Performance Comparison Between Differential Evolution and Bat Algorithm in P.I.D Tuning for Optimization of Speed Control on Parallel Hybrid Electric Vehicle

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ABSTRACT

In the last decade, there have been many means of transportation that use fuel oil (Internal Combustion Engine (ICE)). This has a serious impact on the environment due to the resulting pollutant gas emissions. One solution is the use of hybrid electric vehicles (HEV) as a replacement for vehicles that use ICE. One of the performances that a HEV must have is to have a stable speed when driving. In this research, several methods used in the metaheuristic algorithm in the disturbance observer have the advantage of describing the inverse model of the plant without creating a mathematical model. Testing was carried out by comparing two methods of metaheuristic algorithms, namely Differential Evolution and Bat Algirthm. The simulation results show that the method used on this HEV is to maintain its speed, so according to the test results it shows that the Differential Evolution method is the best method for controlling speed on a Parallel Hybrid Electic Vehicle.

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1. INTRODUCTION

Currently, land transportation is crowded with many vehicles which causes many global problems. Such vehicles use internal combustion engines (ICE) as propulsion. The increasing use of fuel oil for motor vehicles has resulted in a decline in fuel oil stocks in the world. This caused an energy crisis in the world.

In addition, the increasing use of fuel oil in motorized vehicles causes air pollution to increase. Pollution produced by motorized vehicles will cause global warming so that the temperature in the earth's atmosphere will increase.

In an effort to overcome the energy crisis and the dangers of global warming produced by motorized vehicles, an energy-efficient and environmentally friendly alternative vehicle was created called the Hybrid Electric Vehicle (HEV)[1]. HEV is a vehicle that uses an internal combustion engine (ICE) and an electric motor as the driving motor [2]. With the presence of this hybrid engine, it is hoped that harmful emissions will be lower, so that the pollution produced can be much lower than conventional vehicles [3].

With the HEV, the ICE does not work alone in moving the vehicle so that fuel use can be minimized [4]. In the acceleration process, an electric motor is needed to help the ICE work so that HEV acceleration can be achieved as desired.

One of the performances that a HEV must have is resistance to all disturbances that may occur on the road. Disturbances can come from various things such as bumpy roads, wind, etc. These disturbances must be overcome in order to speed up the vehicle becomes stable. some researchers have made HEV speed controller researchers.

One of the disadvantages of ICE vihecles is pollutant emissions. These pollutants are one of the many causes responsible for today's global warning issues. The use of hybrid electric (HEV) is one solution to overcome the problem of pollutant emissions. HEV is a certain type of vehicle that has two sources of propulsion, namely ICE and electric motor. The energy source is gasoline, and the potential electricity is stored in the battery.

Researchers use a fuzzy controller in HEV speed simulation, which uses changes in reference speed [5]. The research result is that the actual speed follows the reference speed as long as the load is not changed. The load makes the actual speed different from the reference speed. Regarding tracking speed on a parallel HEV with a fuzzy input shifting reference speed controller used in testing. This research shows that the fuzzy controller can make the actual speed track the reference speed. However, if the load is changed, a decrease in speed actually occurs.

In other research it is said that using the neuro-fuzzy inverse model can be used to describe plant inverse models without creating a mathematical model. In this research it was shown that the inverse neuro-fuzzy model had a smaller mean square error compared to the inverse model with a parametric model. Therefore, so that the HEV can follow the reference speed, and can withstand any disturbances, there is an idea to create a fuzzy controller combined with a disturbance observer, where the inverse model uses a neuro-fuzzy inverse model. Considering the many methods in developing vehicle control systems, something called the metaheuristic method emerged.

Metaheuristics are a more popular method than exact methods because they are simpler and the results are more certain in solving optimization problems in the world of business, transportation, and especially in the world of engineering. Metaheuristics is a development of previous heuristic methods. Heuristic means "to search" or "search by trial and error". While the word meta means "beyond"or “higher level. Therefore, metaheuristics can be interpreted as a method that has a higher level than the previous heuristic method. The metaheuristic method aims to find solutions to problems that are faster and can solve complex problems.

