Intelligent Energy Management System Simulation for Battery Electric vehicles

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Abstract: "The Intelligent energy management" refers to the design of the higher-level control algorithm determining the proper power level to be generated. This project aims at developing an Intelligent Energy Management System (IEMS) targeted towards Battery Electric Vehicles that prioritizes power distribution to various vehicle systems based on driving scenario and battery SOC. The second goal is to implement machine learning algorithm and database management feature for Intelligent Energy Management System (IEMS) in BEVs.

Index Terms –IEMS, EMS, Machine learning, database, BEVs

I. INTRODUCTION

Power management for vehicle systems is desired for many objectives, such as improving fuel economy; reducing pollutant emissions; prolonging lifetime of some power sources, e.g. the battery, fuel cell, etc.; and enhancing vehicle drivability and reliability.

In an EV, the power resources are limited. However, it is essential that the power requests from systems to have on board energy storage systems with a continuous power rating several magnitudes higher than the average power usage just to meet load power transients. Is it however possible to all loads be met . But it would be impractical and cost prohibitive mitigate short term peaks by coordinating the activation of certain loads.

This paper aims at conserving the power by the systems based on the various driving scenarios and the battery SOC .The battery SOC is maintained to be positive irrespective of the driving conditions by applying suitable Energy Management Algorithm.

Sl.no	Conventional Energy Management System(EMS)	Intelligent Energy Management System(IEMS)
1	Conventional EMS predicts the power consumption by the EV subsystems using limited input data.	In intelligent EMS, we consider additional input factors like Road terrain, traffic information, weather data etc. This would be difficult to achieve in case of conventional EMS as it will add complexity to the system.
2	Performs computations based on mathematical model.	Performs computations based on prediction using machine learning algorithm.
3	System functionality is slow	System functionality is fast
4	Complex system	Simple system
5	Optimal control scheme and fuzzy logic are the examples of conventional EMS	Machine learning algorithm scheme is example for IEMS.

Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist.

Simulation software is used-Where it is too expensive or risky to do live tests, In Large or complex systems for which change is being considered, Systems where predicting process variability is important- Simulation can help us to understand how various components interact with each other and how they affect overall system performance, It is widely used in flight simulators which can help us to explore the behavior of a system under specified situations in a low risk environment.

Simulation provides an inexpensive, risk-free way to test changes ranging from a "simple" revision to an existing production line to emulation of a new control system or redesign of an entire supply chain.

This paper describes the methodology for developing the Intelligent Energy Management System (IEMS) framework that was built using open sources tools – Python

1. Generating the track data for HVAC and Drivetrain subsystems of a Battery Electric Vehicle (BEV).
2. Storage of simulation data using the feature of sqlite3 database storage.
3. Implementation of the Machine learning algorithm feature to the existing IEMS framework.
4. Testing the Machine learning model with different track data.
5. Prioritizing the subsystems by assigning the strategy values for the subsystems taken into consideration.

II. THEORY

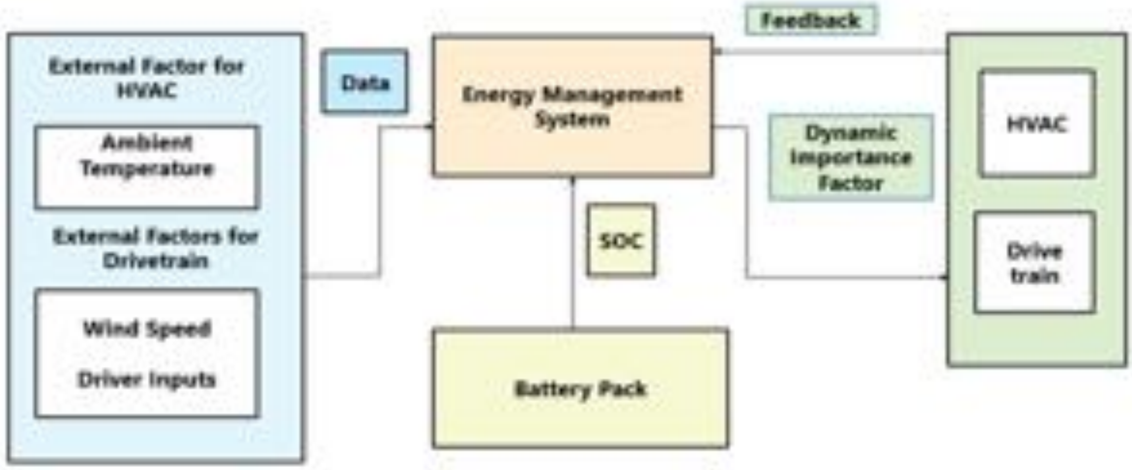

Fig.1Block diagram of Intelligent Energy Management in Battery Electric Vehicles

System description

External Factors:

(1) Data pertaining to factors external to system such as ambient temperature, driving conditions etc. would be analyzed and collected.

(2) On the basis of above obtained factors driver behavior, would be predicted. The final subsystem output would be driving pattern and external information.

Producer System:

(1) Producer System would consists of battery packs, which mainly would interact with the Energy Management System, giving it information about various battery parameters.

(2) Regulatory instructions from the Energy Management system would be transmitted to the block, depending on system performance.

Consumer System:

(1)Consumer systems would consist of all the power drawing systems in an automotive. For, this particular work the emphasis would mainly focus upon HVAC and Drive Train system.

(2)Power drawn by the different consumer systems, would be a function of the importance factor. This importance factor would be dynamic in nature, w.r.t the vehicle operating conditions.

The simulation framework described in this paper contains the file for generating the track data for the subsystems, mathematical model for calculating the power consumption by HVAC and Drivetrain, Machine learning algorithm for predicting the power consumption by the subsystems, integration of sqlite3 database for storing the simulated and predicted data from simulation framework. An EMS algorithm for assigning the power values based the strategy values assigned to each subsystems, matplot library for visualizing the predicted and conserved energy. The foundation of this framework is python. Python has numerous packages also called modules that provides various functionalities.

The framework contains files for developing the Intelligent Energy management system which includes,

1. File for generating track data–This file will generate the track data for Drivetrain and HVAC subsystems in BEV's. Inputs for drivetrain includes terrain data, traffic data, wind speed, coefficient of friction, gear ratio etc. Inputs for HVAC include weather information, ambient temperature, user fan level etc.
2. Mathematical model for calculating the power consumption by HVAC and Drivetrain – This will calculate the power consumption by HVAC and Drivetrain subsystems using track data as inputs.
3. Machine learning algorithm feature-This feature will take in the inputs and power outputs by HVAC and Drivetrain subsystems and predict the power outputs by these systems using machine learning model.
4. EMS Algorithm – The EMS Algorithm will allocate the power for the HVAC and Drivetrain subsystems by allocating the strategy values for each systems depending on the driving scenario.
5. Sqlite3 database feature– This feature comes readily available with the python package .The predicted data will get stored into sqlite3 database.

