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Optimization of Vehicle Engineering Control Based on Improved Simulated Annealing Algorithm

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Abstract: Electric vehicles with its advantages of less pollution, low noise and high energy conversion rate gradually attracted the attention of the government and various automobile manufacturers, which is one of the development trends of the future automobile industry. How to improve the power performance and driving range of electric vehicles by matching the transmission system parameters reasonably has become the main research objective at present. This paper mainly studies vehicle engineering control optimization based on improved simulated annealing algorithm. In this paper, the energy consumption mechanism model of electric vehicle driving motor under complex working conditions is constructed by using simulation software. On this basis, the objective function and constraint conditions based on the optimal energy consumption are established, and the simulated annealing algorithm is used to find the optimal value of the objective function, so as to obtain the optimal torque solution of four wheels. The experiment verifies the effectiveness of the torque coordination optimization control strategy based on the optimal energy consumption, guarantees the expected torque output under multiple constraints (that is, meets the driver's operating intention), and realizes the comprehensive energy consumption optimization of the vehicle.

1. Introduction

The development level of the automobile industry can indeed reflect the comprehensive strength of a country. But it cannot be ignored that while cars bring us convenience and economic benefits, they also bring us a series of problems, such as environmental pollution, energy crisis and traffic accidents. Among them, the problem of environmental pollution and energy crisis is a global problem, which is also a serious problem faced by the entire automobile industry. With the global energy crisis and air pollution increasingly serious, zero emission and zero pollution of new energy vehicles has become the future development trend of the global automobile industry. As an important member of new energy vehicles, pure electric vehicles have significant advantages in many aspects, such as high energy efficiency, low noise, wide power sources, and zero emissions [1-2]. As the development of electric vehicles can effectively solve the global energy crisis and environmental pollution problems, the development and design of pure electric vehicles is also more and more attention by experts and scholars. Although electric vehicles are an important breakthrough to achieve energy conservation and environmental protection, there are still many problems in the current development of electric vehicles, especially the charging and battery life problems that have attracted much attention, which have not been well solved at present. Although countries around the world are paying attention to the research and development of battery technology, no breakthrough has been achieved so far [3-4]. Therefore, before the battery technology is solved, how to improve the power performance and range of electric vehicles through reasonable matching of power system parameters under the same battery performance conditions has become the focus of research by experts and scholars around the world [5]. At present, the mainstream transmission system of pure electric vehicles in the market almost adopts single-stage reducer transmission scheme, which has the advantage of compact structure and can reduce the whole vehicle quality [6]. Its disadvantages are also obvious, that is, the performance requirements of the driving motor and battery are relatively high, and there are many problems and defects such as low energy utilization rate of the driving motor and short driving range.

Electric vehicle power system matching mainly includes the selection of driving motor and battery, the configuration design of parameters, and the selection of transmission gear number and speed ratio. For electric vehicles loaded with multi-gear transmission, it is necessary to set relevant shifting rules [7]. According to the research situation of parameter matching optimization of pure electric vehicle transmission system at home and abroad, as well as the different degree of demand for economy and power performance during vehicle development, it can be roughly divided into the following three categories: the matching design with the power performance of the vehicle as the optimization goal; The matching design is based on the economic efficiency of the vehicle. The matching design takes the economy and power performance of the vehicle as the dual optimization objective [8-9]. In the parameter matching and optimization of the electric vehicle transmission system, the economy or power performance of the electric vehicle is generally taken as the optimization objective function or constraint condition, and then appropriate optimization algorithms are selected to optimize the relevant parameters of the transmission system [10]. In addition, the power system parameter matching of electric vehicles should be based on the overall performance requirements, fully analyze the characteristics of each component, and consider the actual performance requirements of electric vehicles to match the transmission system parameters [11].

In this paper, the relevant parameters of the electric vehicle powertrain are preliminarily calculated and matched, and then the speed ratio and shifting rule of the electric vehicle model are optimized by the simulated annealing algorithm through the establishment of the vehicle model.

