

A Project Report on

# Performance Prediction And Range Estimation Based On Road Information For Electric Vehicle Using Model Based Design

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**Academic Year: 2020-21**

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**C E R T I F I C A T E**

This is to certify that *Mr. Pratik Thorat*, has successfully completed the Project entitled *"Performance prediction and range estimation based on road information for electric vehicle using model-based design"* under my supervision, in the partial fulfilment of Bachelor of Engineering-Mechanical Engineering of Savitribai Phule Pune University.

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## **A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle**

### **ACKNOWLEDGEMENT**

With all due respect and gratitude, we would like to thank all the people who have helped us directly and indirectly for this project report.

We express our heartily thankfulness towards **Dr. P. B. Kushare** to complete this project work on “**A model-based performance prediction and range estimation based on road information for electric vehicle**”. His suggestions, ideas and directions helped us complete this project report.

Thanks to Principal **Dr. K. N. Nandurkar**, Head of Mechanical Department **Prof. M. B. Murugkar**, project coordinator and all the teaching and non-teaching staff members of Mechanical Engineering Department for providing necessary information and required resources timely.

We intend to conclude this acknowledgement with heartiest thanks and sincere gratitude to our friends who have helped us to complete this project report.

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

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## **A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle**

### **Abstract**

Electric vehicles are likely to be an alternative energy mode of transportation for the future as it has shown a great ability to reduce the consumption of petroleum-based and other high CO<sub>2</sub> emitting transportations fuels by 43%. As Electricity being high-grade energy, it is lighter and easier to control as compared to fluidic and mechanical systems. On the downside of this integration of the electric vehicle into modern transportation systems is largely limited by the higher cost, long charging times, furthermore the low driving range, which has been considered as one of the major factors that affect the acceptance of electric vehicles. Driving behavior, road topography information, and traffic situation is hard to predict, therefore it is a challenge to select optimum motor parameters and battery pack capacity to meet the required range and performance of the bike. This study will help to reduce product development cycle time, considering real-time conditions, and improve design process efficiency.

In this research of model-based design process, a 2-wheeler cargo electric vehicle is targeted, considering the agility of 2-wheeled bikes to tackle challenges on Indian public roads and the ability of the vehicle to carry a different amount of load required. The study was focused on designing, a simulation model for a generic bike to accurately predict its range and estimate its performance parameters. Vehicle speed, energy consumption, battery and motor temperature, cargo load on bike, driving style, road conditions are monitored through prototype bike. Through a data acquisition system, various drive cycles were derived for the operation of cargo delivery in a real-world usage pattern (RWUP).

The full vehicle model includes the road load model to input drive cycle data, the powertrain model including motor and controller, the vehicle dynamics model, the auxiliary system model, and the battery model. Different drive cycle inputs were given as per data obtained during physical testing to the full vehicle model. Further, as an output, voltage, battery temperature, energy consumed are plotted against time in the simulation model and validated to actual values obtained during prototype testing. The range is calculated based up on energy consumption. The results show that the model can estimate the energy consumption with a maximum error window of 5%.

Our model-based Simulation will ensure that all electrical, mechanical, and software control systems of electric vehicles interact safely and optimally early in product development cycles without building a physical prototype, according to individual needs to select optimum battery pack capacity and motor size. These simulations can tackle Multiphysics and multifunctional performance issues quickly so that the product meets aggressive development cycles.

## **1. INTRODUCTION**

In the last few years, electric vehicles (EVs) have shifted from absolute novelty to ordinary in most sectors of public and private transportation. The market demand for electric vehicles is rapidly growing as a large number of logistics companies such as UPS, DHL and Amazon are heavily investing on electrical bikes for package delivery. However, the reduced energy storage capacity of the batteries translates into range limitation problems for EVs, acting as a barrier to widespread adoption compared to traditional vehicles based on internal combustion engines (ICEs). Range prediction for battery-operated vehicles is receiving ever-growing attention. The reason of this interest is to be found in the increased diffusion and critical role of EVs in various application domains (personal and commercial transportation, surveillance, etc.) as well as in the technical and logistic difficulties involved with the re-charging. Compared to traditional ICEs, range estimation prediction is a very challenging multi-factorial problem, involving a large number of variables that are not always easy to estimate in EVs. Besides the technical characteristics of the vehicle, for on-road EVs, the factors that need to be taken into account include road topology and grade, speed, acceleration/deceleration patterns, use of the in-board electric devices (e.g. A/C) as well as driving style (e.g. normal vs aggressive). As a matter of fact, it is very time consuming and costly process to estimate the SOC of battery pack during the prototype phase by actual manufacturing of it. Also Cost and time increases as the the of iteration changes.

To address this issue, we propose a battery aware model-based methodology that is suitable for all battery operated vehicles. More specifically, we incorporate the state-dependency characteristics of a state-of-the-art battery into the range estimator and provide an overall methodology to build a model and extract accurate range predictions in a realistic scenario. The MATLAB simulation is used to investigate the SOC, SOH, Current and initial cost of Battery. Also we have proposed the impact of a real-world driving pattern on the energy and power requirements of electric vehicle.

### **1.1 Problem Statement**

To predict the performance and estimate range based on road information for electric vehicle using model based design

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## **A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle**

### **1.2 Objectives**

1. To accurately predict vehicle's range by simulating real time situations
2. To estimate vehicle's performance parameters for actual scenarios
3. To reduce product development cycle time
4. To improve design process efficiency
5. To simulate vehicle for actual Indian Drive Cycle of road

### **1.3 Scope**

1. Design time required can be considerably reduced
2. These simulations can tackle Multiphysics and multifunctional performance issues quickly
3. Future scope of this includes machines learning models for accurate estimations of range prediction and performance estimation.