Metaheuristic methods use algorithms to solve optimization problems. Metaheuristic algorithms combine rules and randomness of natural phenomena to search for optimal results globally using the trial and error method. Metaheuristic methods have become increasingly popular in recent years. Their use in various cases shows the efficiency and effectiveness of metaheuristic methods for solving large and complex problems.

2. METHOD

The method used in this research is a quantitative method, where the test results of the two systems will be compared to the final value of the P.I.D. control tuning. where the research steps are depicted in Figure 1.

The stages carried out in this research are as follows:

1. The first step taken was a literature study on the development of speed control system technology on PARALLEL HYBRID ELECTRIC VEHICLE (PHEV) in order to obtain an optimal speed control system.
2. From the results of the literature study, two speed control systems for P.I.D tuning were obtained, namely:
   a. Differential Evolution.
   b. Bat Algorithm.
3. The next step is to design a system in Matlab for each of the speed controls above. In this stage the author will design the system.

4. Testing the P.I.D tuning control system from the design results made in Matlab.
5. Data collection from each speed control system method.
6. Compare the output data results from the system design in Matlab for each speed control system method.
7. Analyzing and evaluating data from the comparison results of speed control systems in P.I.D tuning between Differential Evolution and Bat Algorithm.
8. Drawing conclusions from the results of data analysis and evaluation.

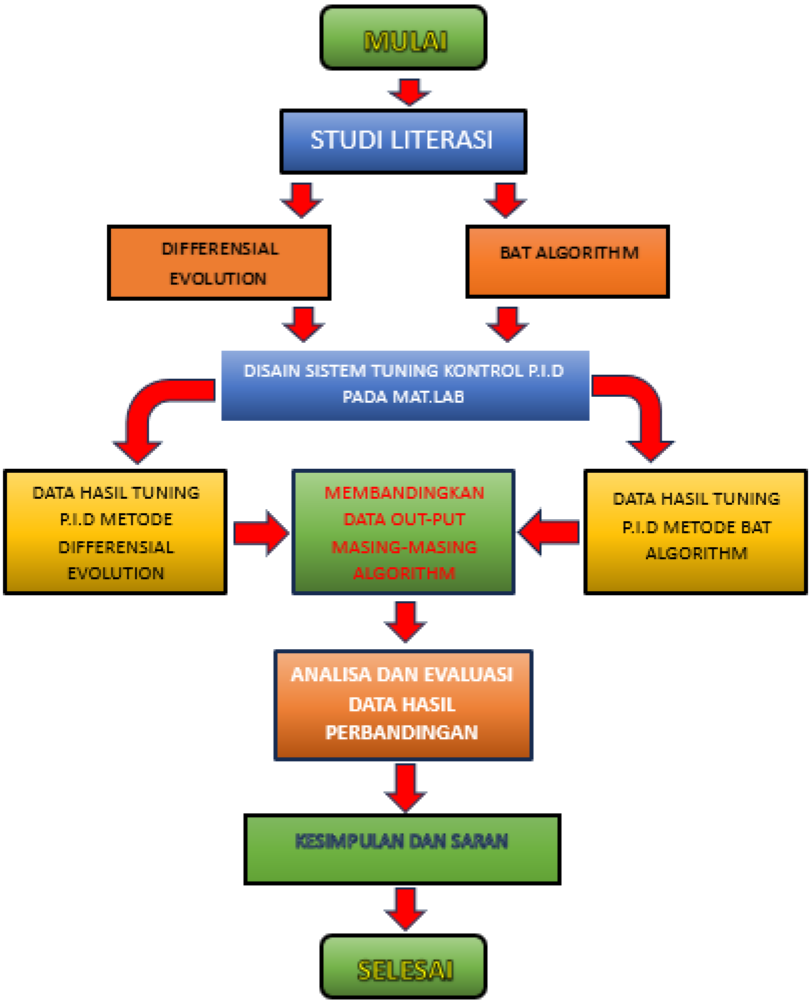

Figure 1. Research Method Block Diagram

Differential Evolution (DE) is a metaheuristic method for solving continuous problems. Differential Evolution is included in the population-based metaheuristic category. The basic idea of DE is to utilize individual differences in the population to search for solutions. That's why this method is called Differential Evolution. Unlike other matheuristic methods whose procedures imitate natural phenomena, DE is based on geometric arguments. However, DE still uses mutation and crossover operators in its search process.