2. Simulated Annealing Algorithm to Optimize Torque Coordination of Electric Vehicles

2.1. Establishment of Simulation Model

In this paper, vehicle dynamics simulation modeling is carried out based on PreScan software.

PreScan is a physical model-based simulation platform from TASS International in the Netherlands, which has been widely used in ADAS technology and autonomous driving. Users can use different road types, infrastructure, and a variety of smart driving applications based on millimeter wave radar, liDAR, cameras, GPS, V2V and V2I communication technologies. PreScan supports multiple usage modes. From model in the ring (MIL) to real-time software in the ring (SIL) and hardware in the ring (HIL), etc. [12-13].

In the process of establishing the simulation model, the following four steps should be completed:

(1) Firstly, a traffic scene needs to be established by using the linear 2-DOF vehicle dynamics model provided by PreScan software. In order to reflect the richness of the simulated road, corresponding buildings, trees or traffic signs can be added [14].

(2) According to the predetermined expected speed and expected trajectory file data, the driving vehicle is followed and controlled, so there is no need to add sensor model;

(3) After completing the setting of the traffic scene and the dynamics model of the controlled vehicle in PreScan software, a simple linear two-DOF vehicle dynamics model can be obtained by connecting it to the operating environment of Matlab/Simulink.

(4) Based on the vehicle state quantity obtained by the PreScan simulation model, the corresponding control algorithm is designed in the simulation environment of Matlab/Simulink. Finally, the simulation experiment is carried out, the simulation step is set as 0.05s, and the end condition of simulation is set as the vehicle reaches the end position of the trajectory, so as to obtain the simulation results.

In the design process of the longitudinal control system, the first factor to be considered is the real-time reliability requirement of the control effect of the driving vehicle in the process of moving, and then the requirements of accuracy and comfort are put forward [15]. According to the control effect of the controller, the following performance requirements shall be met:

Real time: The requirement of real time is very important when the vehicle is driving in the driving mode. The control system should avoid too much control delay to ensure the timely response of the control process and the whole control system has good real time.

Accuracy: Based on the inverse longitudinal dynamics model of the driving vehicle, the required output control quantity is obtained according to the control algorithm, which not only ensures the rationality of the response time in the control system, but also ensures that the steady-state error of the system tends to zero to the maximum extent.

Stability: Driving a car will eventually face the passenger comfort evaluation, the control system to ensure the stability of the whole control process, which affects the passenger comfort.

Robustness: In the real driving process, the speed must be changed frequently according to the current road conditions, so the control algorithm has strong adaptability to the changes of speed and trajectory curvature.

In this paper, the model predictive control algorithm is used to design the upper controller of the speed following control system. The structure of the controller is shown in Figure 1.