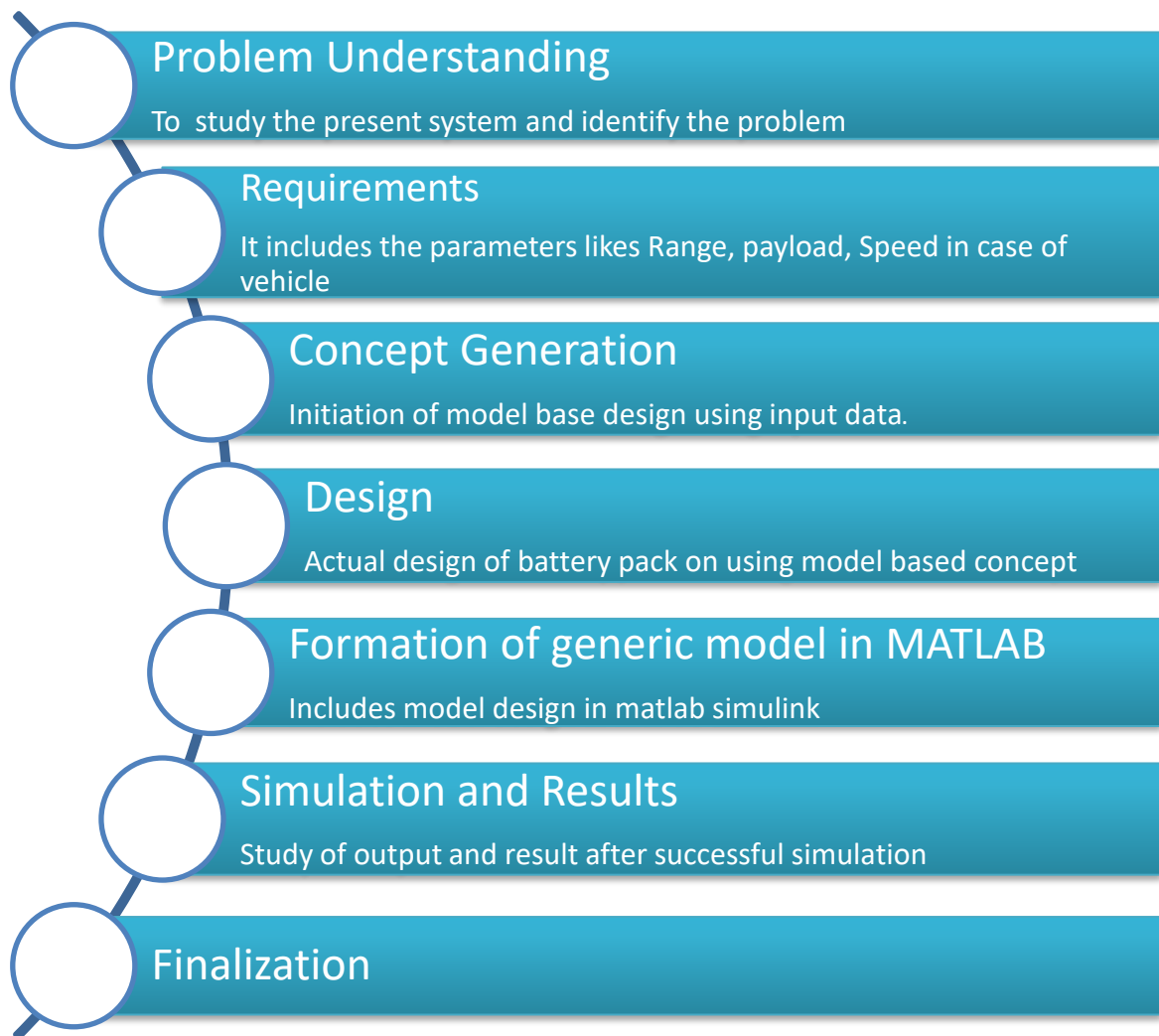


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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 1.4 Methodology

Proposed methodology flowchart is as follows:



## **2. LITERATURE REVIEW**

In this section, literature related to model-based design of electric vehicle has been studied. The references related to the same are listed below:

1. Shaik Amjada et al. [2011] had investigated a topic titled “Impact of real world driving pattern and all-electric range on battery sizing and cost of plug-in hybrid electric two-wheeler”. The authors addressed the impact of an actual drive pattern on the sizing and cost of a battery pack for a plug-in hybrid electric two-wheeler. Also they have developed the MATLAB simulation model for estimating the energy and power requirements in an all-electric strategy using an Indian driving cycle (IDC) and a real-world driving pattern were discussed.
2. Jiquan Wangl et al. [2015] had quoted “Electric vehicle energy consumption modelling and prediction based on road information”. They have explained an accurate electric vehicle energy consumption model validated using driving tests on different public roads, and then the model is used to predict future energy consumption based on road information.
3. Kaveh Sarrafan1 et al. [2016] published a paper titled “Accurate range estimation for an electric vehicle including changing environmental conditions and traction system efficiency. In this paper, an accurate SoC and range estimation model for EVs was described. The net battery energy usage was estimated, taking into account the time-domain losses and efficiency of the traction system along the specified route, and including environmental and behavioral factors.
4. Ahmet Onur Kiyaklil et al. [2018] elaborated a paper titled “Modeling of an Electric Vehicle with MATLAB/Simulink”. In this paper, the dynamic model of an electric vehicle was created with MATLAB/Simulink. The energy consumption values of the electric vehicle were determined. The effect of parameters on vehicle performance and energy consumption has been examined. As a result of tests, the vehicle consumes 15.82 kWh of energy per 100 kilometers and the vehicle has a 177 kilometers range, according to NEDC and WLTP. In the WLTP cycle, the vehicle consumes 17.93 kWh of energy per 100 kilometers and the vehicle has a 157 kilometers range. With regenerative braking, an energy saving of 8% was achieved in 100 kilometers.
5. Javier Romero Schmidt et al. [2019] had published a paper, “Prognosis of the energy and instantaneous power consumption in electric vehicles enhanced by visual terrain classification”. This work presented the analytical derivation of the instantaneous power consumption (IPC) and energy in an electric vehicle and its dependence on the nature of the terrain. In particular, four terrain types were tested: clay, gravel, grass and pavement.

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## **A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle**

The empirical tests allowed to build polynomial model of the IPC, that was used for predicting the energy consumption in different field trials.

6. Matthew Guttenberg et al. [2021] had studied the topic titled “Software for high-fidelity electric vehicle en route state of charge estimation, fleet analysis and charger deployment”. This paper combines Agent-Based modelling along with well calibrated and tested vehicle and battery dynamics models while incorporating environmental and local effects to properly simulate electric vehicles and estimate their performance based on the specific scenario in which they exist. On an individual scale, the simulations demonstrate the significant impacts the environment has on the vehicles, causing, in this case, up to a 30% difference in range travelled. The scale of the analysis can then be expanded to fleets of vehicles to provide statistics on the performance of the fleet which, in this case, has shown that the environmental effects combined with geometric restrictions due to the road network has lead to a bimodality in the energy used per mile for the vehicles. This analysis has demonstrated the importance of including the environment in the estimation of the individual vehicle's performance which has further implications on the performance of the fleet and deployment of infrastructure required to support that fleet.

Thorough study of the above-mentioned research papers concludes that, the information obtained from this paper is useful to perform actual simulation on Matlab. Also, this paper covers most of necessary topics required to complete the full vehicle simulation.

## **3 DESIGN**

### **3.1 Application Details**

The whole aim of the project is to accurately estimate the range and performance parameters for particular given application. In this project we are trying to achieve accurate range and performance parameters for 'Electric Cargo Scooter'.

This vehicle is specially designed for travelling of cargo and goods and also it is intended to use on Indian roads specifically. So, while simulating our model we had given the input of complete 'Indian Drive Cycle' and 'NYC Drive Cycle' to get results according to actual driving pattern of Indian road profile.[1]

Details of Vehicle Specifications:

1. Mass = 150 kg (with payload)
2. Wheelbase = 1350 mm
3. CG Height = 675 mm

Also details of other components are as follows:

1. Motor
  - Type: Permanent Magnet DC Motor
  - Voltage: 48 V
  - No Load Current: 3.5 A
  - Rated Current: 50 A
  - Peak Current: 70 A
  - Rated Speed: 3300 RPM
  - Rated Torque: 7.6 Nm
  - Maximum Output Torque: 400% of Rated Value
  - Rated Power: 2000 W
  - Maximum Output Power: 3000 W
  - Efficiency: >87% on full load and full rpm
  - No. of rotor poles: 8
  - No. of stator poles: 12
2. Battery
  - Battery Voltage: 48 V
  - Current Capacity: 73 Ah
  - Battery Capacity: 3000 Whr
  - Battery Configuration:
    - 13 cells in Series
    - 21 in parallel
3. Gear Reduction

Overall gear reduction via Chain-Sprocket = 5

## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 3.2 Simulink Model Generation

As this project aims for the Range and SoC estimation of electric cargo bike using new method of Model Based Design using MATLAB Simulink software instead of using traditional method of complete actual manufacturing of whole vehicle after designing, then to take the test runs of the vehicle actually and from that testing, range and time required for complete discharging of vehicle is estimated. Either this traditional method gives actual result of range and discharging time of particular vehicle but this process requires lot of capital investment and also time to carry out whole process to reach up to final stage of results. Also, if we want to estimate the performance parameters of the same vehicle for some iterations in technical parameters such as; ground clearance, Center of Gravity height, Wheelbase, distance of CG from front and rear axle, gear ratio given after motor, we are unable to iterate this parameters in traditional method as in that method we are actually manufacturing the vehicle, due to which we cannot change this parameters once vehicle is manufactured. Also, if anyone wants to calculate range for different types of electric vehicle it is too difficult to calculate it using traditional way as it will involve complete designing, manufacturing and testing of each and every single vehicle which requires very high capital and time investment.[4]

For this purpose, to reduce capital and time investment and also to get close to reality results of performance parameters Model Based Design is very versatile tool. The Simulink model of electric cargo bike is shown below in fig.1

