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Efficient Power Management of Electric Drive system using Fuzzy Logic Control

S. Indirani[1], PratikshyaMohanty[2] and SouhardyaMoulik[2]

[1]Assistant Professor, Electronics and Instrumentation Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
[2]B.TechElectronics and Instrumentation Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India

ABSTRACT

Electric vehicle (EV) is the currently trending and most talked about technology in the world. The pace of innovation in this field is leading to advancement in production technology as well as optimization of vehicles. The electric vehicles (EV) make use of an electric motor instead of an IC (Internal Combustion) engine as compared to the conventional fuel based vehicles. A gasoline vehicle uses a spark ignited (SI) engine and a diesel vehicle uses compression ignited (CI) engine. In these engines, the fuel is ignited combined with air and combustion takes place which leads to the emission of toxic gases which harm the environment as well as affect the health of human and animal life.Hence, the world is going for a revolution in the automobile industry by replacing current generation automobile with electric vehicles (EV). Electric cars such as “Nissan Leaf”, “Ford Focus Electric”, “Tesla Model S” and“Chevrolet Volt”have already been introduced in the market and they have been a proof that electric vehicles (EV) have lesser wear and tear due to lesser mobile parts, lesser heat generation, more economical and greater performance. The idea behind this work is to develop a strategy to optimize power requirements using a“fuzzy logic controller (FLC)”.By making use of this, the performance of this electric drive system is good enough as compared to that of an “IC engine vehicle”. The proposed idea is to implement fuzzy logic on the vehicle powertrain to improve efficiency as well as drawing less voltage from the power source which is the battery using the techniques of voltage matching and forward driving. The adopted methodology will ensure that high power requirements are mettakingthe various losses involved into consideration.

Keywords: Fuzzy Logic Controller, Forward Driving, Voltage Matching, Electric Powertrain, Fuzzy Inference System, Fuzzy Logic Designer

INTRODUCTION

The growing environmental concerns and the dependency on crude oil for petrol and diesel has led to a surge in demand of electric vehicles. Such vehicles, are also known as PHEV-Plug in Hybrid Electric Vehicle, which has all the built in capabilities that a driver would need. Additionally, it takes care of unwanted emissions. There are two kinds of EVs available in the market- “all-electric vehicles (AEVs)” and “plug-in hybrid electric vehicles (PHEVs)”. Which sort of vehicle will accommodate your way of life relies upon your necessities and driving propensities. In an electric vehicle, the powertrain has various components which are used to generate power and deliver that power vehicle. The power train makes use of two different motors, one of high-speed characteristics, and another one of high torque characteristics. It uses a planetary gearset which effectively switches between the motors, in turn resulting in a wider range of speed and control. The control logic incorporates inputs based on which, switching between the motors is done as per requirement. There are numerous benefits of Electric Vehicles (EVs) as compared to

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conventional petrol/diesel cars- cost effective, cheaper to maintain, environment friendly and has more energy security.An Electric Vehicle has lesser mobile parts than a conventional fossil fuel based vehicle. There is relatively lesser need of servicing, eliminating the use of any expensive or high maintenance equipment like “exhaust systems, starter motors, fuel injection systems, radiators”. There is just one mobile part which is the rotor. These vehicles are simple and very robust. Since we are utilizing“renewable energy to” recharge “EV (Electric Vehicle)”, we significantly help in reducing the greenhouse gas emissions. Electric vehicles need to be more energy efficient, our paper discusses about improving the “state of health (SOH)” of the battery by increasing “discharge time”. The control strategy we have adopted, will ensure that the energy demand can be met without drawing a huge amount of power from the source considering the losses. This strategy is basically about power optimization.