Differential Evolution is different from other evolutionary methods because in DE, a new solution is produced by selecting 3 individuals in a randomly selected population, where one of them is used as a basis vector while the other two individuals are searched for the difference in vectors, to then be added to the basis vector. These three vectors are often called strategic vectors. in a new parallel direct search that utilizes NP parameter vectors. as a population for each generation of G. NP does not change during the minimization process.

If an initial solution is available, the initial population is often generated by adding normally distributed random deviations to the nominal solution xnom,0. The important idea behind DE is a new scheme for generating vector experimental parameters. DE produces a new parameter vector by adding a vector of weighted differences between two members of the population into a third member. If the resulting vector produces a lower objective function value than the members of the specified population, the newly generated vector replaces the previous vector being compared.

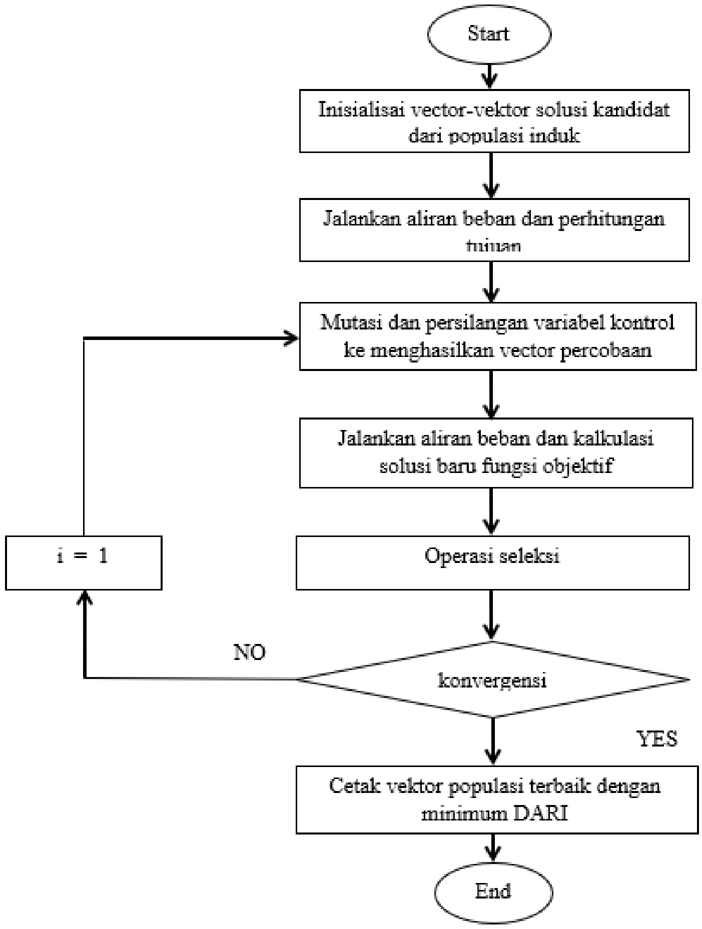

Figure 2. DE Algorithm Flowchat

Bat Algorithm (BA) is a new type of metaheuristic algorithm introduced by Xin She Yang in the 2010s. This algorithm is inspired by the behavior of bats. Bats are very amazing animals because they are the only type of mammal that has wings to fly and has advanced abilities in echolocation. Bats use a type of sonar called echolocation to detect food, avoid obstacles and find their nests in the dark. The main steps of the Bat Algorithm start from initializing a population of bats, each of which is determined by an initial position (initial solution), generating random pulses and noise and determining the frequency. During the iterative/loop process, all bats will move from the initial solution towards the global best solution(s).

After moving, if any bat finds a better solution, then the bat will update the pulse and noise emission levels. During iteration, the best solution is always updated. The iteration process is repeated until the stopping criterion has been met. Finally, the best solution is the solution to the problem that is solved through this algorithm.