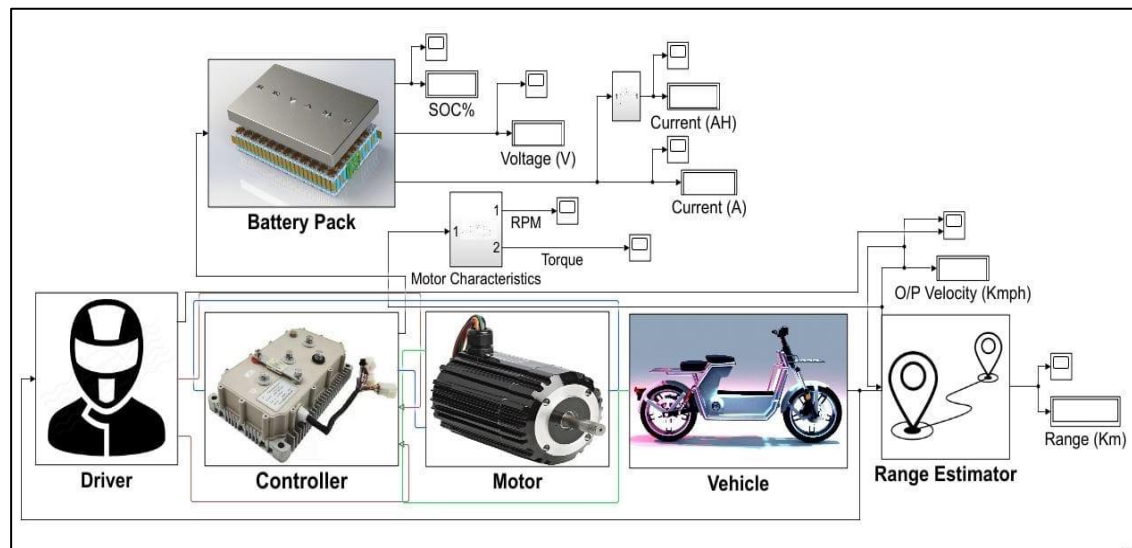


Fig.1 Simulink Model of Vehicle

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

The complete model of electric cargo bike is mainly divided into Vehicle parameters, Motor Specifications, Controller parameters, Battery Specifications and Driver inputs and in results we get estimated range of vehicle, SoC of battery, live time current and voltage values and output velocity of vehicle considering all losses in the system.

Now let us see detail classification of different parameters given as input for simulation of Simulink model.[4]

### 3.2.1. Battery Pack

Battery pack is considered as power source for any electric vehicle, as every component on electric vehicle draws the current from battery pack to fulfill its requirement of working. Here also after theoretical calculations for requirement of battery capacity we can give the same input for battery capacity in MATLAB Model.

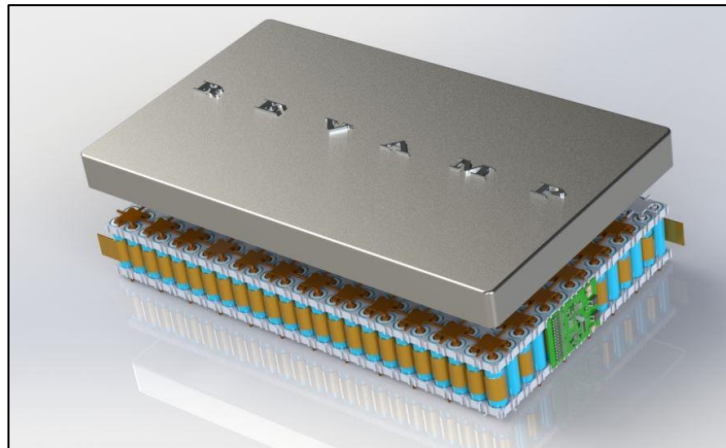


Fig.2 Battery Pack

Above shown battery pack in fig.2 is actual battery pack which is used in electric cargo bike. The number of cells used in this battery pack are calculated by doing calculations for required power for further components such as motor, electronics, etc. Also, number of cells in series and in parallel are decided according to space constrain in vehicle. In MATLAB model it is required to give inputs of technical specifications of battery pack like Battery capacity, Current capacity, Voltage, etc. After giving this input for Simulink model it is possible to simulate the battery parameters considering other technical parameters also.

## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

The detailed block diagram of different parameters used in MATLAB Model is as shown in figure below.

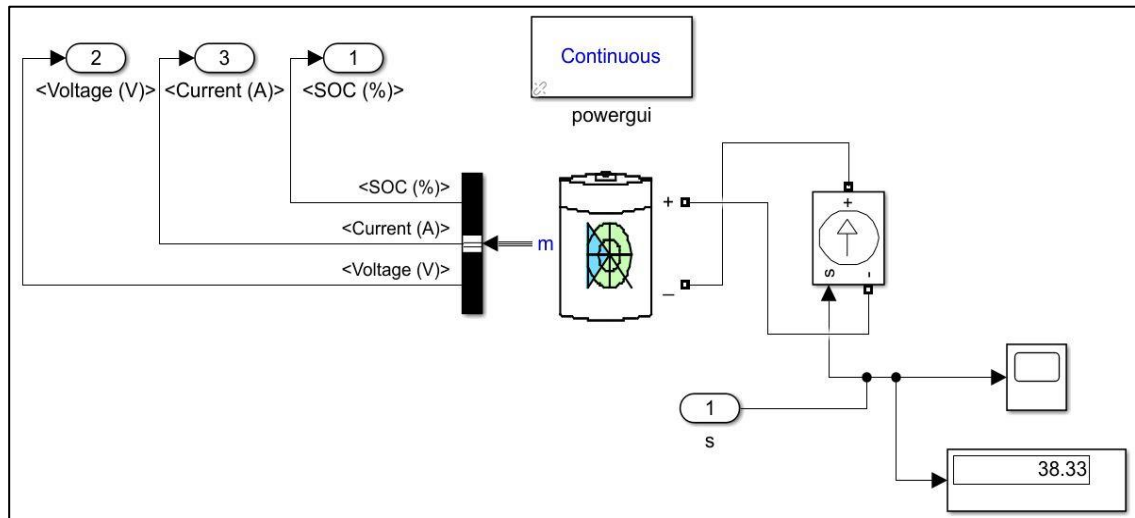


Fig.3 Circuit diagram of Battery in MATLAB

In this detailed diagram shown in fig.3, there is block for battery specifications at center of diagram. In which, initially we can select type of battery pack. In our case we have selected Lithium-Ion battery, as it is used in our specified application. Further it is required to add other specifications of battery pack for simulation of vehicle. So, we have added the input of Nominal Voltage, Rated Capacity and Initial State of Charge, which are the important parameters of battery pack. Next, to simulate this type of battery it is needed to include 'Power GUI' block. And to see the results of Current, Voltage and SOC of battery we included 'Bus Selector' block which will take input from battery pack and as a output it will show us how values of SOC, Current and Voltage changes instantaneously.

Also to study how current, voltage and SOC changes graphically, we added block of 'Scope', through which we can see the nature of change in values. And to see instantaneous values for the same, we added 'Display' block. After running the complete model, we can see those graphs of change in SOC values over the period of certain amount of time. We get this values for change in time period of every one second. Similarly, for the change of values of Current and Voltage, we can go through scope provided for Current and Voltage respectively

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 3.2.2. Driver

The inputs given to the vehicle while simulating it are given by the Driver command in which there are mainly six ports for giving inputs. Which includes reference velocity, feedback velocity, Grade, acceleration command, deceleration command and info. In which there are mainly two outputs viz. acceleration and deceleration command and others are given as input to driver module. In inputs, Drive cycle is main input given to vehicle which is very much responsible for making simulation close to reality.



