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# Design of Artificial Intelligence Based PID Controller for Electric Vehicle Power train Modelling

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**ABSTRACT:** Accurate electric vehicle (EV) powertrain modelling is paramount for critical design and control decisions in high performance vehicle designs. Although simulation of EV powertrains in software simulation environments plays a significant role in the design and development of EVs.Artificial Intelligence algorithm is used to improve the stability of system by implement hybrid model of PID controller and Fuzzy system.The major goal of this research is to create an Artificial Intelligence Based PID Controller for Electric Vehicle Powertrain Modelling that could predict EV energy usage over a specified driving cycle. The effect of parameters such as battery's voltage and energy capacity, motor's rated torque and power, and gear ratio of the transmission on vehicle performance and energy consumption has been examined.

**Keywords:** Electric Vehicle, Power train, PID controller, Metaheuristic Approaches, Fuzzy Logic Controller.

## 1. INTRODUCTION

In 1884, 25 years after the development of lead-acid batteries, Thomas Parker created the first electric vehicle. Numerous versions of electric vehicles debuted after that time. Electric cars, however, have fallen behind as mass manufacturing prices have decreased and internal combustion engine technology has advanced. The impact of various gearboxes on energy was investigated by T.

HOFMAN and C.H. DAI. Utilizing a fixed gear system, a manual gearbox, and a CVT gearbox, the powertrain system has been studied [1]. E. Schaltz created the model and concept for an electric car. The energy used by this car every mile is 148.3 Wh. Energy. Additionally says that a significant portion of energy loss is brought on by auxiliary loads, such the lighting system, security system, comfort system, and battery [2]. The right electric motor for electric cars was something that X. D. Xue attempted to ascertain. Electric motors were contrasted based on efficiency, price, safety, and weight standards. The permanent magnet synchronous motor is the best motor type, according to the study's findings [3]. The analytical calculation of the Mahindra e2o is supported by its technical specifications [4]. Literature [5] demonstrates a thorough analytical estimate of EV. The EV may be created in the MATLAB®/Simulink® environment using analytical calculations, providing clear performance data for the actualized vehicle model [6]. Designed and development of EV power train via modeling, simulation & validation on a real- world vehicle system with detailed analysis of the results[12].Additional in future research focused on developing the model of serial hybrid power-trains for urban buses and optimizing using diagrams through the suggested technique's [13]. The performance of suggested controllers was demonstrated by the performance and output analyses of the control systems installed. In compared to the vehicle's uncontrolled situation, the proposed approach which shows lateral stability & management, has been enhanced satisfactorily[15].

This study will create the analytical calculation and simulation model. For driving cycle US06, the energy consumption and range figures for electric vehicles will be established. We'll look at how several factors, like the battery's voltage and energy capacity, the motor's rated torque and power, and the transmission's gear ratio, affect how well a vehicle performs and how much energy it uses.

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## II. METHODOLOGY

There are primarily five blocks of models –

- Glider(with vehicle dynamics)
- Driveline/Transmission
- Electric motor
- Battery
- Driver(with PID controller)

The driver block receives input in the form of the intended driving cycle for the vehicle to adopt. This driver block will include a PID controller to continually match the vehicle's speed with the intended drive cycle and to reduce the discrepancy between the desired and actual speed of the vehicle. Fig. 1.1 displays the whole Simulink model.

A model like this may provide a great deal of specific information on the operation of a motor, battery, as well as what is happening in the drive line for a certain input. The inputs in this situation are driving cycles for EPA certification. Then it can calculate how large the battery should be or how powerful the motor should be. It can also produce some information for visualisation, such as a torque envelope for the motor and how the battery's state of charge varies over the driving cycle.

