IMPLEMENTATION OF ECO-FRIENDLY RETROFIT ELECTRIC TVS XL MOPED

[1]DILIP.R, [2]HARIHARAN.D, [3]KAMALESH.M, [4]BALAMURUGAN.E,[5]Dr.R. UTHIRASAMY, M.E., Ph.D.,

[1234]Student, [5]Professor, Department of Electrical and Electronics Engineering,
Mahendra Engineering College, Namakkal, India.

Abstract: The research project focuses on the development of a retrofit electric conversion kit for the TVS XL moped, a popular two-wheeler in many regions. The project aims to seamlessly integrate an electric powertrain into the existing moped framework, ensuring minimal modifications to the framework while maximizing the benefits of electrification. The conversion process involves the integration of a high-performance electric motor and a compact and efficient battery pack. The project is designed for user-friendly installation, allowing moped owners to upgrade their vehicles with minimal technical expertise. The key objectives of the research include optimizing the electric powertrain for the TVS XL moped to maintain or improve its overall performance metrics, including load capacity, range, and speed. This project combines theoretical analysis, computer simulations, and practical experiments to validate the performance and reliability of the retrofit kit. The outcomes of this project aim to contribute valuable insights into the development of retrofit electric conversion kits for conventional mopeds, particularly the TVS XL. The successful implementation of the project plays a significant role in reducing the carbon footprint of existing fleets and promoting the widespread adoption of electric mobility in the two-wheeler segment.

Index Terms **–Retrofit, BLDC Motor, Battery Selection, Lithium-ion, Dynamic analysis, Electric Vehicle, DC-DC converter.**

I. INTRODUCTION

The escalating concerns surrounding environmental sustainability and the imperative shift towards cleaner transportation have intensified the exploration of innovative solutions within the automotive industry. Among these solutions, the retrofitting of internal combustion engine (ICE) vehicles with electric powertrains emerges as a promising avenue for achieving a rapid transition to eco-friendly mobility. This research focuses on the development of a retrofit electric conversion kit for the TVS XL moped, a ubiquitous and widely utilized two-wheeler renowned for its reliability and fuel efficiency. As the global transportation sector grapples with the challenges of carbon emissions, air pollution, and finite fossil fuel resources, the imperative to electrify existing vehicle fleets becomes increasingly evident. The TVS XL Moped, a staple in many rural and urban settings, represents a considerable portion of the two-wheeler market. Transforming this iconic and widely adopted moped into an electric vehicle through retrofitting presents an exciting opportunity to significantly contribute to the paradigm shift toward sustainable transportation. The motivation behind this research stems from the recognition that retrofitting offers a pragmatic and cost-effective approach to integrating electric mobility into existing transportation infrastructure. Unlike introducing entirely new electric vehicles, retrofitting leverages the familiarity and longevity of well-established models, reducing the need for extensive infrastructure changes and promoting the widespread adoption of electric technology. The goal of this study is to address the various difficulties involved in creating an electric conversion kit that is particularly designed to fit the TVS XL Moped. These difficulties include the smooth integration of an electric drivetrain into the moped's design, guaranteeing ideal performance metrics, preserving user-friendly installation procedures, and assessing the conversion's viability from an economic standpoint.

II. SYSTEM DEVELOPMENT

The key components in electric TVS XL moped

1. BATTERY

In electric vehicles, the battery is used mainly to store electric energy while charging and regenerating. As shown in the table, a study of several types of batteries has previously been performed listed below, These are the fundamental materials that allow recharging. When the energy is held constant specific energy, energy per unit of mass indicates an efficient battery.

Parameter	NiCd	NiZn	NiMH	Li-ion/Li-Po
Specific Energy (Wh/kg)	40-60	100	60-120	100-265
V	1.2	1.65	1.2	NMC 3.6/3.7,
Energy Density (Wh/L)	50-150	280	140-300	250-730
Charge/Discharge Efficiency (%)	70-90	80	66	80-90

Specific Power (W/kg)	150	>900	250-1000	250-340
Self-Discharge	10	13	30	8-5
Cycle Durability	2000	400-1000	500-1000	400-1200

Table 1: Batteries comparison

From the above comparison, we can conclude that Li-ion has a more Specific Energy and Energy density than others. These discharge at a remarkably low rate It can be very dangerous, and it needs an essential protective implementation and lithium-ion cell management. It can able to store more energy with less voltage.

2. BATTERY CHARGER

Some main supply sources for EVs are solar systems and grid systems. The retrofit electric TVS XL moped is equipped with a high-capacity lithium-ion battery pack. The battery is strategically positioned within the moped to maintain balance and optimize space utilization. The battery's voltage and energy capacity are carefully chosen to provide an optimal balance between range and performance. It is a type of on-board charger: A charger that is mounted within the vehicle.