Fig.4 Driver

While simulation velocity from input Drive cycle is taken as reference velocity for vehicle and output velocity of vehicle is again taken as feedback velocity for driver input from which it can be decided that whether to accelerate the vehicle or decelerate it. Also we can give input for grade of road profile to simulate the vehicle for actual parameters of road. Detailed block diagram of parameters in driver module is as shown in fig.5 below

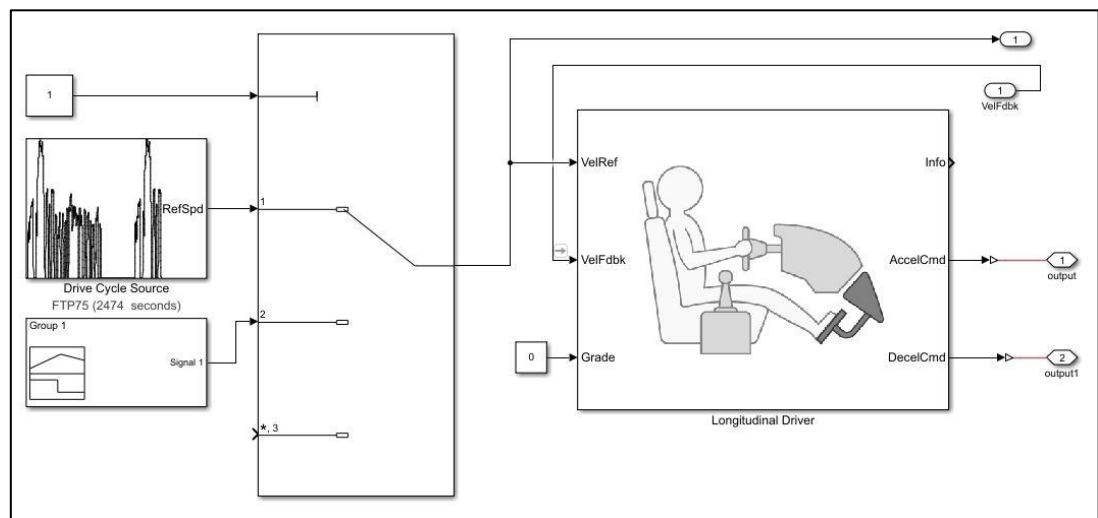


Fig.5 Simulink Driver Module



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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 3.2.3. Controller



Fig. 6 Controller

Battery pack has fixed output of current and voltage, if anyone connect battery directly to motor then there won't be any control on the vehicle motion and it won't be possible to accelerate and brake the vehicle as and when needed. To solve this problem controller shown above in fig.6 is used on actual vehicle.

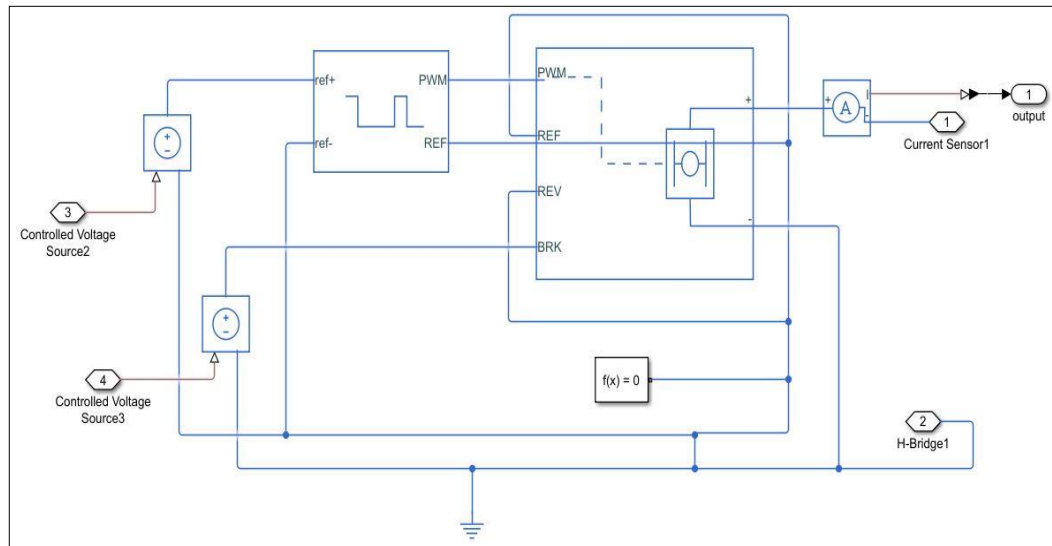


Fig.7 Circuit diagram of Controller in MATLAB

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## **A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle**

In model-based design of controller shown above fig.7, H-bridge PWM controller is used which works on logic level, but the driver model gives output in the power form. To convert the power form into logic level-controlled voltage source is used. This controlled voltage source gives the PWM controller logic input which it converts into pulse form and then gives it to H-bridge and accordingly acceleration of the vehicle takes place. While to control the braking of the vehicle another voltage-controlled source is used which is connected to 'BRK' input of H-bridge.

With the help of H-bridge block it is also possible to achieve success of producing regenerative braking which helps us in increasing SoC% of battery which eventually resulted increase in range of our vehicle.

### **3.2.4. Motor**



Fig.8 Motor

From the battery pack we get output in electrical units that is in terms of current and voltage. To convert the electrical energy into mechanical, motor is been used. Motor shown above in Fig.8 is used in actual application. According to the requirements of our vehicle permanent magnet DC motor is used.

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

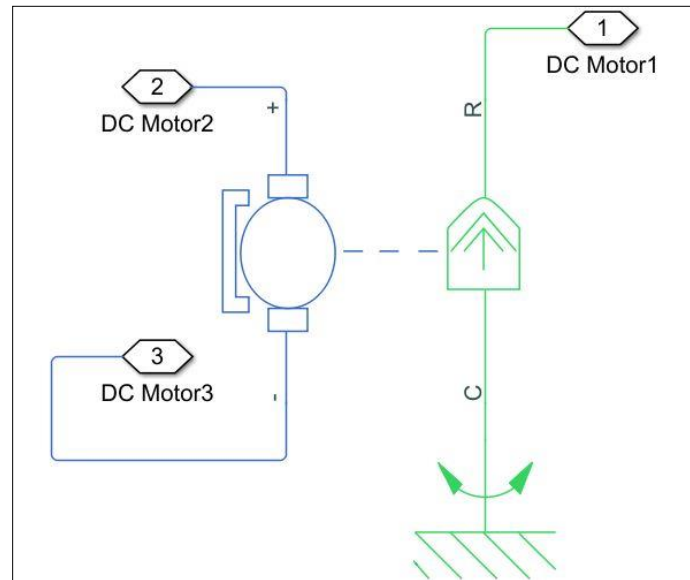


Fig.9 Circuit diagram of motor in MATLAB

Output of H-bridge controller is connected to motor. In the motor model block inputs of parameters:

- No load-speed
- Rated load speed
- Nominal voltage

Were given. The output of motor was then connected to the gearbox model of our vehicle. Circuit diagram of motor is shown in Fig.9.

### 3.2.5. Vehicle

The vehicle body is one of the important part of this mathematical model. The subsystem models like motor, the controller and battery (lithium ion) are integrated with vehicle body. Vehicle dynamics associated with the bike has also been studied to provide the required road reaction for correct simulation. CAD model of vehicle is shown in Fig.10.



Fig. 10 Vehicle

## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

Vehicle model as shown below in Fig.11 includes the all parameters related to suspension, steering, brakes and Drive line. All these values are set to get desired configuration of vehicle. This information concerns the mechanical and electrical characteristics that can affect the power consumption of the vehicle, such as electric motor power, torque/speed characteristics, curb and gross weight, aerodynamic drag, etc. Some of these data depend on the type of vehicle, for instance aerodynamic parameters have different meaning for a terrestrial vehicle. Also, the proposed model of overall concept, showing the all main components in model is shown in Fig.12.