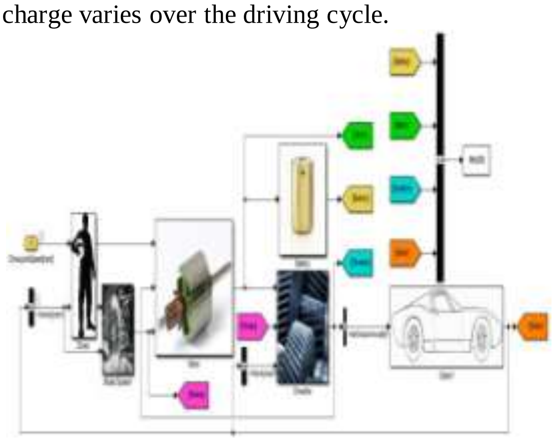

**Fig 1. Complete simulink model of an Electic Vehicle**

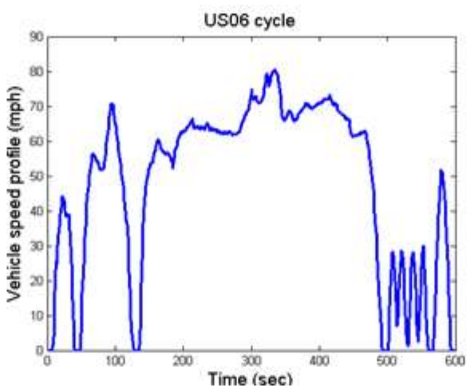


**Figure 2. US06 drive cycle**

In terms of aggressive, high-speed and high- acceleration driving behaviour, frequent speed fluctuations, and driving behaviour, US06 is the cycle. The US06 cycle is an 8-mile route with a 48.4 mph average speed, a top speed of 80.3 mph, and a total travel time of 596 seconds.

**PID Controller Design**

Since a AC drive's second order transfer function looks like this: PID control is usually needed when managing its exact displacement.

$$\frac{Y(s)}{U(s)} = \frac{b}{s(s+a)}.$$

An ideal PID controller has the transfer function

$$C(s) = K_c\left(1 + \frac{1}{\tau_I s} + \tau_D s\right),$$

where Kc is the proportional gain, $r$I is the integral time constant and $r$D is the derivative gain.

The rest of the paper is organized as follows: In Section II discussed the Fuzzy logic controller. In Section III presents the literature survey and Section IV and Section V shows the proposed methodology and results, Section VI conclusions are drawn.

**FUZZY LOGIC CONTROLLER**

A PI controller could be tweaked for a single operating points, but there are multiple operation points in Electrical vehicles. As a result, an adjustable PI improves performance of the controller, implying improved system response. As a result, a PI auto-tuning-fuzzy controller was created for the application of indirect control methods in order to ensure controller tuning depending on various operating situations.

Fuzzy logic is an artificial intelligence technique based on language norms and information. These rules are written as follows:

$$if\ x\ is\ A\ \ AND\ y\ is\ B\ \dots\ then\ z\ is\ C$$

Where A, B and C represent membership functions, for the expression presented A and B are fuzzy sets in the input and C is the fuzzy set for the output.

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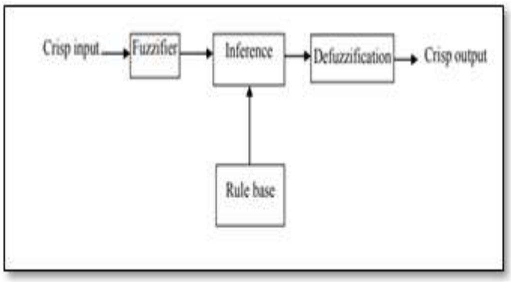


**Figure 3: Block diagram of Fuzzy Inference system[11]**

Designing of FLC is consisting of the following steps:

1. Fuzzification strategies and selection of fuzzification operator.
2. Database: a. Discretization or normalization of U.

b. Input and output variables are partitioned. c. Selection of MF of primary FS.

3. Proper derivation of fuzzy control rules.
4. To form a decision making logic which includes fuzzy implication, then interpretation of the sentence connectivity and the compositional operator. Consequently, it includes inference mechanism.
5. Proper selection of DF strategy and defining the DF operator.

## III. RESULTS

Depending on the design parameters, both uncontrolled or controlled models are tested and compared in this study. Matrixx's System_ Build component was used to construct the control method, which included the fuzzy controller. Every control variable has been separated into seven categories for the fuzzy controller, resulting in a fuzzification output vector of length seven. A change of error block outputs the change in error membership values, while an error block outputs the error membership values over the seven subgroups. Defuzzification for the PD controller is achieved by matrix multiplying the error membership vector by the rule gain table. The crisp output is obtained by taking the inner product of the resultant vector and the change of error block.

**Motor Torque:** Torque is defined as a transient force created when force is applied to a motor. The torque unit is N.m (Newton-meter). To put it another way, Torque T(N.m) is the proportion of electrical power P(W) in watts to acceleration.

