to retrofit a conventional bike into an E-motorcycle. In the proposed work, the motor controller and converter parameters like output power, efficiency, power to weight ratio, torque, load, cost, aerodynamics, compactness, throttle response of the motor are determined.

A software program using Python language is written to determine the rating and specification of the motor. The program allows the user to select the most optimal motor for the E-Motorcycle after considering all the affecting factors such as load, riding conditions, environmental factors, budget. The controller and converter circuits are designed to fit in this E-motorcycle compactly. The designed motor controller and converterare fitted to the E-Motorcycle. Tests such as load test, no load test,testing the E-motorcycle various gradients and surfaces, safety test, braking test, dynamo tests are performed on this bike. After the completion of tests, validation is done and if there is any deviation from the acquired theoretical value, modifications will be done to the E-motorcycle.

Keywords: E- Motorcycle, Motor controller, Battery, Testing of E-Motorcycle, Automation, Braking system.

I. INTRODUCTION

An e-vehicle, short for electric vehicle, is a type of vehicle that is powered by one or more electric motors, using electrical energy stored in rechargeable batteries or other sources of electrical power. E-vehicles are becoming increasingly popular due to their lower environmental impact and potential for reduced operating costs compared to traditional gasoline or diesel-powered vehicles.E-vehicles are considered more environmentally friendly than traditional gasoline or diesel-powered vehicles because they emit less greenhouse gases and pollutants. They also have the potential for lower operating costs, as electricity can be cheaper than gasoline or diesel fuel, and maintenance costs may be lower due to the simpler design of electric motors compared to internal combustion engines. BLDC motors are preferably used in E-Vehicles for its efficiency [5].Optimal selection of motor by comparing various motors used in E-Vehicles [11]. A BLDC motor controller has been used in the E-Motorcycle to control the speed of the motor [10]. The motor can either be chain driven or a hub motor and preferably a hub motoris used due to low power losses [7].

A. INDIAN EV MARKET

The Indian electric vehicle (EV) market is still in its early stages of development, but it is growing rapidly. The Indian government has set an ambitious target of having all new cars sold in the country be electric by 2030, and has implemented various incentives to promote the adoption of EVs.The two-wheeler segment dominates the EV market in India, with electric scooters and motorcycles being the most popular types of EVs. This is primarily due to the high level of urbanization and the popularity of two-wheelers for daily commuting. In addition, the lower price point of electric two-wheelers compared to electric cars makes them more accessible to the general public. The passenger car segment is also growing, with several automakers launching EV models in India, including Tata Motors, Mahindra & Mahindra, and Hyundai. However, the adoption rate for electric cars is still low due to higher prices, limited charging infrastructure, and range anxiety. The government of India is taking several steps to encourage the growth of the EV market, including offering incentives for the manufacture and sale of EVs, establishing charging infrastructure, and promoting the use of renewable energy sources. Buyers of EVs can receive financial benefits through the FAME (Faster Adoption and Manufacture of Hybrid and Electric Vehicles) programme, which also offers financial incentives to manufacturers to create EVs and infrastructure for charging them. In general, the Indian EV industry is anticipated to have rapid growth over the next few years as more people learn about the advantages of EVs and the government continues to offer incentives and assistance.

B. NEED FORRETROFITTING OF EV IN INDIA

Retrofitting is the process of converting existing vehicles with internal combustion engines (ICE) into electric vehicles (EVs). In India, there is a need for retrofitting of EVs to accelerate the adoption of electric mobility and reduce vehicular emissions.One of the major advantages of retrofitting is that it offers a cost-effective solution for vehicle owners who cannot afford to purchase a new electric vehicle. Retrofitting also helps to reduce carbon emissions, which is essential for improving air quality in urban areas. As India is one of the world's most polluted countries, retrofitting offers a viable solution to reduce emissions from existing ICE vehicles.Furthermore, retrofitting can help to reduce the dependence on imported fossil fuels, as India is heavily dependent on oil imports to meet its energy needs. By retrofitting existing vehicles with electric drivetrains, India can reduce its dependence on imported oil, and move towards a more sustainable energy future.