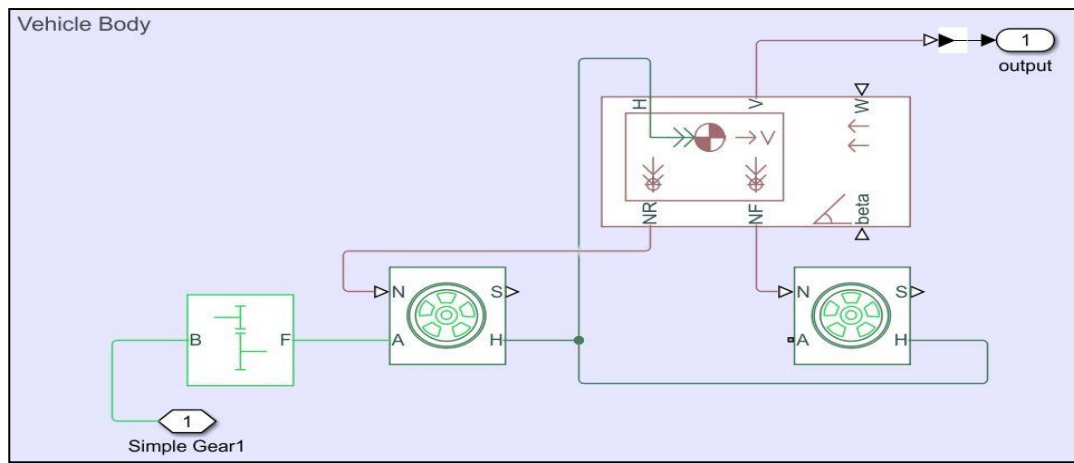


Fig.11 Circuit diagram of Vehicle Body in MATLAB

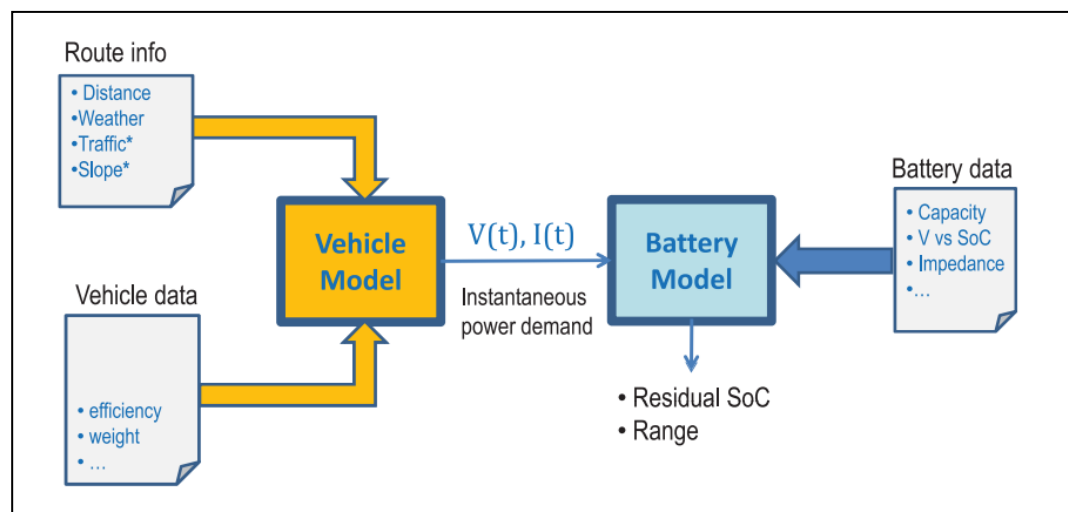
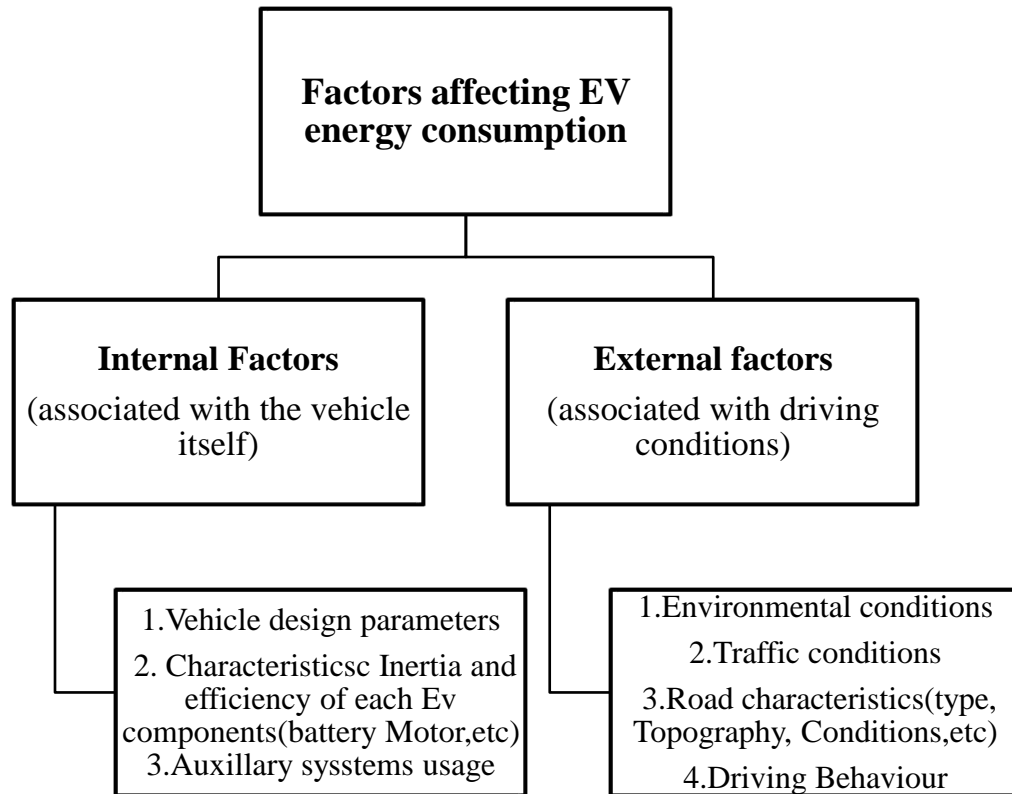


Fig.12 Overall concept of the proposed Model

### 3.2.6 Range Estimator

Range estimation is one of the main factor while designing the electric vehicle. The range of electric vehicle depends upon the factors including battery size, average speed, terrain, rider weight, and energy consumption due to various factors mentioned below-



As given below in Fig.14, integration of the model of range estimation with vehicle body model and using simple mathematical relation between distance travelled and time, it is possible to estimate the range of vehicle.[3]



Fig.13 Range Estimator

## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

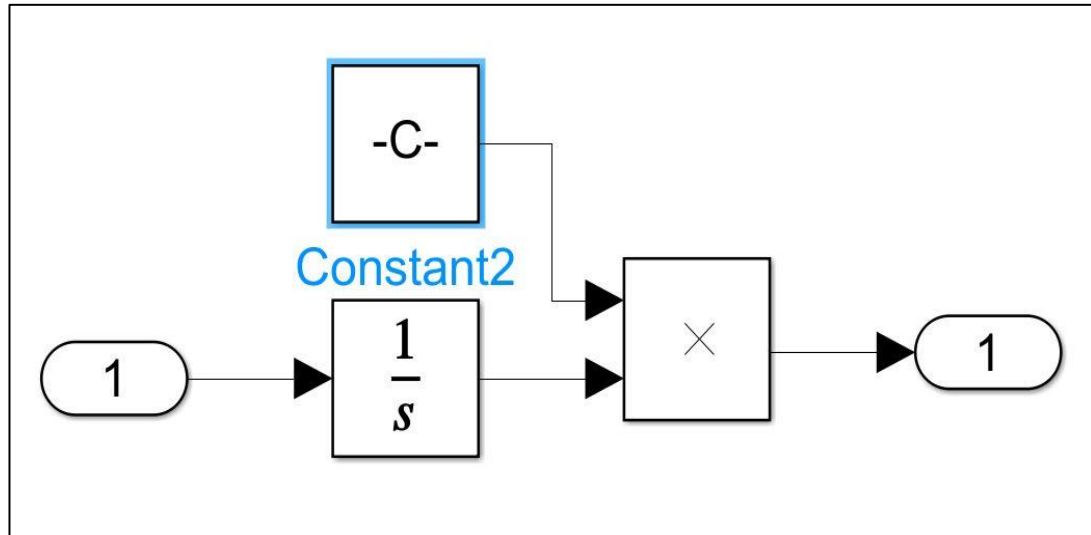


Fig.14 Circuit diagram of Range Estimator in MATLAB

### 3.3. Results and Outputs

After simulating the complete model of cargo bike over Indian Drive Cycle and NYC Drive Cycle, results obtained of estimated range of vehicle and State of Charge of battery shows how battery gets discharged over the period of time for given road profile.