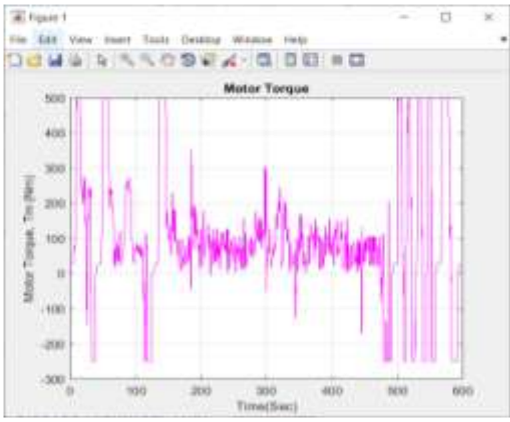


**Figure 4 :Motor Torque**

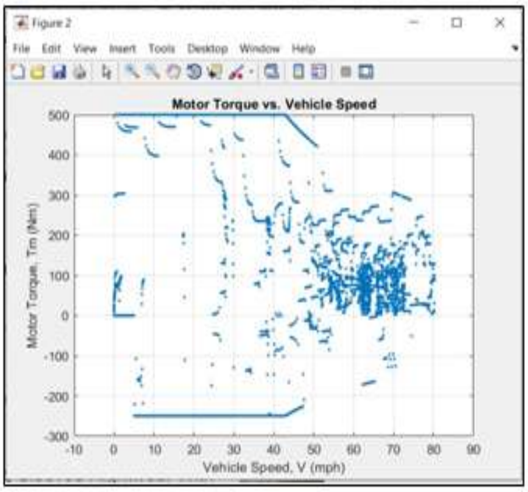


**Figure 5:Motor Torque Vs Vehicle Speed**

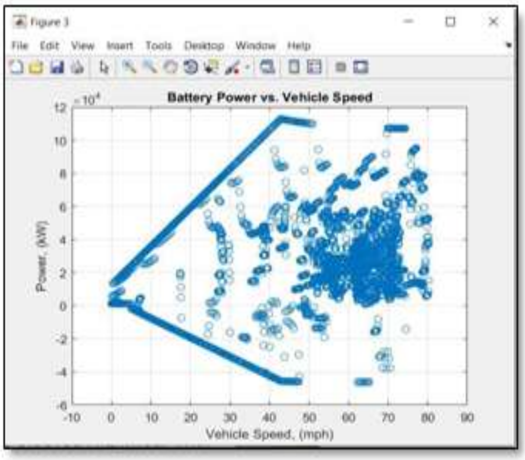


**Figure 6: Battery Power Vs Vehicle Speed**

**State of Charge (SOC):** The distinction among a fully charged battery and same battery in use is described by the SOC of a battery. It has something to do with the amount of electricity left in the cell. It is calculated by dividing the remaining charge in the

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battery by the total charge that the battery could give. As shown below, it is expressed as a percentage.

$$\mathrm{SoC}/\% = 100\frac{(Q_0 + Q)}{Q_{max}} = \mathrm{SoC}_0/\% + 100\frac{Q}{Q_{max}}$$

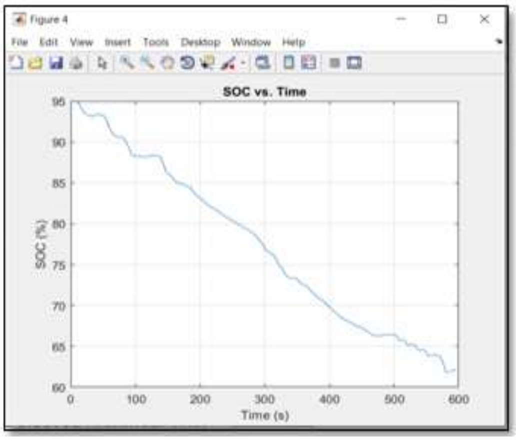


**Figure 7:SOC vs Time**

**MSE:** The MSE, or mean squared error, is a critical metric for evaluating an estimator's efficiency. The second moment of the error, calculated around the origin, is also known as the mean squared error. It takes into account the estimator's variance and bias. The MSE of an unbiased estimator is equal to the variance of the estimator. The unit of measurement for the quantity being estimated is like the unit of MSE.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(x_{obs,i} - x_{model,i})^2$$