- 48V-24Ah

Advantages

1. High energy density provides an extended range per charge.
2. Lightweight and compact design for optimal space utilization.
3. Long lifespan with low maintenance requirements.

3. BLDC MOTOR

Instead of using mechanical brushes, a brushless DC (BLDC) motor employs electronic commutation, making it a highly dependable and efficient form of electric motor. Because of their improved power-to-weight ratios and increased efficiency, BLDC motors are the perfect choice for applications needing great performance and small size. Smoother operation and improved control are achieved by accurate timing of the current delivered to the motor windings by the electronic controller. BLDC motors are renowned for their long lifespan, little upkeep needs, and strong torque production across a broad speed range. Their capacity to provide regenerative braking helps electric vehicles operate more energy-efficiently. Because there are no brushes, there are fewer mechanical losses and electromagnetic interference, which makes them appropriate for a variety of consumer, automotive, and industrial uses.

Figure 1: BLDC MOTOR

The moped is powered by a Brushless DC motor, known for its efficiency, reliability, and compact design. This motor is integrated into the wheel hub or drivetrain, eliminating the need for a traditional gearbox. The BLDC motor provides instantaneous torque and a quiet, low- maintenance operation.

Advantage

1. High efficiency and reliability, reducing energy losses.
2. Compact design eliminates the need for a gearbox, reducing weight.
3. Silent operation enhances rider experience.
4. Instantaneous torque delivery improves overall dynamic performance.

4. CONVERTER

Here is a two-buck converter for setting down 24/12V and 48/2 V DC voltage. The converter has types such as rectifier AC-DC, inverter DC-AC, and chopper DC-DC. Two choppers were used in the project, where one for the motor controller from the battery and another for indicators from the previous chopper.

5. MOTOR CONTROLLER UNIT

Serving as a vehicle's central nervous system, the controller manages every setting. Using data from the battery regulates the pace of the charge. A sophisticated electronic controller serves as the central nervous system of the electric moped. This controller, often utilizing advanced microprocessor technology, regulates the power flow from the battery to the brushless DC motor. It manages variables such as speed, torque, and acceleration, ensuring smooth and efficient operation.

- Rated Voltage – DC/48/60/72V

- Phase angle - 120°
- Protect Voltage – 42/52±0.5v

Figure 2: CONTROLLER UNIT

6. FRAME MODIFICATION

To accommodate the new electric components seamlessly, specificframe modifications are implemented. These modifications maintain the structural integrity of the moped while ensuring proper placement andsupport for the battery pack, electric motor, and associated components. In this project, where retrofitting a TVS-XL moped into electric mobility from an internal combustion engine vehicle by only changing its frame without the original design.

III. SYSTEM OPERATION

The system features current flow from the power source to the motor through components like a battery charger, controller, converter and electronic unit. The BLDC motor is powered by a 48V battery through the MCB. The MCB has overcurrent protection. The charging unit has a 240/48V rectifier which then sends it to the motor control unit of the motor through a 48/24V step-down converter which has connection points to the throttle body and another 24/12V step-down converter for the vehicle

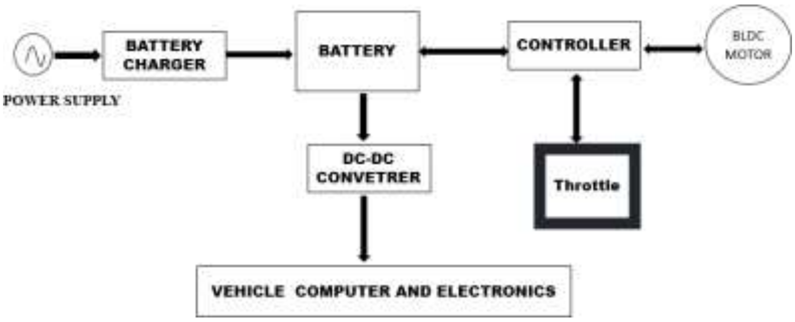

Figure 3: Block Diagram proposed model

electronics. The throttle is connected to the motor control unit and increases the speed of the engine by changing the voltage. Other parameters of the motor and battery like speed, battery voltage etc. can be displayed on the main display using the motor control unit. It has a Hall Effect sensor which detects the motor speed and then sends an electrical signal to the motor control unit.