Outputs of simulation are as follows:

#### 3.3.1. Indian Drive Cycle

Below graph shown in Fig.15 gives idea about the variations in velocity profile which is designed specifically, by considering Indian road conditions.[1]

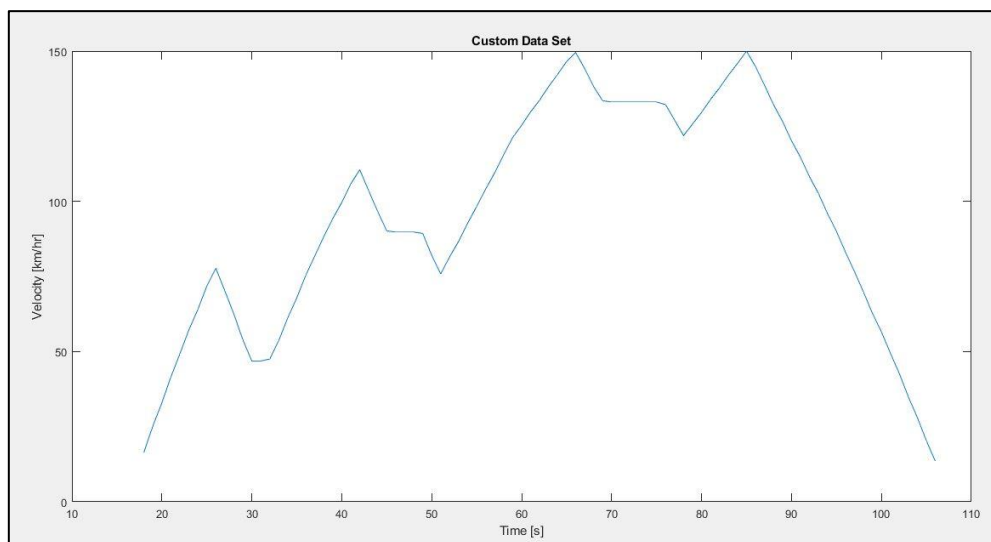


Fig.15 Indian Drive Cycle

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 3.3.1.1. Range Estimation

Range of any electric vehicle mainly depends on battery size, average speed, terrain, overall weight on vehicle, component efficiencies, etc. In traditional methods for range estimation it is easy to calculate the range of vehicle based on theoretical calculations but in that terrain information is not used for vehicle's performance, which plays very significant role in accurate estimation of range of vehicle. Here the inputs of 'Indian Drive Cycle' for pattern of road profile are given so, certainly estimation of very accurate range of electric cargo scooter for it's defined application is possible to obtain.[3]

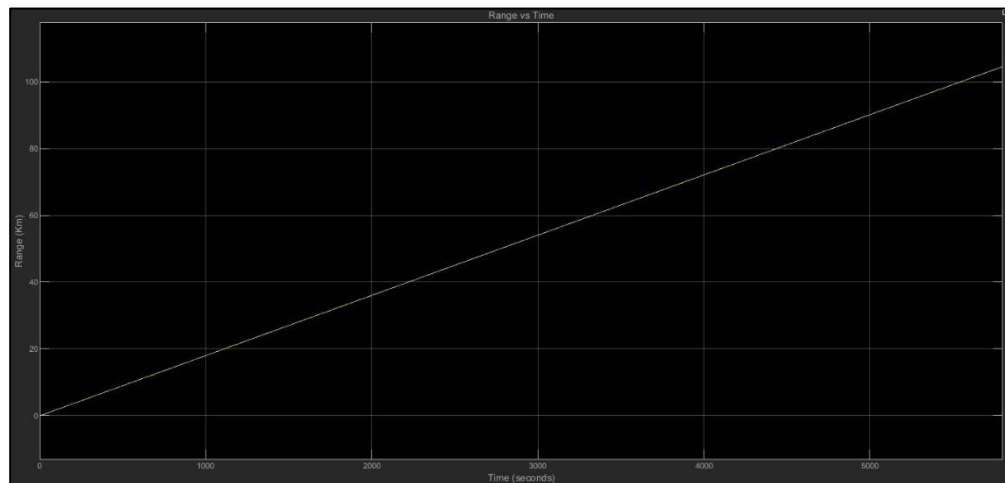


Fig.16 Range Vs Time

The above graph, Fig.16, shows that how range is changing according to given Drive Cycle over the defined period of time. As range is one of the important parameter to know about any electric vehicle. After simulation of complete Simulink Model it is possible to get range for any electric vehicle as shown in above graph.

### 3.3.1.2. SoC Estimation

Estimation of State of Charge of battery plays vital role to know about how vehicle can behave in different scenarios of loading, change in terrain profile. Which nothing but tells how vehicle draws the current while driving over the given road profile. Similar to range estimation, for SoC estimation road profile has important role for getting accurate results.[6]

The graph in Fig.17 of SoC for our application is as shown in figure below,

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

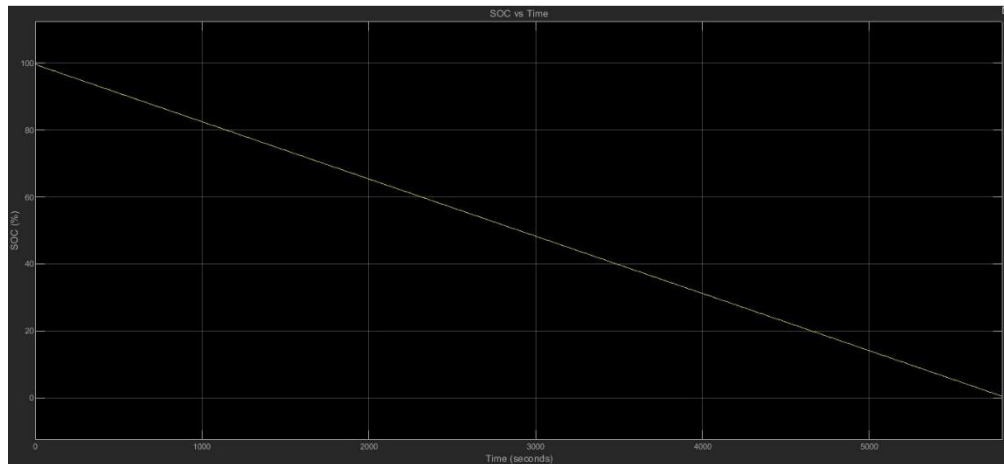


Fig.17 SOC Vs Time

It is seen from above graph that how battery gets discharged over the period of time for given road profile. Also, from deep study of this graph we can understand in which region of drive cycle battery is draining fast or in which region battery is performing with more efficiency. This study will certainly help us to know what parameters should be more focused to enhance battery performance. And to achieve better results from battery pack. In some region there is increase and decrease in nature of the graph, it is due the implementation of 'Regenerative Braking' in Simulink Model. In which when driver applies brake, the resistance offered to motor from ground is again used to charge the battery pack resulting in more range of the vehicle. [4]

### 3.3.1.3.Voltage Vs Time Graph

Graph shown below in Fig.18 shows the variation of voltage drop over the certain time period. Which will help to know about nature of voltage drop.