II. PROPOSED SYSTEM

The first step is to do a thorough investigation of the various motors, controllers, and converters utilised by all existing electric cars. Its advantages and disadvantages are compared. The speed, torque, and power requirements of the electric motor are ultimately determined by the size, total weight (motorbike weight plus load), overloading, and aerodynamics of the vehicle. These factors are crucial for choosing the proper motor since they will make it easier to comprehend how the vehicle's operating circumstances affect it. The way the vehicle is utilized is also crucial. What will be the electric motorcycles typical driving pattern is also taken into consideration like whether the electric motorcycle is driven through a city with plenty of stops or whether it is driven for extended periods of time with limited stops. This information will be used to choose the vehicle's configuration. Once the motor is selected then the next step is to derive the ratings and specifications of the selected motor type. Based on the selection of motor its controller and converter are designed. Hardware implementation is done and the motor is subjected to several testing.

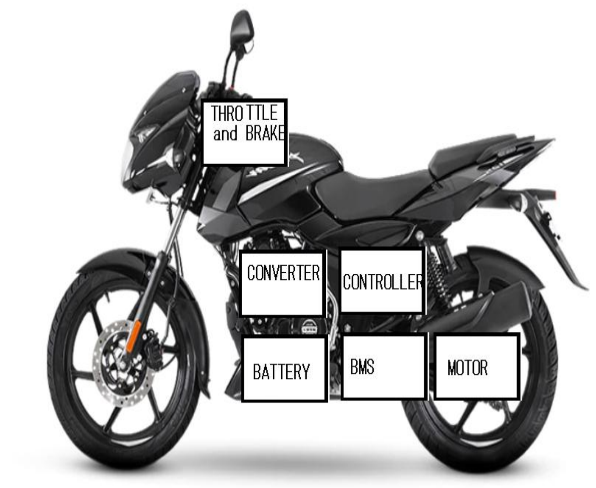

Fig. 1. General architecture of E-motorcycle

The above Conventional bike pulsar 150 has been taken from scrap and will be retrofitted into an E-Motorcycle. A general block diagram of the E- Motorcycle has been given in Fig.1.

III. SELECTION OF MOTOR, CONTROLLER, CONVERTER AND BATTERY

A. BLDC MOTOR

A brushless DC electric motor (BLDC) is a type of electric motor that is powered by a direct current voltage source and is commutated electronically rather than using brushes like standard DC motors.The traction properties of BLDC motors include high starting torque, high efficiency of 95–98%, etc. For high power density design approaches, BLDC motors are appropriate. Due to their traction properties, BLDC motors are the most popular motors for use in electric vehicle applications. The BLDC motor, which does not use brushes, is also more robust and lasts longer than brushed motors, allowing your business to save money on additional costs associated with future maintenance or complete replacement of that equipment.The BLDC motor has been modelled in a simplified model in reference with the simulation [12]. During motor use, the brushes can also wear out, which can result in sparking and could cause fire hazards as well as additional worries and costs for your business. Another advantage of using a brushless motor is that it is more efficient than a conventional brushed motor.Table1 consists of the specifications of the following motor used in the E- Motorcycle.

Table 1. Specification of the BLDC motor

Motor Type	BLDC Hub Motor
Motor design	Double axle out with 17inch Aluminium rim
Rated Power	1500W
Rated Voltage	72V
Speed	55 km/h
Torque	40 NM
Max Efficiency	92%
Brake type	Disc brake

Fig. 2. Hardware implementation

In general, brushless motors are faster and more powerful than conventional brushed motors, and they also make less noise. Problematically, they also operate more effectively and lose little to no power. An example of a synchronous motor is a brushless direct current (BLDC) motor, in which the magnetic fields produced by the stator and the rotor have the same frequency. As there are no brushes required, the BLDC motor has a longer lifespan. In addition, it boasts a high no-load speed, a strong beginning torque, and little energy losses. The BLDC engine can be set up in 1-, 2-, and 3-phase configurations. E-bikes frequently employ three-phase motors since they are the most regularly used configuration.