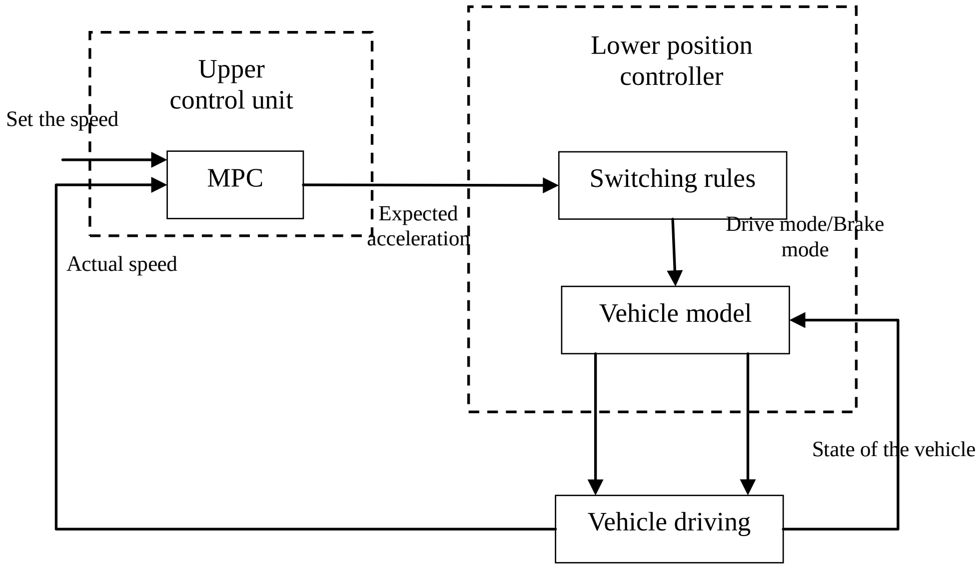

Figure 1. Speed follows controller structure diagram

2.2. Optimization of Extremum Based on Simulated Annealing Algorithm

Simulated annealing algorithm is an approximate method for solving optimization problems, and its core idea is Monte Carlo [16]. This is because solving the maximum value of the problem is similar to finding the minimum value of the system energy. As the temperature of the system decreases, the energy decreases and the corresponding solution approaches the maximum value. The whole process is similar to the annealing process of thermodynamics [17-18].

When annealing is used to simulate combinatorial optimization problem, the internal energy E is simulated as the objective function value C, and the temperature T is evolved as the control parameter T, that is, the simulated annealing algorithm for solving combinatorial optimization problem is obtained.

The specific steps of the algorithm are as follows:

Initialization: initialization temperature T, iteration number L of each T value, initial solution state S, which is the starting point of the algorithm;

When k =1, 2... When, L, the algorithm carries out the following steps;

The new solution S' is obtained by adjusting the current solution according to the constraints.

Compute њ C(S ') -c (S), where C S ǫ is the objective function;

If t is less than 0, then S 'is the new current solution; If t is greater than or equal to 0, we accept S 'as the new current solution with probability

If several consecutive new solutions do not meet the requirements, the current solution is the optimal solution, and the algorithm ends.

Otherwise, decrease T step by step, jump to the initial step and continue to perform subsequent steps until T is less than the initial set threshold.

When the total output torque is given a value Ttotal, according to the above objective function formula and constraint formula, the simulated annealing algorithm is used to optimize the extreme value. In the simulated annealing algorithm, the temperature T is the consumed power P of the vehicle, and the solution state S is the torque size of the four wheels, which are Tfl, Trl, Tfr and Trr.

A reasonable initial solution state, decay factor T, iteration number L at each T value and stopping condition S were set, and the optimal torque distribution combination under current conditions was calculated through iterative solution.

This algorithm takes the torque combination of four wheels equally distributed as the initial solution state. In general, the vehicle power of four wheels equally distributed torque is not the lowest, and the energy consumption is not optimal. It needs to be solved several times iteratively to gradually try to reduce the consumption power P of the vehicle, and finally obtain the optimal solution. If in some special cases, the energy consumption of four-wheel average distribution algorithm is optimal, then the initial solution of this algorithm is the final solution.

The output torque of the four-wheel hub motor is taken as the quarter of the total driving torque as the initial solution, as shown in Equation (1) :

$$T_{fl} = T_{rl} = T_{fr} = T_{rrl} = \frac{T_{total}}{4} \tag{1}$$

Therefore, the initialization power in the simulated annealing algorithm is shown in Equation (2):

$$P = \left(\frac{\omega_{fl}}{\eta_{fl}} + \frac{\omega_{fr}}{\eta_{fr}} + \frac{\omega_{rl}}{\eta_{rl}} + \frac{\omega_{rr}}{\eta_{rr}} \right) \frac{T_{total}}{4} \tag{2}$$

The power value of the objective function is calculated. If the difference between the power value of the new objective function and the initialization power is less than 0, the new solution is accepted; otherwise, p=e-de/T and random(0,1) are used for comparison to determine whether to accept the new solution.