LITERATURE SURVEY

S.K.Jha, Prerna Gaur and Anil Kumar Yadav have provided a “comparative study” of the use of “fuzzy logic controllers (FLCs)” and “PID controllers” in power management in electric vehicles, which have been used in different modes namely regenerative braking and forward driving. The idea behind this project is to develop a power train model, which is then simulated and analyzed. [1] ZhiHang Chen, M. AbulMasrur, and Yi L. Murphey in 2008 have discussed the use of fuzzy logic techniques and developed their own machine learning algorithm LOPPS(Learning Optimal Power Sources). It has been used to switch between power sources for optimal power management. [2]Richard Saeks, Chadwick J. Cox, James Neidhoefer, Paul R. Mays, and John J. Murray have talked about a decentralized adaptive control system for a four motor–generator hybrid electric vehicle (HEV). They have developed a nonlinear simulation model for the vehicle dynamics. [3]

M. H. Hajimiri and F. R. Salmasi discusses the use of Fuzzy Logic Controller (FLC) for energy management based on the predictability. The future state of the vehicle was determined and fuel consumption has been reduced and emission as well as performance has been improved. [4] J. N. Rai, MayankSinghal, MayankNandwani in IOSR Journal of Electrical and Electronics Engineering in 2012 discussed the use of fuzzy logic technique in the estimation and control of speed in a DC motor. The proposed controller frameworks comprised multi-input fuzzy logic controller (FLC) and multi-input integrated fuzzy logic controller (IFLC) for the speed control. [5]

IMPLEMENTATION

We have used“voltage matching technique”which is a process of designing both“input and output impedance” of an “electrical load”according to the source in order to ensure maximum power is transferred. Whenever there is a power source with fixed output impedance, “maximum power transfer” takes place when “load impedance” is exactly equal to the “complex conjugate”of the“source impedance”.

$$\mathbf{Z_{load}=Z^*_{source}}$$

Here * represents the complex conjugate.

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Our strategy is based on"voltage matching" between the "demand voltage"based on inputs and the "battery voltage"accessible to a particular powertrain. The high voltage demand is taken care of, by"decreasing the voltage value" and "increasing the current" by a certain factor to keep the "power constant". The issue of working withlarge currents handled by using a proper voltage converter circuit (Buck Converter). The "DC/DC converter" draws a certain current "I_m"which is generated by the electric motor at a certain voltage "V_m". Thevoltage "V_m"which is generated depends on speed of the motor.It hasa unique value corresponding to every value of speed. The "DC/DC converter"uses"electrical power" which is the "product of voltage and current" and generates the output at an "increased voltage value"and "reduced current value" so that it matches our"rechargeable battery". This factor "K"which is the variable under consideration for the controller we have used (fuzzy logic controller) is the out variable. The control strategy used here is to manipulate the factor "K" to achieve optimized power which is desired. Thus,"power management" is accomplished by "manipulating and controlling" thefactor" through"fuzzy logic controllers (FLCs)" for"forward driving mode".

PROCESS FLOW

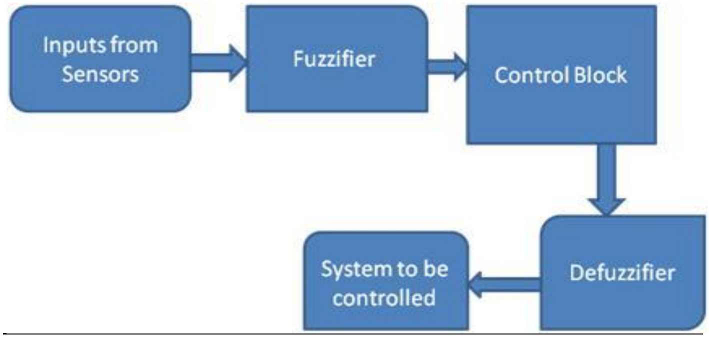

Fig 1- Process Flow Diagram of the System

DESIGN OF THE "FUZZY LOGIC CONTROLLER (FLC)"

"Fuzzy inference system" is the GUI available on MATLAB using whichwe have designed our fuzzy logic controller. It utilizes "If-then" explanations with connectors like "OR" or "AND" for describing the logic.

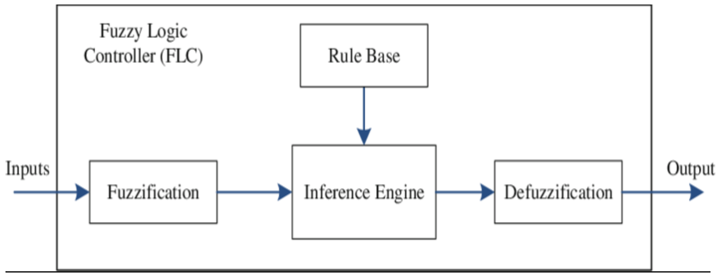

Fig 2 – Design of the Fuzzy Logic Controller (FLC)

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1. **PREPROCESSING**
   The inputs used here, are readings from some measuring devicesand not linguistic in nature. It shows the state of the inputs before they are given as inputs to the controller.