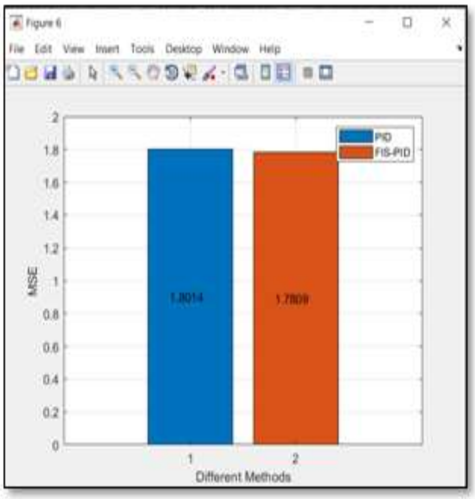


**Figure 8: Snapshot Between MSE Vs Different Methods**

In Figure 8, it is clear that the MSE range of proposed method(FIS-PID)reduced the error as compared to the existing approach (PID).

**Table 2:Mean Square Error (MSE) for different Methods**

| Methods | MSE |
|---|---|
| PID(Existing ) | 1.8014 |
| FIS-PID(Proposed) | 1.7809 |

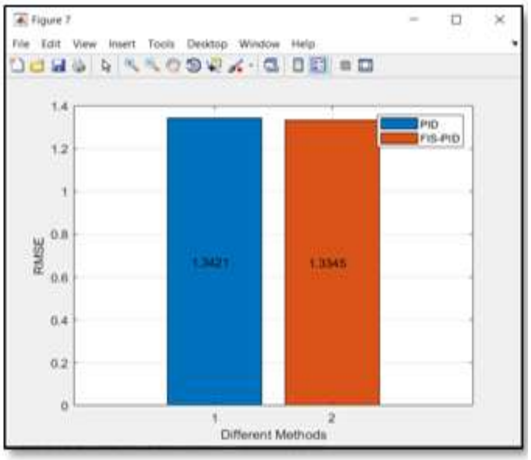


**Figure 9: Snapshot Between RMSE Vs Different Methods**

**Root Mean Square Error Formula**

The RMSE is a commonly used metric for making a comparison among an estimator's or model's projected values and the actual observed values. The square root of differences between

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predicted and observed values is the RMSE. "Residuals" are the individual differences in this calculation. The root mean square error (RMSE) calculates the magnitude of the errors. It is a scale-dependent accuracy metric that is used to compare forecasting errors from different estimators for a single variable, but not between parameters.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}$$

In figure 9, The Proposed technique has lesser square root of differences between predicted and observed values which shows that proposed approach perform better as compared to existing technique.

**Table 3:Root Mean Square Error (RMSE) for different Methods**

| Methods | RMSE |
|---|---|
| PID(Existing ) | 1.3421 |
| FIS-PID(Proposed) | 1.3345 |

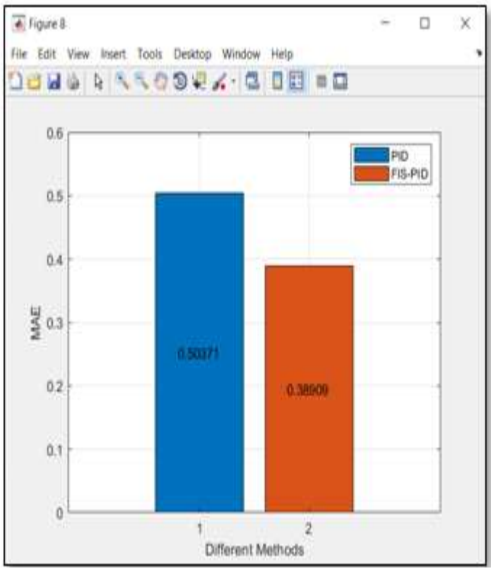


**Figure 10: Snapshot Between MAE Vs Different Methods**

**Mean Absolute Error(MAE):** The Mean Absolute Error (MAE) is an effective criterion for evaluating prediction performance. As the term indicates, It is the mean of the absolute error.

$$MAE = \frac{1}{n}\sum |e_t|$$

**Table4: Root Mean Square Error (MAE) for different Methods**

| Methods | MAE |
|---|---|
| PID(Existing ) | 0.50371 |
| FIS-PID(Proposed) | 0.38909 |