3. Torque Optimization Simulation Experiment

In this paper, the state estimation model, driving intention recognition model and model predictive control model are proposed for the torque distribution control of hub motor. In this section, these models are embedded in the driving simulator for joint driver-in-the-loop simulation.

In order to test the steering characteristics of vehicles at different speeds, the minimum turning radius test and double line shift test were set up.

Minimum turning radius of the experimental scheme: driving simulation of structures, test site, the drivers driving simulation of vehicle running at low speed and control vehicle maximize the front wheel Angle, and maintain the status quo, when the speed is achieved by software of data acquisition function records the motion of the vehicle mass center point trajectory, such as state response of the vehicle test data.

Double wire shift experiment scheme: According to the requirements of double wire shift test, this paper built a virtual site in PreScan, and the virtual vehicle was tested at a speed of 120km/h. The vehicle state response data is recorded through the data acquisition function of the software.

4. Simulation Experiment Results

4.1. Minimum Turning Radius Experiment

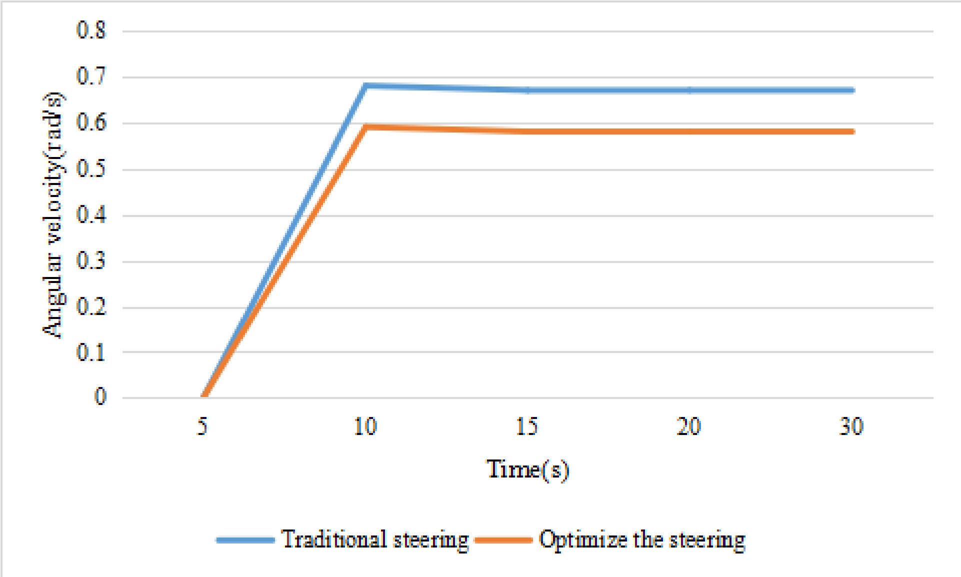

Figure 2. Yaw velocity comparison

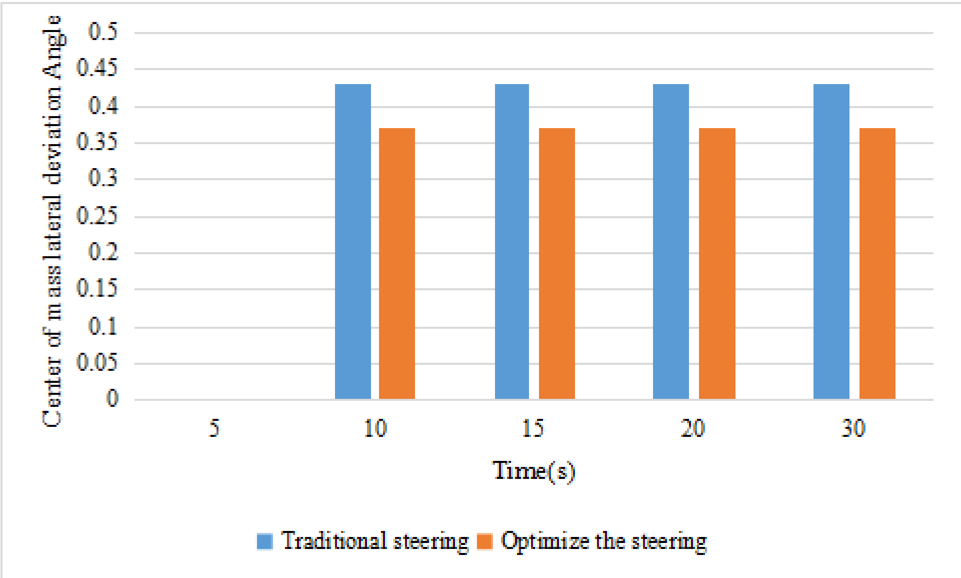

Figure 3. Center of mass side deviation Angle contrast

As shown in FIG. 2 and 3, the model predictive control system based on the driver's intention accurately identifies the driver's intention of low speed and large Angle steering, and uses the model predictive control for torque distribution to reduce the turning radius and improve the vehicle's maneuverability. However, the additional yaw moment provided by the torque distribution makes the driving stability of the vehicle slightly decrease, but the vehicle is still driving under stable conditions, and no dangerous and safe phenomenon occurs.

4.2. Double Line Shift Experiment

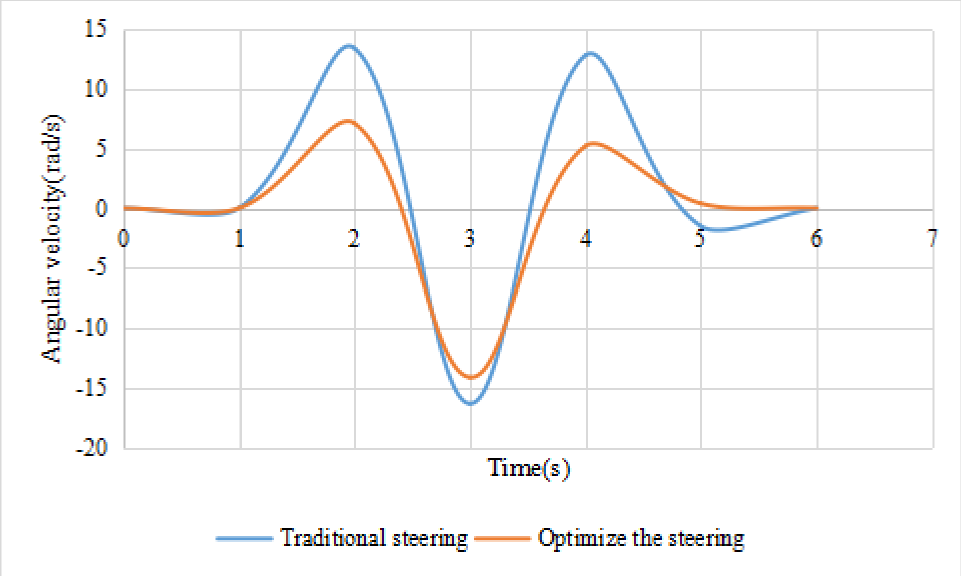

Figure 4. Yaw velocity (double line shift experiment)