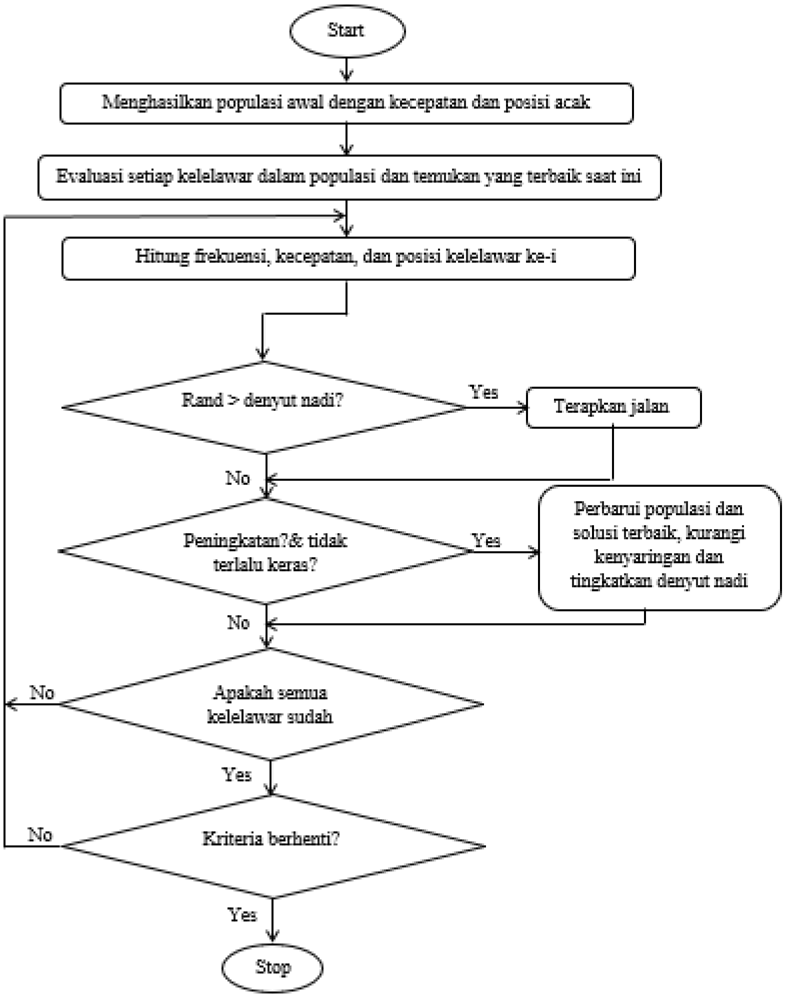

Figure 3. BA Algorithm Flowchat

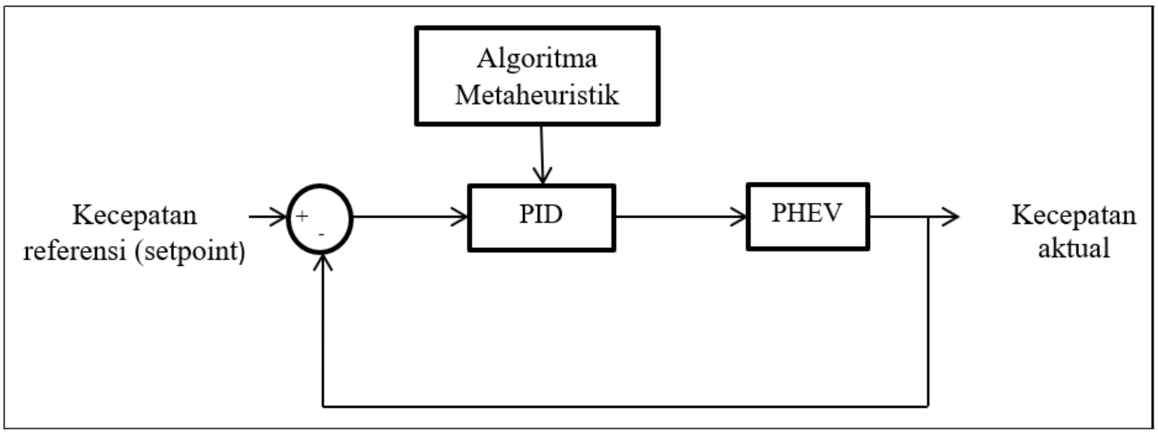

Figure 4. PHVE Block Diagram

In the block diagram above, a Parallel Hybrid Electric Vehicle system is used or a vehicle that has two driving forces, namely: a combustion motor and an electric motor. This system is controlled by PID which is closed loop because it has feedback between reference speed and actual speed. The expectation is that the reference speed (input) must be the same as the actual speed (output).