III. FLOW OF IEMS FRAMEWORK

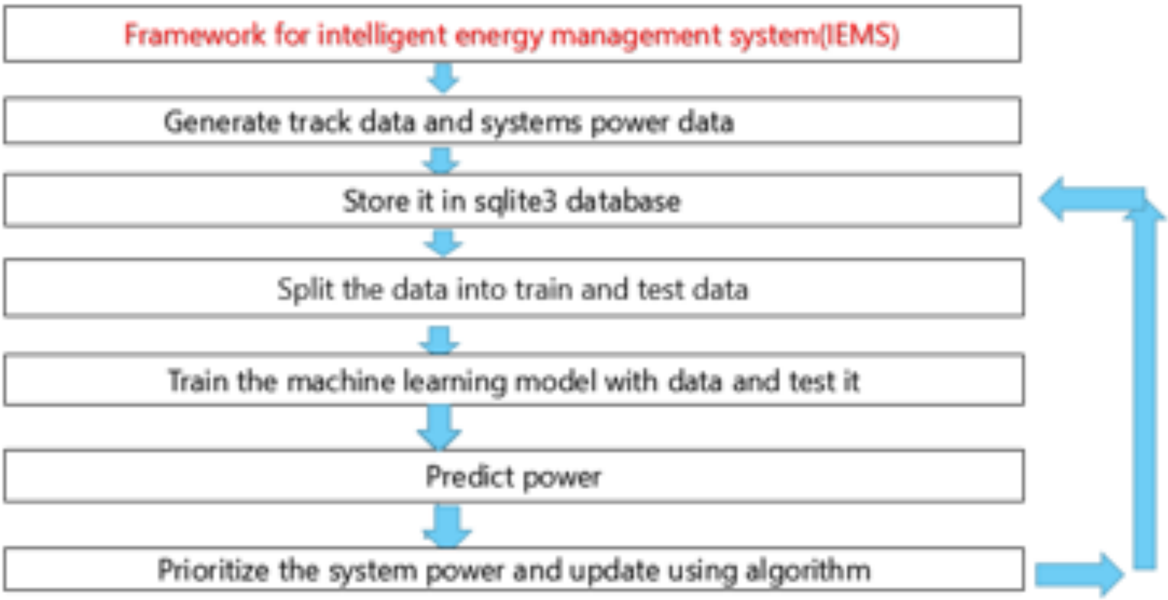

Fig.2 flow of IEMS Framework

1. First the track data is generated for HVAC and drivetrain systems.
2. This data is stored in sqlite3 database. Later this data is split into train and test set. This data is then trained with the machine learning model and tested with the test set.
3. The new predicted power by machine learning model is then stored in the database /appended to the database.
4. Then the Energy Management System (EMS) algorithm takes in the new predicted data and checks the State of the charge of the battery (SOC).If the SOC is negative then EMS works on the systems power data by applying different strategy values for the systems so that the battery SOC remains positive throughout the cycle.

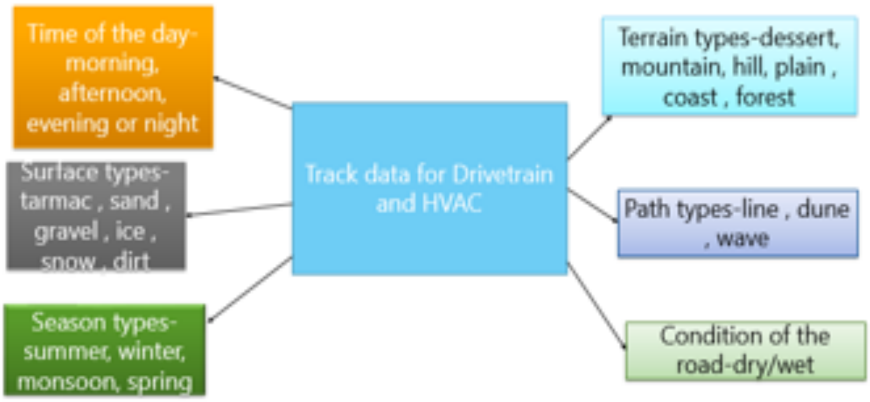

Fig.3*Inputs taken for generating the track data*

The track data generated includes environmental data such as distance (initial value=1000), slope of the road(initial value=0), elevation(initial value=0), season, average temperature(25 degree),wind, rain, snow, fog, battery SOC ,path, time etc.
It also takes in the weather data-whether it is summer, winter, monsoon, autumn etc. It also takes the terrain information whether it is desert, hill, mountain forest, coast or plain area.
It also takes in the traffic information, time of the day etc.
The track information is generated in segments of points of distance 1000.it is divided into 10 points each of points having its own cof , corf, elevation slope, wind speed.

Feature 1 – mathematical modelling of the HVAC and Drivetrain subsystems

Modelling Dive train:

The Power calculation for Drivetrain is done by taking inputs such as Coefficient of friction, coefficient of rolling friction, wind speed, mass of the vehicle, area of cross section of the vehicle, and air density.
It also takes data into consideration whether it is
Two wheel drive i.e power wheels=2, or four wheel drive i e power wheels=4
From the above inputs we calculate drag force, friction force, gravity force and calculate the drivetrain force using the formula
Drivetrain force=drag force+ friction force+ gravity force

Vehicle Dynamics	Vehicle Powertrain Parameters	Wheel Parameters	Motor Parameters	Battery Parameters
Speed=40m/s Torque=0Nm	Gear ratio=9.5	Rim diameter =17m Tyre width=255m	Motor power=160watts	Battery capacity=62Amphr

Vehicle mass =1100 Vehicle area of cross section=2.22m		Tyre aspect=60	Peak torque=320Nm Continuous torque=210Nm	Battery SOC=80 Battery volts=360V Maximum charging volts=1.2 *battery volts Min charging volts=0.9*battery volts Maximum charging current=300A

Table 1.*Vehicle parameters influencing power consumption by Drivetrain*

Constant speed Regeneration model: The constant speed regeneration model calculates the change in elevation between points with a constant speed. The corresponding change in time is also calculated. This gives the change in elevation and change in time.