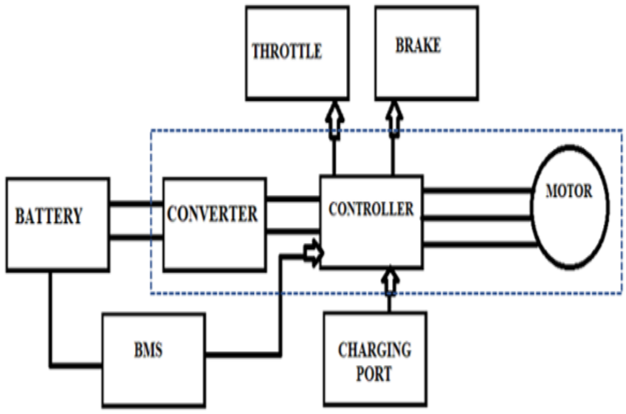

Fig. 3. Complete block diagram

B. CONTROLLER

The purpose of motor controller and converter in retro -fitting is to replace the engine which helps in the movement of vehicle by internal combustion. This electric motor generates the torque required to rotate the outer part of the motor which becoming a wheel that powers the vehicle to move forward. The controller's main function is to take inputs from all the E-motorcycle parts like throttle, battery, speed sensor, display and motor and determine what to be returned signal. The controller is also used to maintain the speed of the motor according to change in throttle given by user. Hence a PI controller is used as a motor controller for the E motorcycle for controlling the speed and torque.

C. CONVERTER

The different EV power supply configurations show that a DC-DC converter is necessary to connect the battery module to the DC link at the very least. An electrical engineering power converter known as a DC-to-DC converter changes the voltage level of a direct current source from one to another by temporarily holding the input energy and then releasing it to the output. Components for electric or magnetic field storage can be employed for the storing. DC-DC converters can convert power from the input to the output. Here, a DC-to-DC buck converter is being employed.This converter's primary function is to lower the supply voltage from the battery to the E motorcycle's auxiliary supplies, such as the headlights and indicators. The duty cycle (the switch's ratio of on/off time), which may be changed, allows one to control how much power flows between the input and the output. This is usually done to maintain a consistent power supply or to control the output voltage, input current, and output current.

D. BATTERY

Lithium-ion battery are commonly used in electric vehicles due to their high energy and power density, long cycle life, low self-discharging and mainly due to their fast-charging capacity. They also have a longer life span than other types of batteries like Nickel Cadmium or Lead Acid batteries. The main advantage of Lithium-ion battery is it can be recharged many times without losing much storage capacity. Additional advantage is that they are environmentally friendly as they do not contain any toxic metal like lead, cadmium, etc. Battery has been selected and designed based on our requirement of E motor cycle and the motor parameters. The capacity of battery is 30Ah and voltage rating of battery is 60V. One hundred and eighty-seven individual cells are combined together to design the required battery in which seventeen cells are connected in series and eleven cells are connected in parallel for the required configuration.

Table 2. Battery specifications

Battery Type	Lithium - Ion (NMC)
Battery capacity	30 Ah
Battery Voltage	60V
Charging Voltage	67V
Energy Storage Capacity	1800Wh
Charging Cycles	500 – 1000 Cycles
Weight	15Kg
Number Of Cells	187
Single Cell Voltage	3.7V
Number of Cell in Series	17
Number of Cells in Parallel	11
Operating Temperature	Charge: 0°C – 45°C Discharge: -20°C – 60°C

E. EMERGENCY BRAKING SYSTEM

The main parts involved in the presented invention are, Speed Sensors to detect the speed of the rotating wheels. This speed signal is sent to the braking system for locking the wheel. This is done is steps to avoid slipping. An Electronic Control unt placed in the Two-wheeler receives this speed information and controls the brake through the actuator. This arrangement is placed in the non-rotating part of the Wheels.