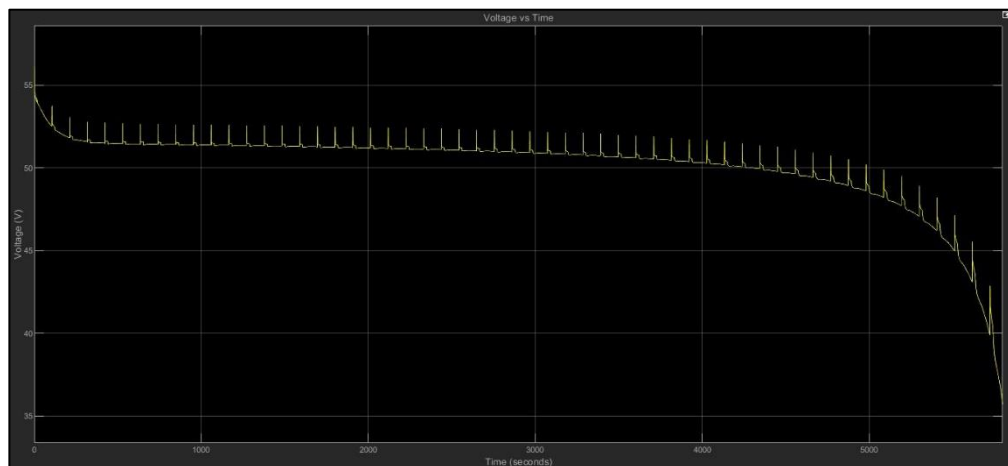


Fig.18 Voltage Vs Time



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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 3.3.1.4. Graph showing Velocity variations in vehicle

After running the simulation of complete model, to know about variation in velocity of vehicle is one of the main parameters. Graph shown below in Fig.19, gives idea about how velocity of vehicle changes for given input drive cycle. It also shows the difference between input given and output obtained in two different colors. Input velocity is shown in blue color while yellow color shows obtained velocity.

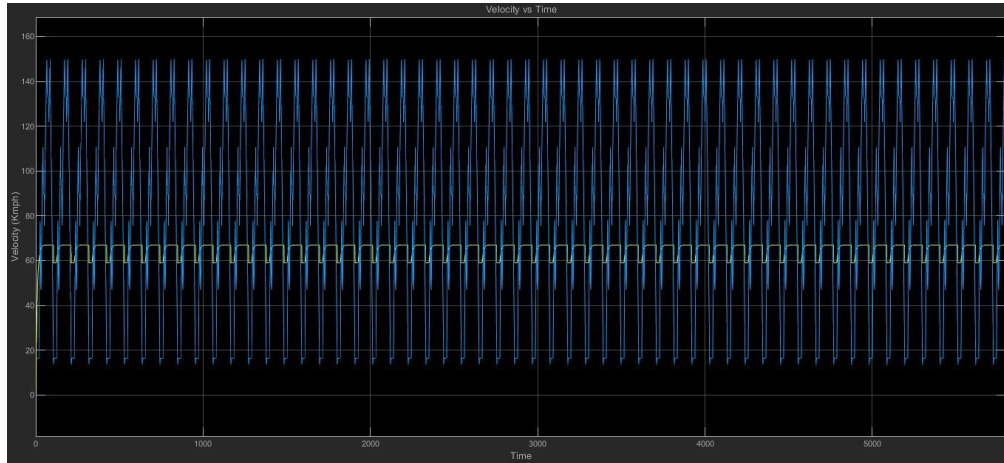


Fig.19 Velocity change in vehicle

### 3.3.2. NYC Drive Cycle

Below graph in fig.20 shows the variations in velocity profile of NYC Drive cycle which is designed specifically for more speed and more up and down in velocity profile.

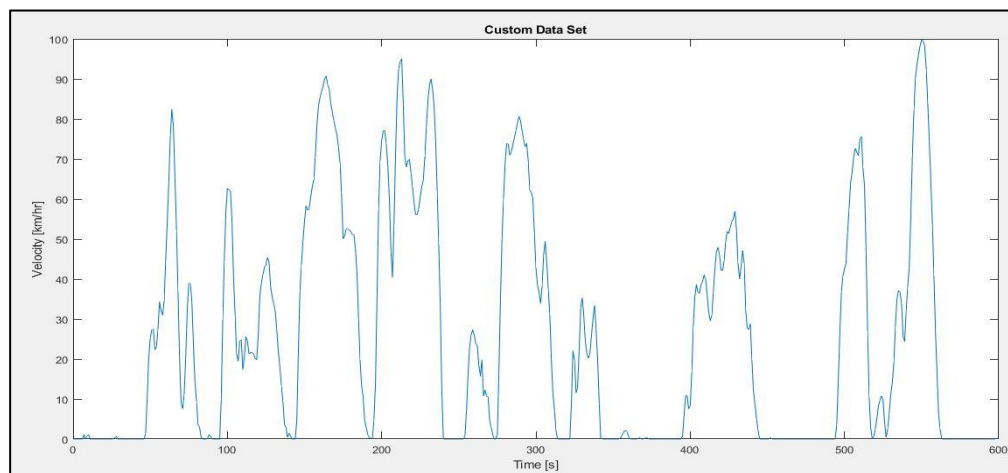


Fig.20 NYC Drive Cycle

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 3.3.2.1. Range and State of Charge Estimation

Figure 21 shows Matlab graph of Estimated range for NYC drive cycle which is 59 Km at the expenses of 66% of state of charge which is shown Fig.22. ripples of state of charge graph shows regenerative braking action.[3][6]

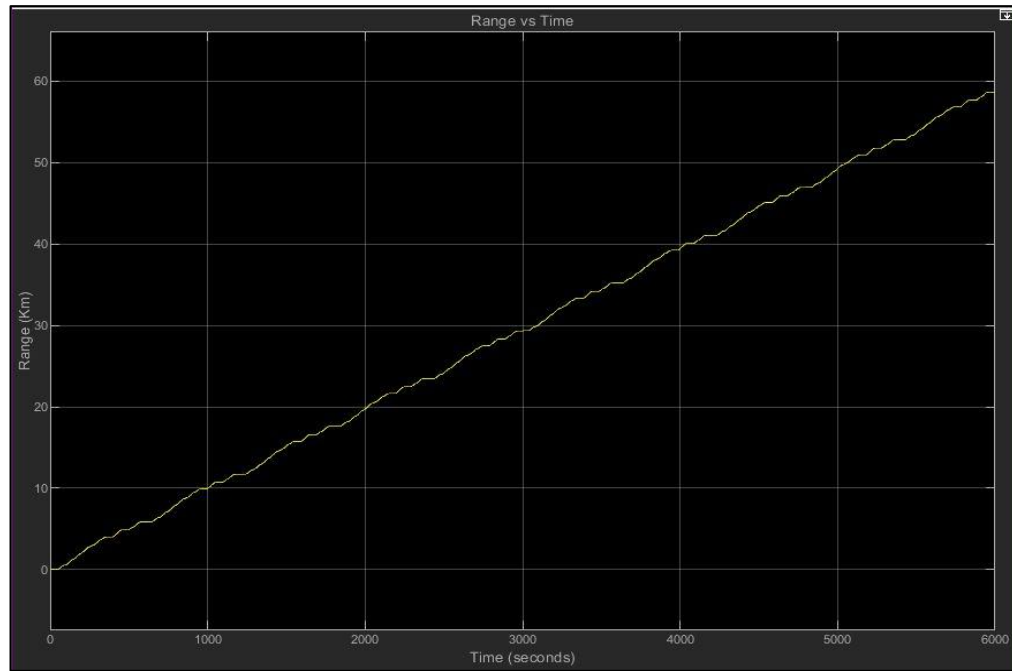


Fig.21 Range Vs Time

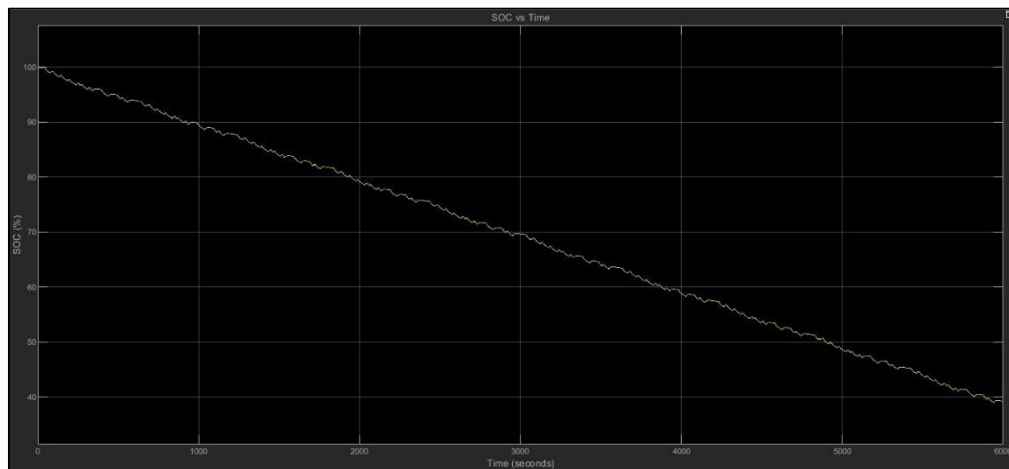


Fig.22 SoC Vs Time

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## A Model Based Performance Prediction and Range Estimation based on Road Information for Electric Vehicle