Modelling HVAC: HVAC model is a dual compressor output with front and rear ac. It also features blowers in front and rear. Environmental parameters such as air density, gravity and air pressure is taken as environmental inputs for HVAC model.

Air density	***1.22***
Gravity	***9.80m/s2***
Number of passengers	***4***
Cabin temperature	***24 degree Celsius***
Air pressure	***1000***
Ambient temperature	
Daylight	
Blower voltage	***24V***
Max blower current	***5A***
Rear ac	***3000W***
Max compressor power	***6000W***
Sun heat flux	***1400***

Table2. Environmental and vehicle parameters influencing power consumption by HVAC

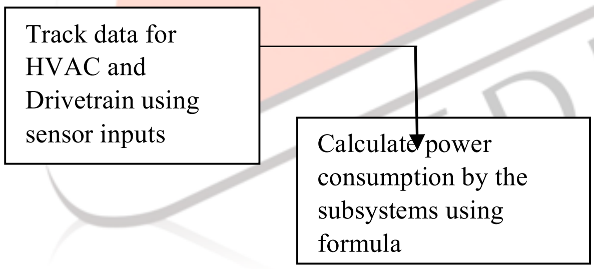

Fig.4Block diagram showing the flow of power calculation from the track data

Feature 2 – Integration of sqlite3 database feature to the existing simulation for IEMS

The generated track data from the simulation for IEMS is stored in the sqlite3 database which is been integrated to the simulation. Although all the data that is generated may not be useful the ones that can prove to be useful for further improvements in the plant model can be stored in a database file

The advantages of storing the sqlite3 database to the existing simulation is:

1. Sqlite3 database comes integrated with python so you don't need to install a separate database for storing the data.
2. Sqlite3 database uses simple sqlite3 commands for storing and retrieving data. So storing and retrieving data becomes easy.
3. Storing and retrieving data is very fast.
4. It can store large amount of data. Storage space is more

Disadvantages of using pandas over sqlite3 database:

1. Every query has to be coded, tested, and debugged. ***Every special case or option*** has to be coded, tested, and debugged.
2. Since it's all special stuff you made up, there's no convention to follow. People coming to use your query program have to understand what it does and how it works. If they want to do anything even slightly different, they (or you) have to get into the code, understand it, modify it, test it, debug it, and document it. This will generate a lot of support requests.

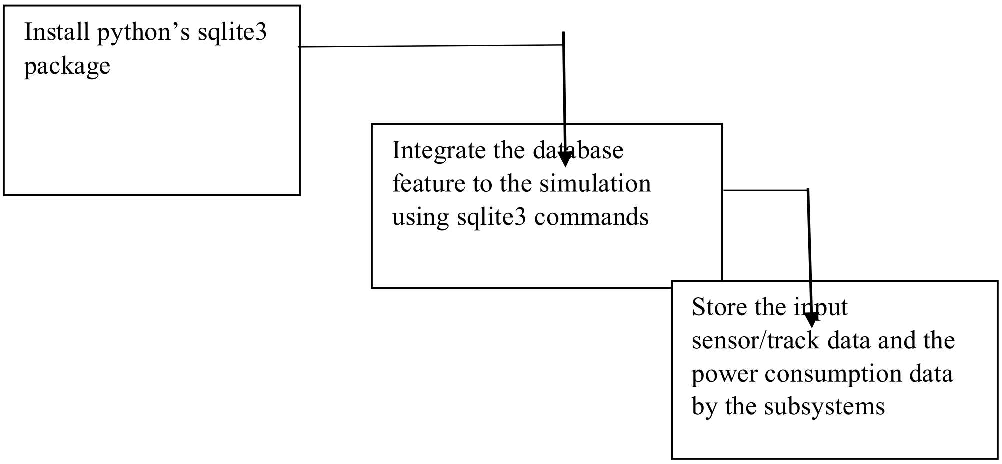

Fig.4Block diagram depicting the flow for adding Simulation data into the database feature

Feature 3 – Integrating the machine learning algorithm feature for the existing simulation to predict the power consumption

Here the machine learning model is added to reduce the complexity of the system which gets increased with addition of formula in case of normal EMS. The machine learning algorithm will make the computations simple and can predict the power without using the formula. Because once it is trained the machine leaning algorithm will learn from the data and can predict the upcoming values. This makes the system intelligent and fast. The suitable machine learning model is selected and then trained with the previously available data stored in the database.