If the system determines that the rider has not applied brake during the emergency situation, then the automated emergency braking system will get activated with in 3 seconds and lowers the speed in both the rear and front wheel to ensure that the Two- wheeler is balanced and does not pose its own risk while applying brake. First the rear brake is applied in steps until reaches the safe limit and then lowers the front brake until the two-wheeler comes to a halt.

Features:

1. Stable Wheel locking system during unsteady braking situations.
2. Safe and emergency acceleration during sudden braking.
3. Safe braking during cornering and in gradient inclinations.
4. Suitable for urban scenarios.

IV. THEORETICAL CALCULATION

The ratings of the motor is calculated in a theoretical way and based on its result the ratings is determined. The weight of the motorcycle is determined to be 130 kg and an average weight of two person is taken as 150 kg and the total mass is 280 kg. The top speed is considered as 45km/hr and the gradient is 70%.

$$F = F_{rolling} + F_{gradient} + F_{aerodynamic} \quad (1)$$

$$Mass(M) = 130(Bike)kg + 150(Load)kg$$

$$= 280\ kg$$

$$F_{rolling} = Cr \times M \times A \quad (2)$$

$$C_r = 0 \cdot 004\ (Asphalt\ road)$$

$$\boldsymbol{F_{rolling} = 10 \cdot 98N}$$

$$F_{gradient} = M \times A \times Sin\theta \ (3)$$

$$\boldsymbol{F_{gradient} = 47.93N}$$

$$F_{aerodynamic} = 0.5\left(\rho \times V^2 \times C_a \times A_f\right)(4)$$

$$V = 45\ km/hr$$

$$= 12.5\, m/s$$

$$A_f = Height \times Weight \times 0 \cdot 7 \quad (5)$$

Constant value 0.7 (Adjusting value)

$$= 1.45 \times 0.76 \times 0.7$$

$$= 0.77$$

$C_a = 0.88$ (Co efficient of air resistance)

$$\mathbf{F_{aerodynamic\,drag} = 51.79N}$$

$$\boldsymbol{F} = 51.79 + 10.98 + 47.93$$

$$= 110.72\, N$$

$$Power = F \times 12.5$$

$$\mathbf{Power = 1384W}$$

Acceleration Force-

$$A_f = (W \times V/T) \quad (6)$$

$$= (280 \times 12.5)/60$$

$$= 58.33N$$

$$F_{total} = 110.72 + 58.33$$

$$= 169.05N$$

$$Torque = F_{total} \times R \text{-(7)}$$

$$= 169.05 \times 0.21$$

$$\mathbf{Torque = 35.50N}$$

Therefore from the above theoretical calculation for a total mass of 280 kg and a top speed of 45 km/hr speed a 1347 W motor is minimum required for the E motorcycle.Therefore 1500 W motor has been used in our E-motorcycle.

V. SOFTWARE COMPUTATION FOR DETERMINING THE OPTIMAL MOTOR RATINGS

A software program has been developed to determine the motor ratings and its specifications. Python programming is used to optimally determine the ratings of the desired motor. By just providing the basic inputs the software will automatically compute and tells us the desired motor and their ratings based on our needs and based on our budget.