IV. PERFORMANCE ANALYSIS

To determine the power rating of a vehicle, it's essential to consider various factors related to vehicle dynamics, such as rolling resistance, gradient resistance, and aerodynamic drag. Here, we will illustrate the procedure for selecting a motor rating for an electric TVS XL with a gross weight of 150 kg.

Total force required:

$$\mathrm{Ft} = \mathrm{Fr} + \mathrm{Fg} + \mathrm{Fad}$$

Where,

- F_t =Total force that the motor output must overcome to move the vehicle.
- F_r= Rolling Resistance force
- F_g= Gradient Resistance force
- F_{ad} = Aerodynamic Drag force
- F_t is the total tractive force.

1. ROLLING RESISTANCE

The resistance that the tire's contact with the road provides to the car is known as rolling resistance. The formula for calculating force due to rolling resistance is given by equation.

$$\mathrm{Fr} = \mathrm{C(rr)} \times \mathrm{M} \times \mathrm{g}$$

Where,

- C_{rr} = Coefficient of a Rolling Resistance,
- M = mass (kg)
- g = acceleration due to gravity (9.81 m/s^2)

For application consideration,

C_{rr} = 0.004 as per the below table and the weight of our TVS XL = 150 kg Then,

$Fr = C(rr) \times M \times g$

F_r =0.004×150×9.81

F_r = 5.8 N (Newton)

2. GRADIENT RESISTANCE

The gradient resistor of the vehicle refers to the resistance encountered while climbing a hill or flyover, or traveling on a downward slope. This resistance is influenced by the gradient or incline, which is represented by the angle θ between the slope and the ground level.

To quantify this resistance, the component of the gravitational force acting along the slope must be considered. This force can be calculated as follows:

$Fg = \pm M \times g \times \sin\theta$

Where,

- +ve sign for motion upslope the gradient
- -ve sign for motion downslope the gradient
- $F_{gradient}$ is the force due to the gradient resistance.
- m is the mass of the vehicle.
- g is the acceleration due to gravity (approximately 9.81 m/s29.81m/s2).
- θ is the angle of the slope for the horizontal ground

For application consideration, let us consider electric TVS XL run at an angle of θ (inclined angle) = 2.50

$Fg = \pm M \times g \times \sin\theta$

=150×9.81×sin2.50

= 64.8N

3. AERODYNAMIC DRAG

The resistive force provided by the opposing force pressing on a vehicle is known as aerodynamic drag. The vehicle's form determines it linearly.

The following formula provides the aerodynamic drag calculation.

$Fad = 0.5 \times Cd \times A(f) \times \rho \times v2$

Where,

- C_d=Drag coefficient,
- A(f) =Frontal area(m$^{2)}$
- ρ = Air density in kg/m^3,
- v = velocity in m/s

For application consideration, the high speed of our TVS XL is 35 kmph is 9.72222 m/s the air density is 1.1644 kg/m^3 at 30° temperature and the drag coefficient is 0.5, the frontal area is 0.7 m^2

Then,

$Fad = 0.5 \times Cd \times A(f) \times \rho \times v2$

= 0.5×0.5×0.7×1.1644× (9.7)^2

= 19.16 N

$Ft = Fr + Fg + Fad$

= 5.8+64.8+19.6

= 90.2 N

The power required to drive a vehicle is calculated as follows,

$Power = Force \times Velocity \times (1000 \div 3600)$

Given: Force=90.2N, Velocity=35Km/h

= 90.2× 35 × (1000 ÷ 3600)

= 890.66 watt.

The power required to propel the vehicle is 890.66 W, which is just below our motor specification of 900 W. This indicates that the design is safe and the motor is capable of meeting the power requirements for driving the vehicle...

V. DESIGN OF BATTERY

From the motor calculation, we determine the following terms:

- Wattage=900w
- Voltage=48v

To find energy in Watt. hours.

$watt.hours = 900w \times 1hr$

$= 900\,w.hr$

Assuming 80% of the battery is used and 20% remains.
Battery watt.hr = 900w.hr×1.20 = 1080w.hr
To find the current in the battery:
Current (Ah) =1080w.hr ÷ 48v = 22.5Ah

1. SELECTION OF BATTERY CHARGER

Assume we have 5 hrs to charge the battery, Required energy:
Wattage of the charger = 1080W.hr ÷ 5hr = 216w
To find the current rating of the charger:
Current (A) = 216w ÷ 48v = 4.5A
Therefore, to charge a 48V,24Ah battery in 5 hrs, we need a 48V, 4.5A charger.