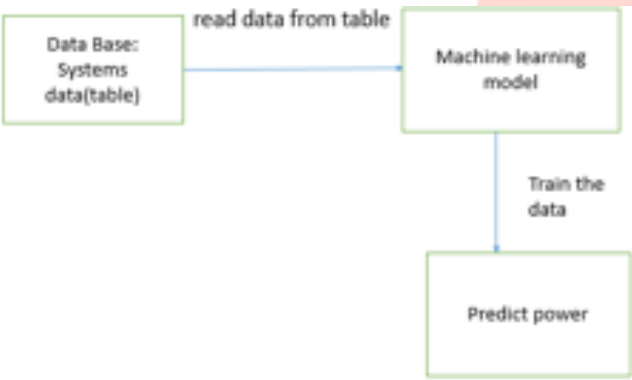

Fig.5: Block diagram showing the data trained using the machine learning model.

Feature 4 – Integrating the EMS algorithm for prioritizing the predicted powers depending on the scenario

In EMS algorithm initially default strategy values are allotted to each systems. ie max power is allocated to each systems initially. But when the total energy demand exceeds the battery SOC then the EMS algorithm starts working on it.

The EMS algorithm checks the battery SOC and if it is negative then it works on the system powers by allocating the power values to the systems so that the battery SOC doesn't go negative. It allocates the strategy values for the systems by triggering the EMS flag.

After applying the strategy values for the systems the systems power is recalculated to match the battery SOC. The EMS Converges at this stage.

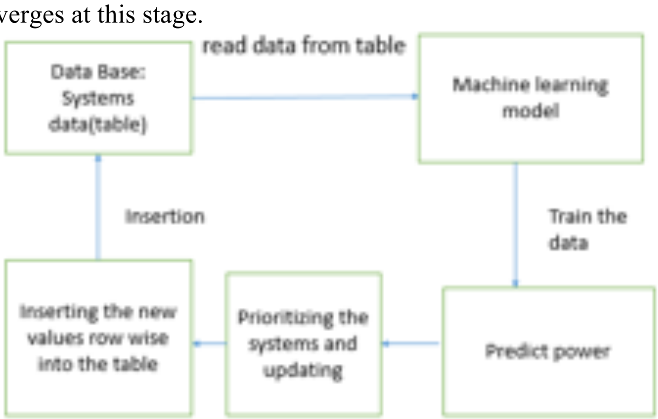

Fig.6.Block diagram showing the prioritization of the predicted powers using EMS algorithm