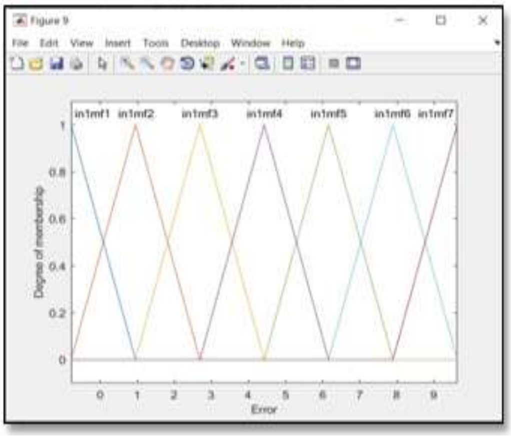


**Figure 11: Snapshot Between Degree of Membership Vs Error**

**Degree of membership:** A fuzzy set's participants are participants to some extent, which is referred to as a membership grade or degree of membership. The degree of belonging to the fuzzy set is determined by the membership grade.

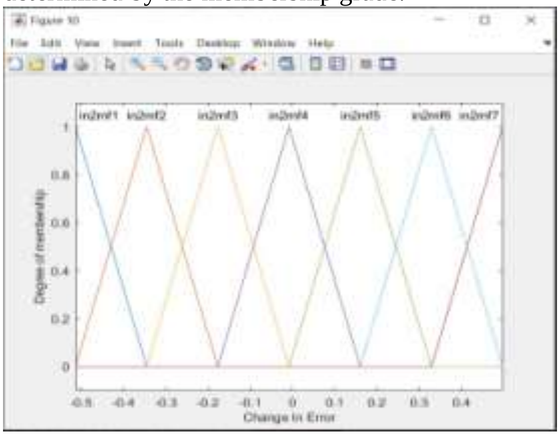


**Figure 12: Snapshot Between Degree of Membership Vs Changes in Error**

The cruise control program's fuzzy logic controller has two inputs: speed error (e), derivative of error d(e), and one output, actuator control (u).

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Fuzzification, FIS, and defuzzification are the three primary steps of the control scheme. The domain information is defined by linguistic variables such as (High Negative, Small Negative, Medium Positive, etc.) with corresponding values ranging from -0.5 to +0.5 for inputs and required suitable values for outputs. The Fuzzy inference system examines the input data and computes the controller outputs in scope with the rule base and data base, while the fuzzification phase transforms crisp values into fuzzy rules. The block diagram of the plant within FLC is shown in Figure 13. The defuzzification method converts the plant's output into the conclusions derived by the inference mechanism.

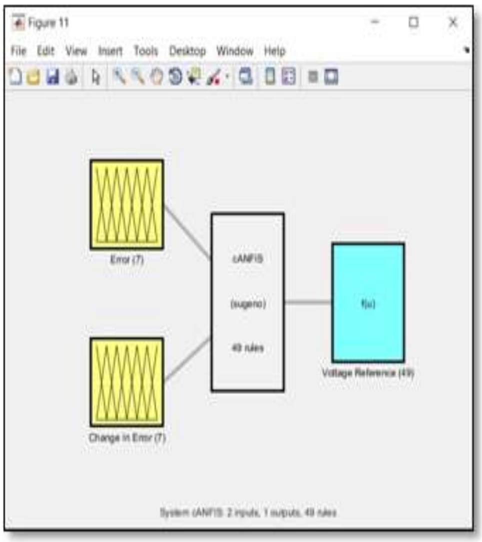


Figure 13:System CANFIS

All of the findings demonstrate that the proposed method, the FIS-PID controller, produces morehigh accuracy than the previous approach.

## IV. CONCLUSION

This paper's main goal is to provide a critical evaluation of electrified power train design with a focus on configuration design, component sizing, and EMS synthesis. First, the development and classification of electric car technologies are discussed. The construction of hybrid power trains are then reviewed and summarized. The main purpose of this study was to develop an fuzzy based PID Controller for Electric Vehicle Power train Modeling that could estimate EV energy consumption over a given driving cycle. A forward vehicle simulation model, such as the power-train system, was constructed in MATLAB/Simulink. All of the results demonstrate that the proposed method, the FIS-PID controller, produces more reliable data than the previous technique. For estimating Electric vehicles, the proposed model has showed a good level of accuracy. The specific protocol could be used as a foundation for EV range calculation in future study. The inertia of the vehicle's spinning elements, like the wheels, brakes, and rotor, could also be computed & included in the model to increase accuracy.