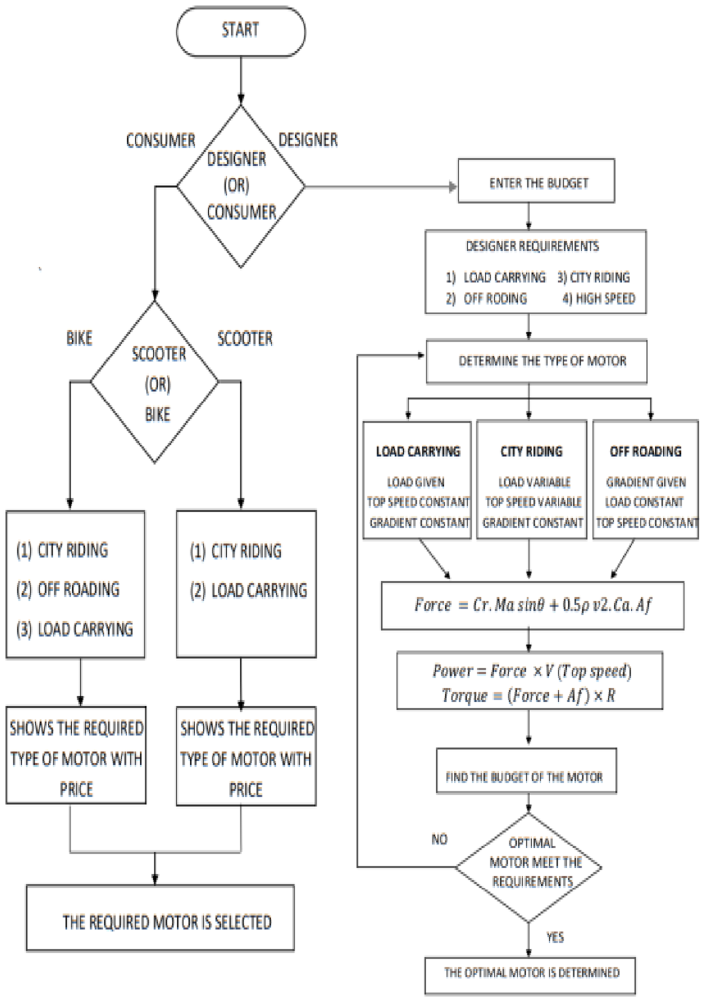

Fig. 4. Flowchart of program

The python code consists option 1 as consumer which can be used by the public who has no knowledge on motors, batteries and by using this software the consumer can get the required specification of the E-Motorcycle with its budget. The E-Motorcycle is varied as bike and scooter.

If option 1 or consumer is chosen,

```
Enter 1 if you are a consumer
Enter 2 if you are a designer
1
Enter 1 for bike
Enter 2 for scooter
1
Enter 1 for Load Carrying
Enter 2 for City Riding
Enter 3 for Off Roading

2
Enter 1: 60,000 RS - 1.5KW BLDC Motor 1.5kWH, Li ion Battery, 5Amp slow chargir
, Top speed 40 KmpH with 180 kg load
Enter 2: 100,000 RS - 3KW BLDC Motor 3kWH, Li ion Battery,10Amp fast charging,
op speed 55 KmpH with 200 kg load, with BMS facility
1
The required specification is 60,000 RS - 1.5KW BLDC Motor 1.5kWH, Li ion Batte
y, 5Amp slow charging, Top speed 40 KmpH with 180 kg load
```

Fig.5. Optimalselection based on consumer requirementusing python programming

The python code for designer can be used by E-Motorcycle designer to design their required E-Motorcycle based on budget and the output torque and output power is found.If option 2 or designer is chosen,

```
Enter 1 if you are a consumer
Enter 2 if you are a designer
2
Enter the budget
30000
Enter the consumer requirement
Enter 1 for Load Carrying (Minimum 18,000 RS)
Enter 2 for City Riding (Minimum 15,000 RS)
Enter 3 for Off Roading (Minimum 22,000 RS)

2
The determined type of motor is BLDC motor
Enter the weight of the vehicle
130
Enter the top speed
45
Enter 1 for wooden road
Enter 2 for concrete road
Enter 3 for asphalt road
Enter 4 for rough paved road
3
Total Force:  62.38941412128316 N
Power:  779.8683004101808 W
Torque:  24.914286415469466 Nm
Price:  15000 Rs
```

Fig.6. Optimal selection based on design parameters using python programming

VI. TESTING AND VALIDATION

The developed E motorcycle is subjected to various test to determine the full capability of the motorcycle. Each test has a distinct consequence that will assist the manufacturer in developing an excellent motorcycle. Some of the various test that has been performed are

- Dynamometer test

A dynamometer, also referred to as a "dyno," is a tool that simultaneously monitors the torque and rotational speed (RPM) of an engine, motor, or other rotating prime mover. This enables the dynamometer to estimate instantaneous power, which is commonly displayed as kW or bhp.