IV. RESULTS

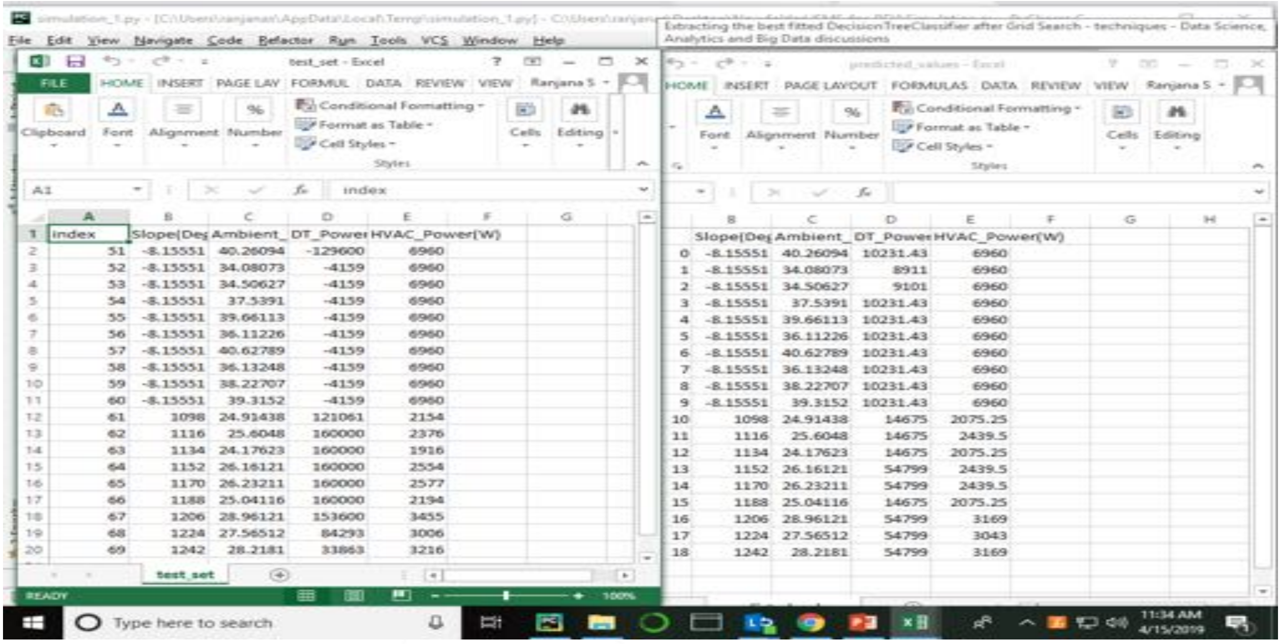

Fig.7*The sheet shows the tested values to the left which are tested for the predictions by the machine learning algorithm. The right sheet shows the predicted values for the tested data .The prediction values for the HVAC subsystem was 90% and for Drivetrain it was 60%.*

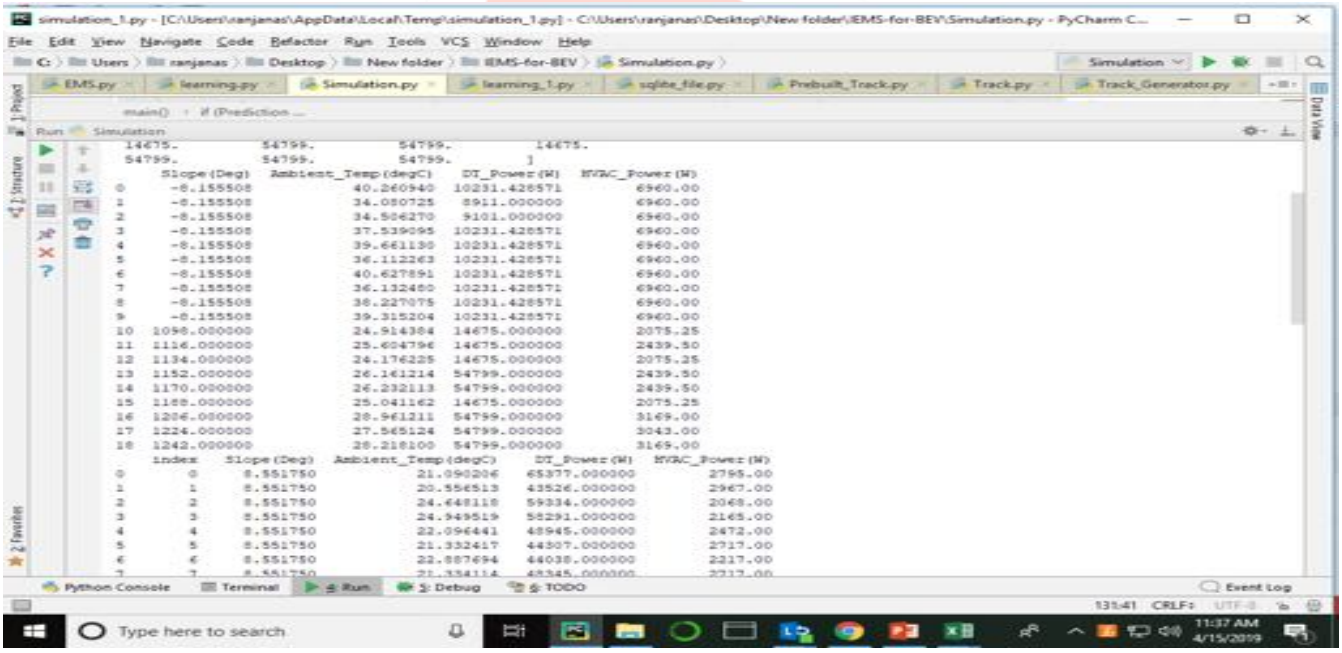

Fig.8This sheet shows the new predicted values from the machine learning algorithm which is stored in the database. The same values are next given for prediction by the machine learning algorithm for prediction