2. **FUZZIFICATION**
   The first block used,is called“fuzzification”and this process so dynamic in nature that it changes with every change in input.

3. **RULE BASE**
   The rules deployed here, are in “If -Then format”, where “If”stands for “conditional clause” and “Then” is called the “conclusion”. PC executes the principles and performs the processing of a control signal based on“input error (e)” and “change in error(dE)”.
4. **DEFUZZIFICATION**
   At this stage, all the activities are consolidated and modified into a stand-alone“non-fuzzy output signal”. The “output levels”rely ona set of “specific guidelines and frameworks”.
5. **POST PROCESSING**
   This involves de-noising and filtering.

In this model presented here, the fuzzy logic controller has two inputs –“voltage error (error)” and “derivative of the voltage error (δ)” and an output whichis the “correction factor (K)”. The “input variable error (e)”has three “membership functions”- “PL (positive low), PM (positive medium), PH (positive high)” and the “input variable (δe)” also has three “membership functions”- “NL (negative low), NM (negative medium) and NH (negative high)”. The output variable “δK”(correction factor) has five “membership functions”- “PVL (positive very low), PL(positive low), PM (positive medium, PH(positive high) and PVH (positive very high)”. The range of “δK”is dependent on the values like “road speed” and “road torque”. These values are provided as inputs and range of output variable is computed from a PID controller. The input and output membership functionsare shown below-

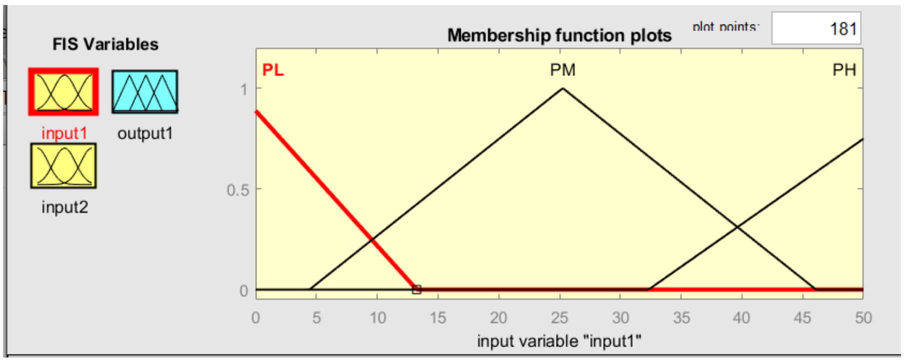

Fig 3- Input (1) “Membership Function” Plot

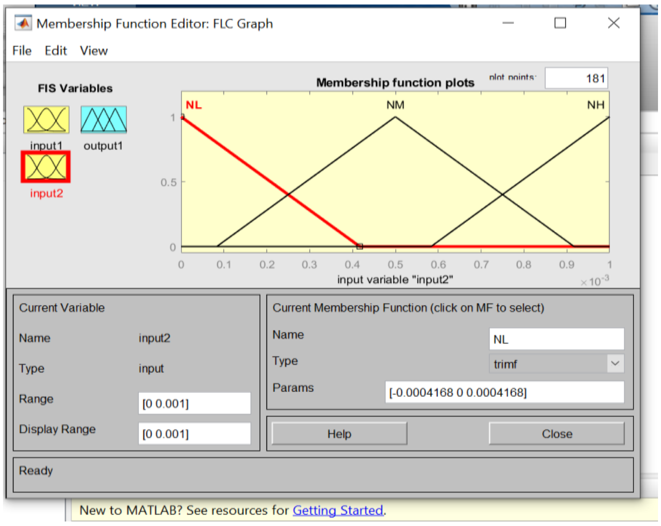

Fig 4- Input(2) "Membership Function" Plot

The rule base has been designed using "input and outputmembership functions". The rule base is summarized in theform of a table. "Centroid method"has been used as the "defuzzification strategy".