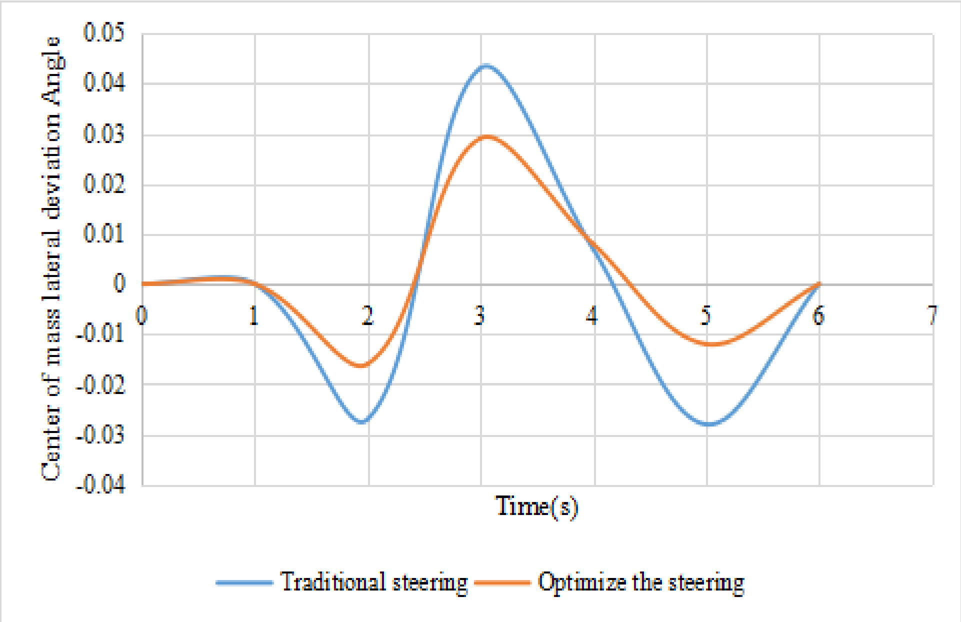

Figure 5. Side deviation Angle of center of mass (double line shift experiment)

As shown in FIG. 4 and 5, the model predictive control system based on the driver's intention accurately identifies the driver's intention of high-speed and small Angle steering, and uses the model predictive control for torque distribution to provide additional yaw moment and improve the stability of the vehicle. Compared with the traditional control, the model predictive control has better vehicle handling and stability performance, and the intervention of the model predictive control is faster than the traditional control because the driver's intention is recognized.

5. Conclusion

Motor drive represents a highly integrated trend in the development of automobiles, where power transmission is accomplished in various hubs, from a single power source to multiple power sources, and does not require the transmission system of traditional vehicles. Hub-driven vehicles are the development trend of new energy electric vehicles in the future. The control of hub-driven vehicles is more complex than that of traditional vehicles. By fully exploiting the control effect, the excellent performance of hub-driven vehicles can be maximized. In this paper, the experimental verification of the torque optimization strategy is carried out, and the driving simulator is adjusted to the Settings that meet the characteristics of driving electric vehicles. The simulated annealing algorithm is embedded into the driving simulator. In the driving simulation, the minimum turning radius test and double line shift test were carried out.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Bingul Z, Karahan O. Real-time trajectory tracking control of Stewart platform using fractional order fuzzy PID controller optimized by particle swarm algorithm. Industrial Robot: the international journal of robotics research and application, 2021, 49(4):708-725. https://doi.org/10.1108/IR-07-2021-0157

[2] Mahdi B, Majid A, Saeid A P. Robust solution for a min-max regret hub location problem in a fuzzy-stochastic environment. Journal of Industrial and Management Optimization, 2017, 13(2):82-82.

[3] A, Adinarayanan, M, et al. Machine cell formation using simulated annealing algorithm in cellular manufacturing system. International Journal of Computer Aided Engineering and Technology, 2018, 10(1-2):111-125. https://doi.org/10.1504/IJCAET.2018.088833

[4] Mahdiani M R, Khamehchi E, Suratgar A A. Using modern heuristic algorithms for optimal control of a gas lifted field. Journal of Petroleum Science & Engineering, 2019(183-):183. https://doi.org/10.1016/j.petrol.2019.106348