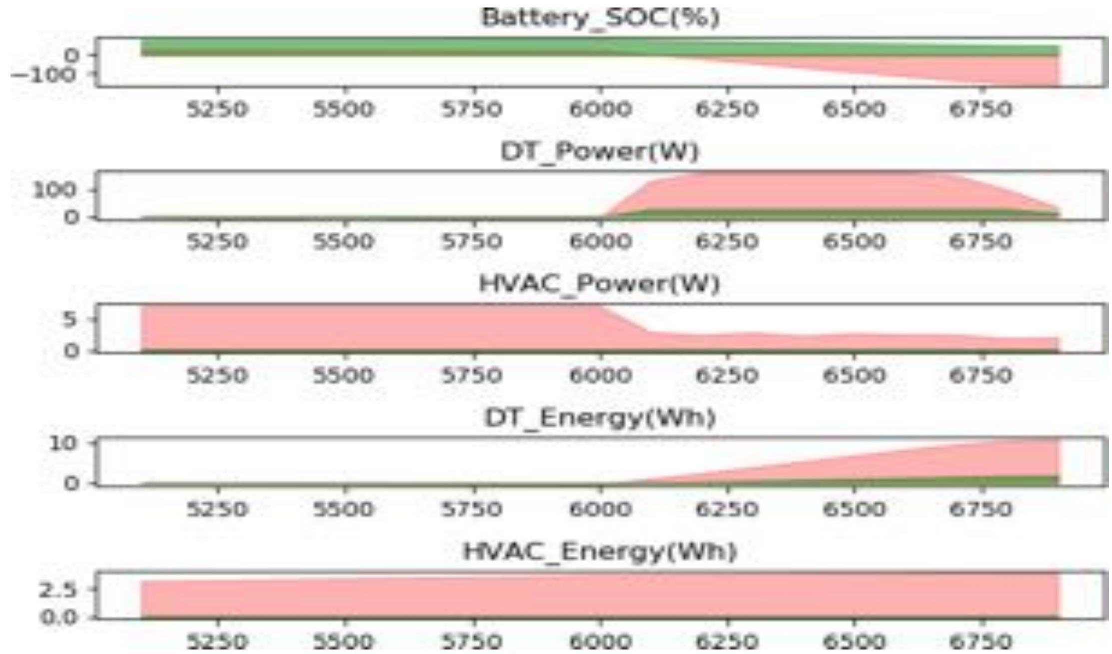

Fig 7.The graph shows the predicted and the conserved powers .The pink colour indicates the predicted power by the machine learning algorithm for the given distance. The green colour indicates the conserved energies over the distance.

The power values for the HVAC and Drivetrain gets adjusted to the battery SOC and the battery SOC doesn't go negative because the EMS algorithm assigns the strategy values to the subsystems according to the driving scenario and the battery SOC.

V. CONCLUSION

The IEMS framework will be able to generate the track data for different driving scenarios in which the user will be allowed to select the terrain type and predict the power consumption by the subsystems namely HVAC and Drivetrain. The power consumption will be calculated without using the formula which makes the system to work fast. The generated predicted power will be stored in the sqlite3 database for further prediction for the next terrain type by the machine learning algorithm. The battery level is maintained to be positive throughout the path by the EMS algorithm. The EMS algorithm will maintain the power level of the HVAC and Drivetrain systems if the Battery SOC is negative

VI. FUTURE SCOPE

In addition to the above subsystems considered we can add

1. Wipers
2. Power steering
3. Power window

Presently the machine learning algorithm prediction varies for different terrain data. Accuracy of prediction is less for Drivetrain system. As a future work the accuracy of the prediction is to be enhanced using suitable algorithm.

VII. REFERENCES

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