2. BATTERY SPECIFICATION

- Voltage Rating = 48 V
- Current Rating = 24Ah

$$\text{Wattage of battery} = \text{Voltage Rating} \times \text{Current Rating}$$
$$= 48 \times 24$$
$$= 1152\text{wh (watt.hr.)}$$

VI. ACCELERATION PERFORMANCE OF EV XL MOPED

To consider rotational acceleration as well as linear acceleration the axle torque equals $Fte * r$, where r is the radius of the tyre and F_{te} is the tractive effort. If G is the gear ratio and T is the motor torque, then we can say that

$$T = Fte * \frac{r}{G}$$
$$Fte = G * \frac{T}{r}$$

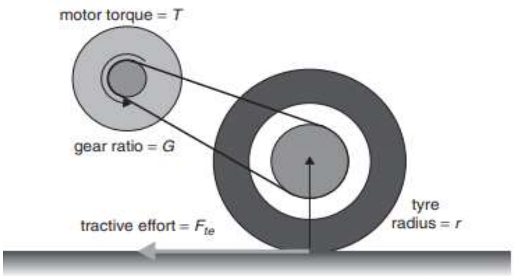

Figure 4: Motor to drive wheel arrangement

Total tractive effort :

$$Fte = Fr + Fad + Fg + Fla + F\omega a$$

Where:

- F_r is the rolling resistance force,
- F_{ad} is the aerodynamic drag,
- F_g is the gradient force,
- F_{la} is the linear acceleration force,
- $F_{\omega a}$ is the angular acceleration to the motor,
  - F_{la} and $F_{\omega a}$ will be -ve if the vehicle is sloping down
  - F_g will be -ve if it is in downslope. By substituting an equation change concerning the acceleration function

$$Fte = \mu rr \times m \times g + 0.625ACd\ v2 + m \times a + I \times \left(\frac{G2}{\eta gr2}\right) \times a$$

Sub $a = \frac{dv}{dt}$

$$\left(\frac{G}{r}\right) T = \mu rr \times m \times g + 0.625 \times A \times Cd \times v2 + \left(m + I\left(\frac{G^2}{\eta gr2}\right)\right)\frac{dv}{dt}$$

In the 1st acceleration phase, when $T = Tmax$,

$$\left(\frac{G}{r}\right) Tmax = \mu rr \times m \times g + 0.625 \times A \times Cd \times v2 + \left(m + I\left(\frac{G^2}{\eta gr2}\right)\right)\frac{dv}{dt}$$

For a vehicle on level ground, with an air density of 1.25 $kg.m^{-3}$

Let, the total mass of an electric moped with a passenger is m = 185 kg, increase m by 5% due to linear acceleration,cd=0.75
A = 0.6 m^2, μ_{rr} = 0.007, G = 2 (2:1) and r = 0.21 m, T max=34Nm, ωc =103 rad/s
So, ωc is the critical motor speed

$$T = 153 - 1.16\omega$$

n_g is a 9.8 efficiently,

For a first-phase motor torque is a constant…

$$\frac{2}{0.21} \times 0.98 \times 34 = 0.007 \times 185 \times 9.8 + 0.625 \times 0.6 \times 0.75v2 + 194 \times \frac{dv}{dt}$$

$$137 = 12.7 + 0.281v2 + 194 \times \frac{dv}{dt}$$

$$194 \times \frac{dv}{dt} = 304 - 0.281v2$$

$$\frac{dv}{dt} = 1.57 - 0.00145v2$$

$$\frac{[vn + 1 - vn]}{\partial t} = 1.57 - 0.00145v2$$

This formula is valid until the torque starts to decrease, at which point

$\omega = \omega c = 103$ rad s^{-1}

$103 \times 0.21/2 = 10.8$ ms^{-1}.

$$\frac{dv}{dt} = 7.30 - 0.53v - 0.00145v2$$

$$\mathrm{vn} + 1 = \mathrm{vn} + \partial \mathrm{t} \times (7.30 - 0.53\mathrm{v} - 0.00145\mathrm{v2n})$$

Steps followed in the simulation process,

- Let's make time steps interval 0 to 15s, in 0.1s steps
- Then make 501 readings of velocity and storing in an array
- For an iteration a looping from a range of 1 to 100 or 500 to velocity equation concerning a readings

```
t=linspace(0,50,501); % 0 to 50 s, in 0.1 s steps
vel=zeros(1,501); % 501 readings of velocity
d=zeros(1,501);% Array for storing distance travelled
dT=0.1; % 0.1 second time step
for n=1:500
if vel(n)<10.8 % Torque constant till this point
vel(n+1)= vel(n) + dT*(1.57 - (0.00145*(vel(n)^2)));
elseif vel(n)>=10.8
vel(n+1)=vel(n)+dT*(7.30-(0.53*vel(n))-(0.00145*(vel(n)^2)));
end;
d(n+1)=d(n) + 0.1*vel(n); % Compute distance travelled.
end;
vel=vel.*3.6; % Multiply by 3.6 to convert m/s to kph
plot(t,vel); axis([0 30 0 50]);
xlabel('Time / seconds');
ylabel('Velocity / kph');
title('Full power (WOT) acceleration of TVS XL MOPED')
```