δe \ e	P.Low	P.Medium	P.High
N.Low	P.VLow	P.Low	P.Medium
N.Medium	P.Low	P.Medium	P.High
N.High	P.Medium	P.Medium	P.VHigh

Fig 5 – A table showing the rule base

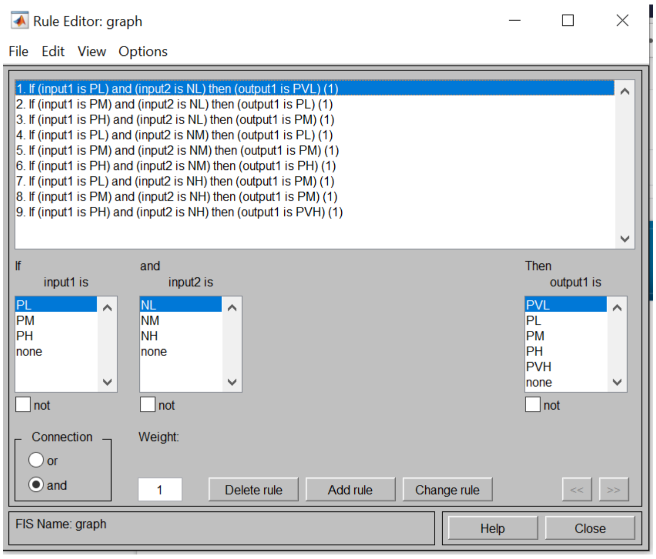

Fig 6- Rule Editor with a set of 9 rules

The Rule Viewer shows that the system is dynamic in nature. The user can manipulate the output by varying inputs using the scale. Therefore, we can get an idea of the relationship between inputs and outputs to understand the system better.

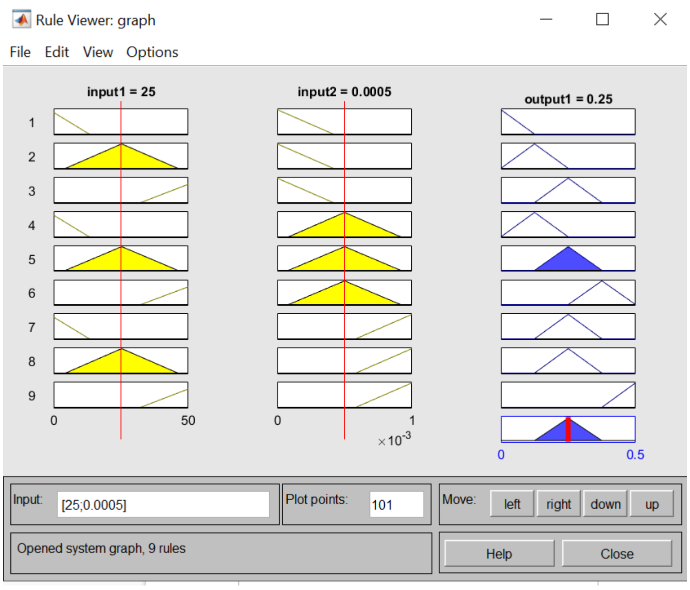

Fig 7- Rule Viewer

POWERTRAIN DESIGN

After the design of the controller the powertrain model has been developed on MATLAB. The powertrain model is shown below which has a DC power source, 2 DC motors, Load Torque and a scope to measure the RPM.