### 3.3.2.2. Voltage Vs Time Graph

Typical nature of Voltage vs time can be seen in Fig.23 wherein maximum voltage at maximum state of charge is 56 volts and as vehicles travels by voltage decreases accordingly. fluctuation in voltage shows drop in instantaneous voltage due to sudden acceleration.

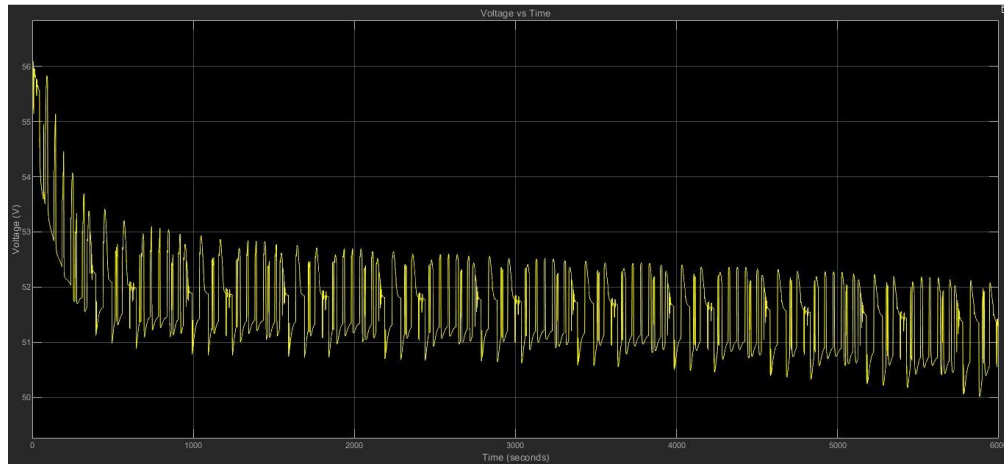


Fig.23 Voltage Vs Time

### 3.3.2.3. Graph showing Velocity change in vehicle

Variation in instantaneous value of velocity vs time is shown in figure 24. Yellow curve represents actual velocity of vehicle against desired velocity shown in blue curve. it can be clearly seen that maximum velocity reached by vehicle is 68 Km/hr.

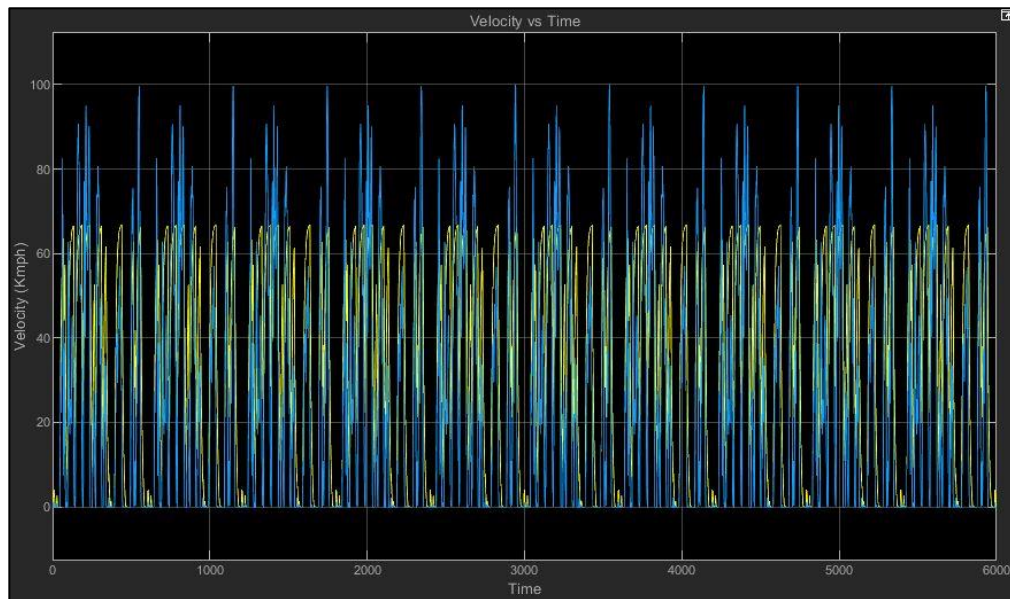


Fig.24 Velocity change in vehicle

## **4. CONCLUSION**

After performing a simulation of complete model of electric cargo bike, results of estimated range for that bike and also nature of SOC for the battery pack are obtained. It can be concluded that the new process used over the traditional process for this performance estimation is very efficient and it is definitely reducing the time required for the process with very less cost for performing it.

## **5. FUTURE SCOPE**

After first iteration of this simulation, we are able to get required results of estimated range and nature of SOC over the period of time. The results from this simulation are also satisfactory and gives us close to reality results.

Using this method over traditional method for estimation of range and SOC of battery will surely reduce the time required to get the results. As we are getting the range and SOC of the vehicle without actually manufacturing it, it is possible to test the vehicle in less time and to perform more iterations to get better results. When we perform a test for technical parameters of vehicle it becomes impossible if we go by traditional methods, but performing by Model Based Design we can do very effective tuning of the same components. Mainly whole process of this type of method requires very less time and also completely cost effective for performing lots of iterations.

These simulations can tackle Multiphysics and multifunctional performance issues quickly. Since when we go by actual testing it requires lot of electronics to gather data from vehicle and which also involves accuracy losses of sensors.

Future scope of this includes machines learning models for accurate estimations of range prediction and performance estimation.

## **6. REFERENCES**

### **1. Journal Article**

- [1] Shaik Amjada, et al., “Impact of real-world driving pattern and all-electric range on battery sizing and cost of plug-in hybrid electric two-wheeler”, Journal of Power Sources, Vol. 196, (2011), pp3371-3377
- [2] Jiquan Wang, et al., “Electric vehicle energy consumption modelling and prediction based on road information”, World Electric Vehicle Journal, Vol. 7, (2015) pp 447-457
- [3] Kaveh Sarrafan, et al., “Accurate range estimation for an electric vehicle including changing environmental conditions and traction system efficiency”, IET Electr. Syst. Transp., 2017, Vol. 7 Iss. 2, pp. 117-124 © The Institution of Engineering and Technology 2016
- [4] Ahmet Onur Kiyakli, et al., “Modeling of an Electric Vehicle with MATLAB/Simulink”, INTERNATIONAL JOURNAL OF AUTOMOTIVE SCIENCE AND TECHNOLOGY 2018, VOL. 2, NO:4, 9-15
- [5] Javier Romero Schmidt, et al., “Prognosis of the energy and instantaneous power consumption in electric vehicles enhanced by visual terrain classification”, Elsevier Publication, 2019
- [6] Matthew Guttenberg, et al., “Software for high-fidelity electric vehicle en route state of charge estimation, fleet analysis and charger deployment”, Elsevier Publication, 2021