Figure 5: MATLAB script for acceleration analysis

- Where the torque constant at this point 10.8m/s at this point iteration will be continue
- when reaching above a point10.8m/s then it is taken into an else statement and must end a loop with the end statement as an end;
- Then convert a velocity from m/s to Kmphr which is multiplied by 3.6 as (18/5)
- Then plot a point by plot(t,v) with an x and Make a label with xLabel () dt and yLable() dv and give the label name inside parentheses within a(‘’) for analyses run a code axis value.

VII. CONCLUSION.

E-mopeds are particularly well-suited for rural areas where access to petrol stations is limited. These vehicles can be conveniently charged using electricity, providing a reliable transportation option for rural residents. Additionally, e-mopeds help reduce the emission of harmful gases, thereby contributing to a decrease in atmospheric pollution.. Thedevelopment of the retrofit electric TVS XL moped presents a holistic solution to the challenges posed by traditional IC engines. It not only showcases the technical feasibility of such conversions but also addresseseconomic and environmental concerns. The following conclusions can be drawn from the successful execution of this project: The retrofitting approach proved to be a cost-effective solution for transforming the conventional TVS XL moped into an electric-powered vehicle. By replacing the IC Engine with an electric motor and optimizing power transmission, the project demonstrated a viable alternative to expensive new electric bike purchases. The emphasis on using existing spares and maintaining the original design played a crucial role in the project's success. This approach not only preserved the structural integrity of the moped but also utilized spare parts effectively, minimizing the overall cost of the retrofitting process.

The implementation of charging optimization software contributed to the efficiency of the electric moped. By reducing charging times and analyzing cost-effective charging strategies, the project addressed concerns related to the practicality and affordability of electric vehicles, making them more accessible to a wider audience. The dynamic performance analysis software played a pivotal role in optimizing the electric moped's performance. This project contributes to the ongoing evolution of the automotive industry towards sustainable and energy-efficient transportation solutions.

VIII. RESULT AND DISCUSSION

In response to the escalating concerns regarding air pollution from conventional fuel-based vehicles, this project delves into the implementation of an eco-friendly retrofit electric TVS XL moped. The focus lies on the integration of sustainable technologies to mitigate environmental impact while maintaining practical usability. The retrofit electric TVS XL moped is powered by a 48V, 25Ah lithium-ion battery, capable of being full charged within 5 hrs using a 48V/ 4.5A charger. This charging setup enables the moped to store between 1150 to 1200Wh of energy, facilitating a single-charge range of up to 50 km at an optimal speed range of 35 to 45 mph. By transitioning to electric power, this moped significantly reduces emissions and contributes to cleaner air quality, promoting a healthier environment for human habitation. The successful implementation of this eco-friendly retrofit underscores the feasibility and efficacy of adopting sustainable transportation solutions in mitigating environmental challenges. This project not only showcases the technical viability of eco-friendly retrofit solutions but also underscores the imperative of transitioning towards sustainable mobility to combat the pressing issue of air pollution.

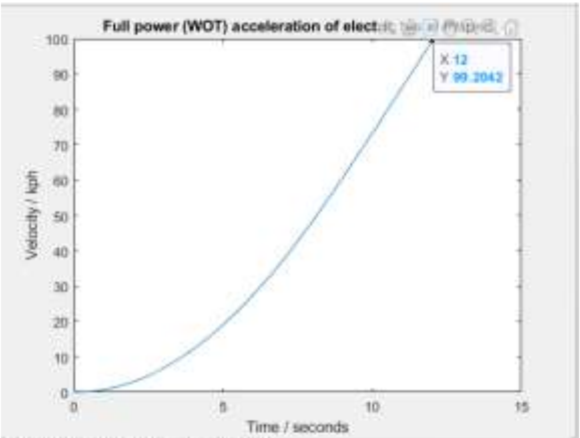

Figure 6: Full power acceleration on TVS XL

The acceleration differences can be observed in the simulated graph, where key performance metrics are highlighted. The maximum speed of 45 kph (28 mph) is achieved, with the e-moped reaching 10 meters from a standing start in 3.2 seconds and 100 meters in 12 seconds..

Figure 7: Snapchat of EV-XL Moped

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