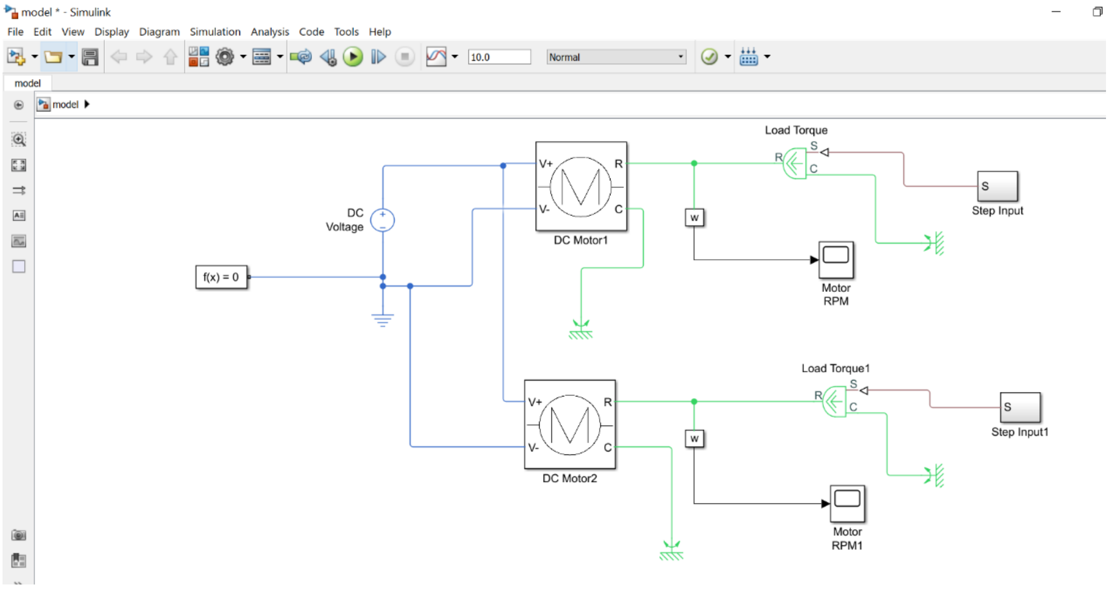

Fig 9- Powertrain Design

ARDUINO INTERFACING

The entire fuzzy logic code is converted to a MATLAB code which is then downloaded into an Arduino board. By using“MATLAB support package for Arduino”the MATLAB code can interact freely with the controller.

Fig 10- Arduino Uno

With “MATLAB Support Package for Arduino Hardware”, wehave established a connection with the Arduino board. The package has provisions for the user to carry out several tasks such as-

1. Acquiring “analog” and “digital” sensor data from Arduino board.
2. Establishing a connection with devices using“digital”and “PWM ports”.
3. All peripheral devices and sensors can be accessed and can beconnected over “I2C” or “SPI” communication protocols.
4. One can establish a communication link with an Arduino board over a USB cable or over any wireless network likeWi-Fi

RESULTS AND DISCUSSION

The voltage which is given as an input to the motor is balanced by the converter circuit. The idea is to ensure that it is compatible with our rechargeable battery. The current is manipulated keeping in mind that the power does not change. The simulationswhich we have carried out have shown better results for“fuzzy logic controller (FLC)”as compared to conventional“PID controller”. The “PID controller” has a “higher settling time”as compared to the“fuzzy logic controller (FLC)” and the “efficiency” in general improves with “fuzzy logic controller (FLC)”.

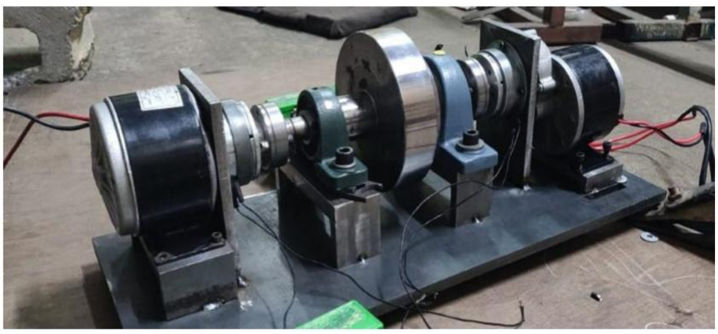

Fig 11- Side-view of the powertrain

The scope output of Motor RPM vs Time is shown below. Time is given on X-axis and RPM on Y axis.