[5] Kewei S, Zhang Z, Wang H, et al. Online self-adaptive proportional-integral-derivative control for brushless DC motor based on variable universe fuzzy inference system optimized by genetic algorithm. Proceedings of the Institution of Mechanical Engineers, Part C. Journal of mechanical engineering science, 2021(10):236. https://doi.org/10.1177/09544062211060303

[6] Buragohain M, Das N K D. A neoteric closed loop feedback controller based on correlative-elemental curvature algorithm. Circuit World, 2021, 48(3):341-353.

https://doi.org/10.1108/CW-06-2020-0107

[7] Meshram D B, Gohil V, Puri Y M, et al. Implementation of multi-objective Jaya optimization for performance improvement in machining curve hole in P20 mold steel by sinking EDM. World Journal of Engineering, 2021, 19(3):381-394. https://doi.org/10.1108/WJE-11-2020-0568

[8] Sun D, Zhang X, Tang J, et al. Optimization of radial flexible mechanism in scroll compressor based on oil film lubrication analysis. Industrial Lubrication and Tribology, 2021, 74(5):514-521. https://doi.org/10.1108/ILT-10-2021-0419

[9] Mamun A A, Liu Z, Rizzo D M, et al. An Integrated Design and Control Optimization Framework for Hybrid Military Vehicle Using Lithium-Ion Battery and Supercapacitor as Energy Storage Devices. Transportation Electrification, IEEE Transactions on, 2019, 5(1):239-251. https://doi.org/10.1109/TTE.2018.2869038

[10] Bian, Jindong, Qiu, et al. Effect of road gradient on regenerative braking energy in a pure electric vehicle. Proceedings of the Institution of Mechanical Engineers, Part D. Journal of Automobile Engineering, 2018, 232(13):1736-1746. https://doi.org/10.1177/0954407017735020

[11] Mehboob N, Restrepo M, Canizares C A, et al. Smart Operation of Electric Vehicles With Four-Quadrant Chargers Considering Uncertainties. Smart Grid IEEE Transactions on, 2019, 10(3):2999-3009. https://doi.org/10.1109/TSG.2018.2816404

[12] Gujarathi P K, Shah V A, Lokhande M M. Emission reduction by combined rule based-artificial bee colony optimization algorithm for converted plug-in hybrid electric vehicle. Journal of intelligent & fuzzy systems: Applications in Engineering and Technology, 2018(2):35. https://doi.org/10.3233/JIFS-169710

[13] Mohapatra T K, Dey A K, Mohapatra K K, et al. A novel non-isolated positive output voltage buck-boost converter. Military operations research, 2019, 16(1):201-211. https://doi.org/10.1108/WJE-06-2018-0214

[14] Simulation investigation of tractive energy conservation for a cornering rear-wheel-independent-drive electric vehicle through torque vectoring. Science China (Technological Sciences), 2018, 02(v.61):103-118.

[15] Samaranayake L, Longo S. Degradation Control for Electric Vehicle Machines Using Nonlinear Model Predictive Control. Control Systems Technology, IEEE Transactions on, 2018, 26(1):89-101. https://doi.org/10.1109/TCST.2016.2646322

[16] Zhou Y, Kumar R, Tang S. Incentive-Based Distributed Scheduling of Electric Vehicle Charging Under Uncertainty. Power Systems, IEEE Transactions on, 2019, 34(1):3-11. https://doi.org/10.1109/TPWRS.2018.2868501

[17] Devi S G, Sabrigiriraj M. A hybridmulti-objective firefly and simulated annealing based algorithm for big data classification. Concurrency Practice & Experience, 2019, 31(14):e4985.1-e4985.12. https://doi.org/10.1002/cpe.4985

[18] Adewumi, Aderemi, Oluyinka, et al. Simulated annealing based symbiotic organisms search optimization algorithm for traveling salesman problem. Expert Systems with Application, 2017, 77(Jul.):189-210. https://doi.org/10.1016/j.eswa.2017.01.053