## REFERENCES

[1] F. Zhang, F. Yang, D. Xue, and Y. Cai, "Optimization of compound power split configurations in PHEV bus for fuel consumption and battery degradation decreasing," Energy, vol. 169, pp. 937-957,

Feb, 2019.
[2] C. M. Martinez, X. Hu, D. Cao, E. Velenis, B. Gao, and M. Wellers, “Energy Management in Plug- in Hybrid Electric Vehicles: Recent Progress and a Connected Vehicles Perspective,” IEEE Trans. Veh. Technol., vol. 66, no. 6, pp. 4534-4549, June, 2017.
[3] K. van Berkel, S. Rullens, T. Hofman, B. Vroemen, and M. Steinbuch, “Topology and Flywheel Size Optimization for Mechanical Hybrid Powertrains,” IEEE Trans. Veh. Technol., vol. 63, no. 9, pp. 4192-4205, Nov, 2014.
[4] X. Wang, L. Li, and C. Yang, “Hierarchical Control of Dry Clutch for Engine-Start Process in a Parallel Hybrid Electric Vehicle,” IEEE Trans. Transp. Electr., vol. 2, no. 2, pp. 231-243, Jun, 2016.
[5] A. Emadi, Y. J. Lee, and K. Rajashekara, “Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles,” IEEE Trans. Ind. Electron., vol. 55, no. 6, pp. 2237-2245,Jun, 2008.
[6] K. C. Bayindir, M. A. Gozukucuk, and A. Teke,“A comprehensive overview of hybrid electric vehicle: Powertrain configurations, powertrain control techniques and electronic control units,” Energy Convers. Manage., vol. 52, no. 2, pp. 1305- 1313, Feb, 2011.
[7] G. Wu, X. Zhang, and Z. Dong, “Powertrain architectures of electrified vehicles: Review, classification and comparison,” J. Franklin I., vol. 352, no. 2, pp. 425-448, Feb, 2015.
[8] Z. Q. Zhu and D. Howe, “Electrical machines and drives for electric, hyrbid, and fuel cell vehicles,” Proc. IEEE, vol. 95, no. 4, pp. 746-765, Apr. 2007.
[9] I. L. Sarioglu, B. Czapnik, E. Bostanci, O. P. Klein, H. Schroder, and F. Kucukay, “Optimum design of a fuel-cell Power train based on multiple design criteria,” J. Power Sources, vol. 266, pp. 7- 21, Nov 15, 2014.
[10] Hu, X., Han, J., Tang, X., & Lin, X., “ Power train Design and Control in Electrified Vehicles: A Critical Review”, IEEE Transactions on Transportation Electrification, Vol. 7, No. 3, 2009.
[11] Ben Salah. C, Yahia. I, Mimouni M.F., “Fuzzy logic controller for the power management in electric vehicle”, Systems, Signals & Devices (SSD), 10th International Multi-Conference on. IEEE, 2013.
[12] Adegbohun, F., von Jouanne, A., Phillips, B., Agamloh, E., & Yokochi, A., “High Performance Electric Vehicle Powertrain Modeling, Simulation and Validation”, Energies, Vol. 14, No. 5, 2021.
[13] Kulik, E., Tran, X. T., & Anuchin, A., “Estimation of the requirements for hybrid electric powertrain based on analysis of vehicle trajectory using GPS and accelerometer data, “25th International Workshop on Electric Drives: Optimization in Control of Electric Drives(IWED),2018.
[14] Liu, P., & Feng, S., “Integrated Motor and Two- speed Gearbox Powertrain System Development for Electric Vehicle”, IEEE Energy Conversion Congress and Exposition (ECCE),2020
[15] Ahmed, A. A., & Saleh Alshandoli, A. F., “Using Of Neural Network Controller And Fuzzy PID Control To Improve Electric Vehicle Stability Based On A14-DOF Model”, International Conference on Electrical Engineering (ICEE),2020.
[16] Ma, G., Ghasemi, M., & Song, X. , “Integrated Powertrain Energy Management and Vehicle Coordination for Multiple Connected Hybrid Electric Vehicles”, IEEE Transactions on Vehicular Technology, Vol.67, NO. 4 ,pp. 2893–2899,2018.