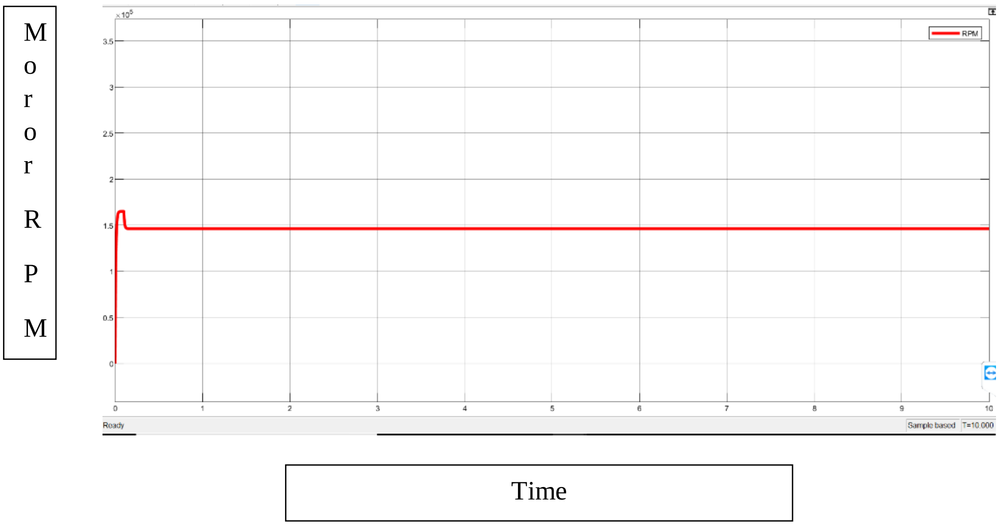

Fig 12- Motor RPM vs Time

The graph shown below is a comparison between the value of error of a Fuzzy Logic Controller and a PID Controller. This indicates that the settling of error is very steep in case of a PID Controller but when it comes to Fuzzy Logic Controller, the depreciationcurve is smooth.

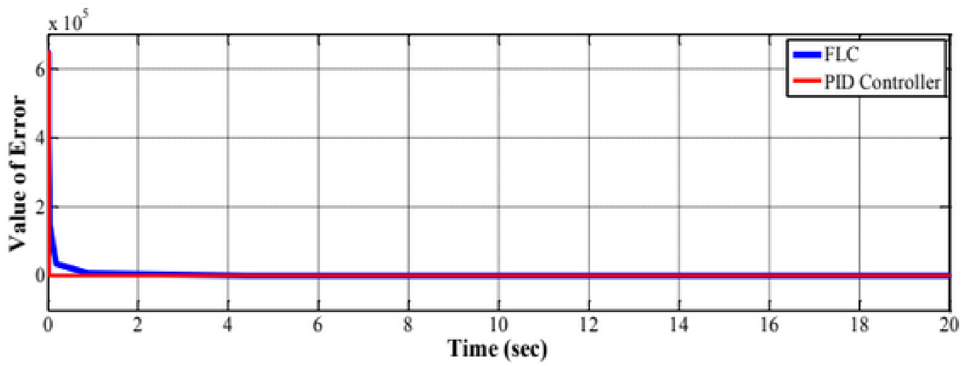

Fig 13- Graph demonstrating the comparison of error between PID vs FLC (Fuzzy Logic Controller)

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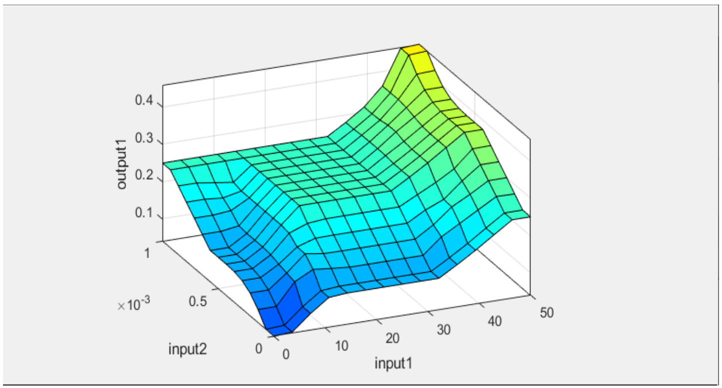

Fig 14- Surface Viewer Graph

The above graph is a 3-Dimensional representation of two inputs- error and derivative of error and the outpur which is the correction factor. It shows how the output can be changed with changes in any one of the inputs.

CONCLUSION

We have implemented fuzzy logic on "powertrain model" by using "brushed DC motor". We have successfully developed a strategy for "optimum power management" using "Fuzzy Logic controller FLC"). We have taken into account all the losses due to motor and come up with a power management strategy which ensures that the power requirementaare met and the discharge time of the battery improves.

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