Fig.7. Dynamometer test

The dynamometer testing was performed and the results were determined. Table 2 consists the results for the dynamometer test.

Table3. Dynamometer test results

Time	Roller RPM	Motor RPM	Horsepower(CV)	Torque(KG*M)
1.98	42	0	0.3	4.62
7.24	252	250	1.2	3.51
22.14	501	500	5.5	7.95
41.52	751	750	0.3	0.28

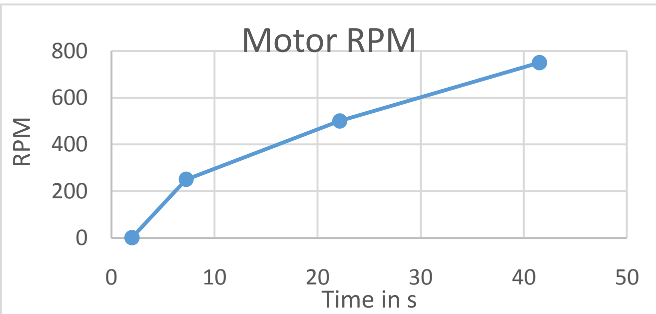

Fig.8. Motor RPM Vs Time

- Load test

GVWR, dry weight, and wet weight are the three common ways to express a motorcycle's weight. The term "GVWR" stands for "gross vehicle weight rating," which includes the motorcycle, the rider, any cargo, and any other consumables. Yet, when comparing motorcycles, dry weight and wet weight are frequently utilised because lighter bikes typically perform and handle better than heavier ones. The maximum weight the motorcycle can safely carry is determined by the difference between the GVWR and wet weight.

To evaluate the performance of an E-Motorcycle, a test would be conducted to determine its power and torque. The test would involve testing the motorcycle at various weights and loads to assess the efficiency of the motor and how the bike responds to different loads.

The following test was performed with a load of 85kgs.

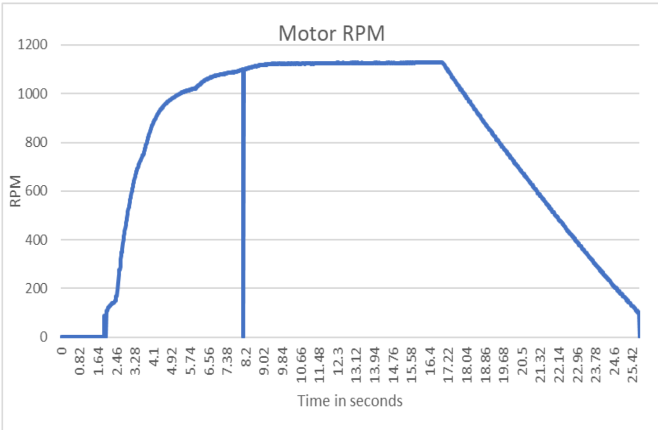

Fig.9. Motor RPM Vs Time with Load 85 kg

VII. CONCLUSION

In our proposed system an optimal motor controller is selected for the retrofitting of the E- Motorcycle. Python software is used to determine the optimal motor for the E-Motorcycle. An algorithm for determining the motor is found where in a public consumer with no knowledge can enter his purpose and the software will determine the optimal motor and their required specifications will be given as output to the consumer. The software also aides E- Motorcycle designers to design an optimal motor for the required purpose by entering load capacity, environmental changes and the conditions under which the E-Motorcycle will be used. Thereby an optimal motor can be selected using the software. The required motor for the project is determined to be a BLDC motor and the BLDC hub motor has been connected to the rear wheel of the motorcycle to be retrofitted. Load Testing and dynamometer testing has been performed on the E - Motorcycle and the results has been found and validated.

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