PID control consists of constants kp, ki, kd where these constants are determined by a metaheuristic algorithm, because this metaheuristic uses two methods, this method is what determines the constant value of the PID. Of the two methods used, which one gives the best response so that the value can be determined by comparing the Integral Time Weighted Absolute Error (ITAE) performance.

3. RESULTS AND DISCUSSION

3.1. DE Test Results

The results of the hybrid DE algorithm trial in getting the optimal solution for the HEV case in finding the PID value so that it can determine the minimum ITAE value.

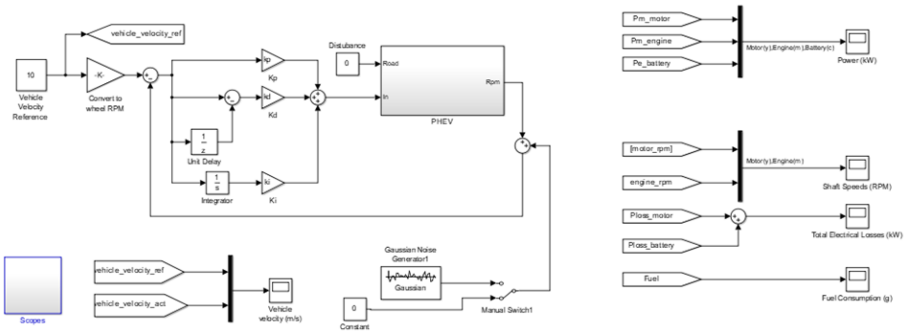

Figure 5. PID-HEV

In this research the controller will be applied to a parallel plant HEV model. This plant model was obtained from simulink in MATLAB R2014a. In the diagram above, there are six main parts blocks. The six blocks consist of the engine, electric motor, gearbox, DC-DC converter, battery and vehicle dynamics. The engine and electric motor are used as parallel HEV drivers, where the engine is the main driver, and the electric motor is the secondary driver of the parallel HEV. Both have different axes, so a gearbox block is needed to combine the two axial drives. Electric motors get their power through batteries, where the voltage is regulated by a DC-DC converter. The two parallel HEV motors (engine and electric motor) will work together to drive the parallel HEV as a single block called vehicle dynamics.

The 1st test with Kp=1000, Ki=1, Kd=1 produces ITAE 10.3228. This is shown in the image below:

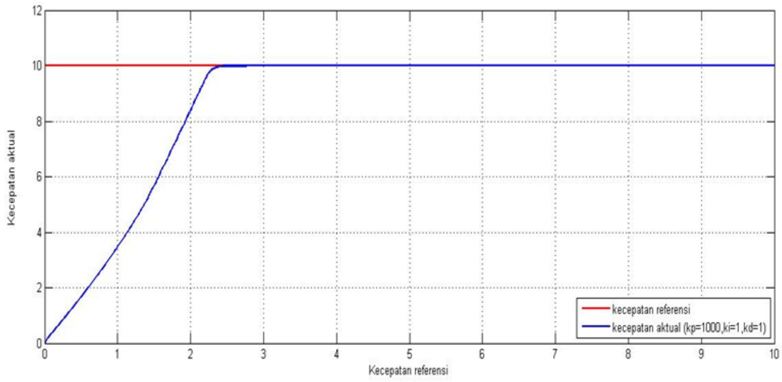

Figure 6. Graph of DE-1 Test Results

The 2nd test with Kp=1050, Ki=1, Kd=1 produces ITAE 10.3160. This is shown in the image below:

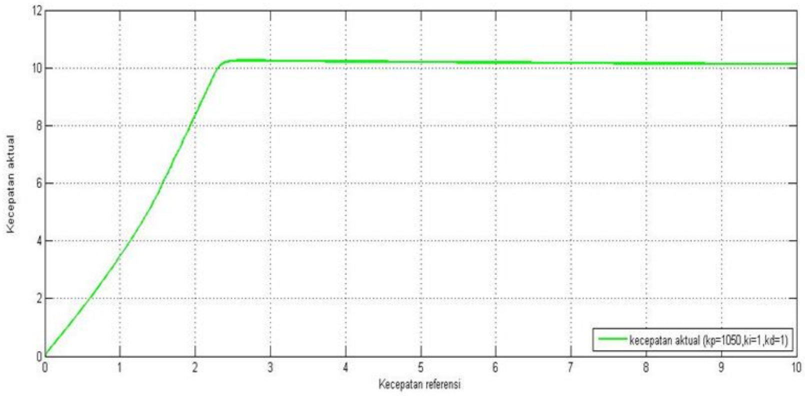

Figure 7. Graph of DE-2 Test Results

The 3rd test with Kp=1100, Ki=1, Kd=1 produces ITAE 10.3232. This is shown in the image below:

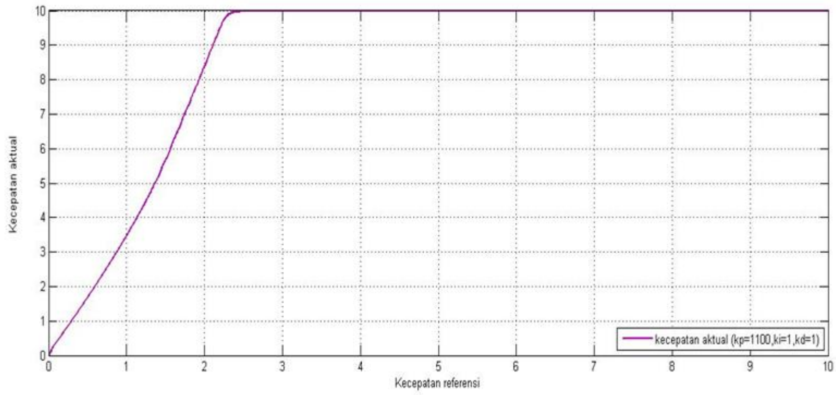

Figure 8. Graph of DE-3 Test Results

The 4th test with Kp=1150, Ki=1, Kd=1 produces ITAE 10.3300. This is shown in the image below :

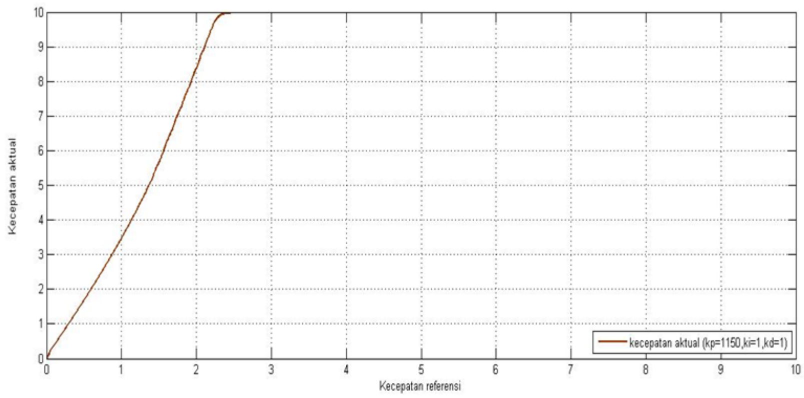

Figure 9. Graph of DE-4 Test Results

The 5th test with Kp=1200, Ki=1, Kd=1 produces ITAE 10.3376. This is shown in the image below:

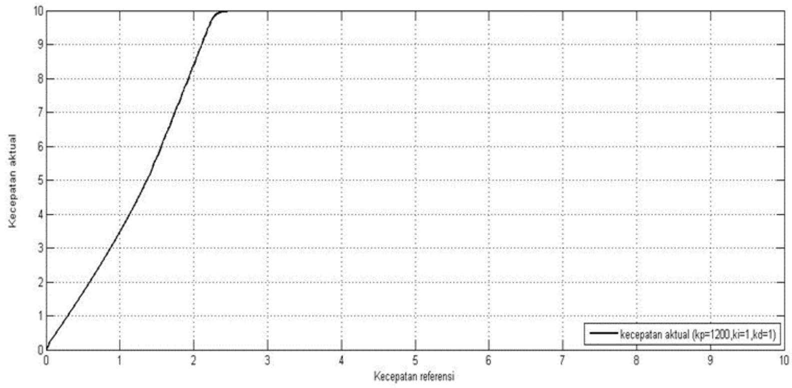

Figure 10. Graph of DE-5 Test Results

In several tests of DE, good results were shown in the second test with Kp=1050, Ki=1, Kd=1 and an ITEA value of 10.3160. When the Kp value is increased, the ITAE value becomes higher. This is shown in the table below:

Table 1. DE Test Results

N0	Kp	Ki	Kd	ITAE
1	1000	1	1	10,3228
2	1050	1	1	10,3160
3	1100	1	1	10,3232
4	1150	1	1	10,3300
5	1200	1	1	10,3376

3.2. BA Test Results

The 1st test with Kp=50, Ki=1, Kd=1 produces ITAE 13.6007. This is shown in the image below:

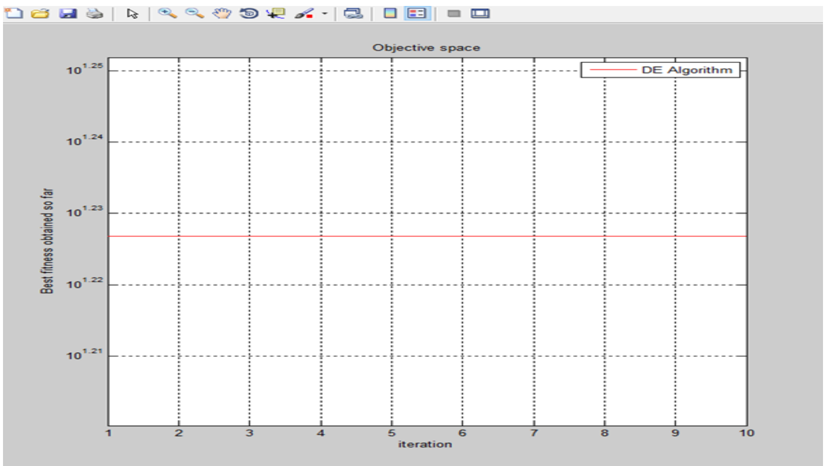

Figure 11. Graphic of BA-1 Test Results

The 2nd test with Kp=70, Ki=1, Kd=1 produces ITAE 12.5928. This is shown in the image below:

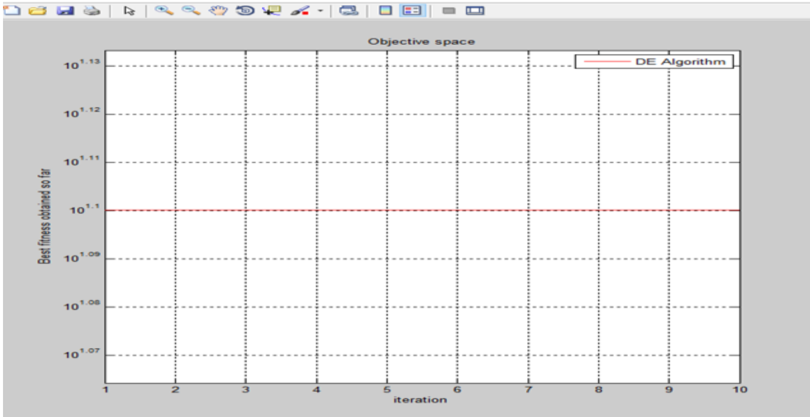

Figure 12. Graphic of BA-2 Test Results

The 3rd test with Kp=90, Ki=1, Kd=1 produces ITAE 12.0513. This is shown in the image below:

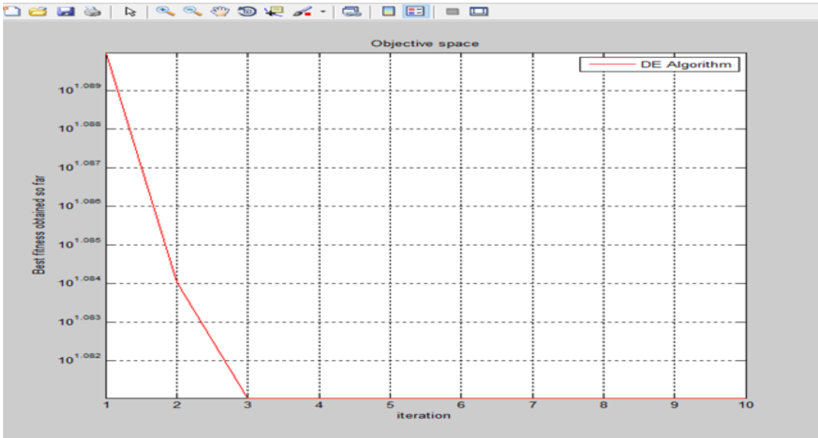

Figure 13. Graphic of BA-3 Test Results

The 4th test with Kp=100, Ki=1, Kd=1 produces ITAE 11.8709. This is shown in the image below:

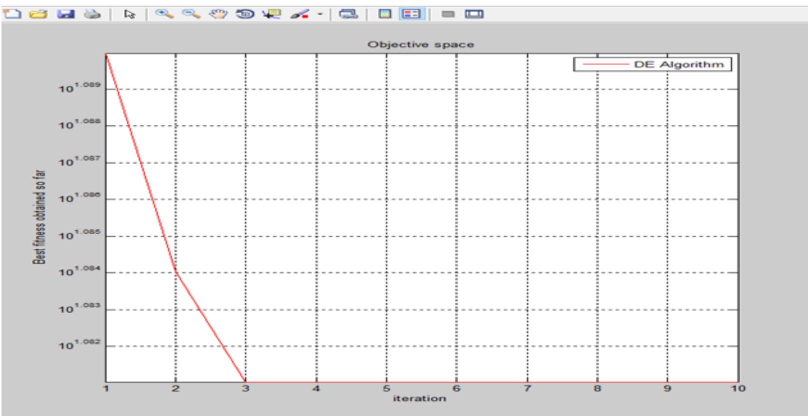

Figure 14. Graphic of BA-4 Test Results

The 5th test with Kp=1000, Ki=1, Kd=1 produces ITAE 10.3228. This is shown in the image below:

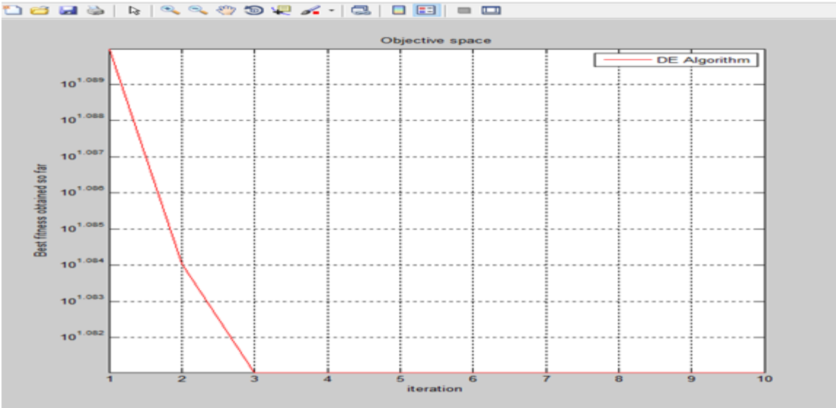

Figure 15. Graphic of BA-5 Test Results

From several tests carried out, I listed 5 tests that had minimum performance, and there was one test result that had good performance with Kp=1000, Ki=1, Kd=1 and produced an ITAE of 10.3228. This is shown in the table below:

Table 2. BA Test Results

N0	Kp	Ki	Kd	ITAE
1	50	1	1	13,6007
2	70	1	1	12,5928
3	90	1	1	12,0513
4	100	1	1	11,8709
5	1000	1	1	10,3228

From the test results of the DE and BA methods above, it can be concluded that the performance comparison between DE and BA is that ITAE DE is almost the same as ITEA BA, so the DE method is a good method because the ITAE is less than the BA method.

4. CONCLUSION

After carrying out the system creation stage, then continuing with the data analysis testing stage, the following conclusion can be drawn: the best method for controlling speed on a Parallel Hybrid Electric Vehicle is the Differential Evolution method with the smallest ITAE.

It is highly recommended for future research to try this research with several other methods on metaheuristic algorithms to get a better performance comparison for controlling the speed of a Parallel Hybrid Electric Vehicle.

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