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Electric Vehicles intelligent speed control, A comparison between COA, ICA and Genetic Algorithms performance

KEYWORDS: Electric Vehicles, Intelligent Control, Optimization, COA, ICA, Genetic Algorithm

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ABSTRACT *In this paper several intelligent speed control methods for Electrical vehicles (EVs) have been studied. We investigated in Evs physical and control systems structure to propose a powerful method for speed controller design. We examined three powerful optimization algorithms performances to show the abilities of each method and select the best choice for utilize in EVs speed control system. Simulations have been performed in MATLAB environment. We will show that the best choice is Cuckoo Optimization Algorithm (COA) with fast and smoothness in output response according to the simulation results.*

I. INTRODUCTION

IN the past decades research in Electric vehicles (EVs) and Plug-in Hybrid Electric vehicles (PHEVs) have been increased. These researches mainly consisting of utilizing different energy sources such as solar and wind energies [1]-[3] and different electric motors such as DC motors and Inductive motors [4]. In an EV there are a lot of important parameters that each of them has a direct effect to the EV efficiency and performance. For example an EV must have a powerful speed controller with fast and smooth response. So we have to design a most powerful control method to decrease the unwanted parameters and behaviors.

This paper is organized as follows. After introduction we will have a brief introduction to EVs structure and control systems. Then we will model an EV motor for simulation and control system design purposes. We will also review two powerful optimization techniques including Imperialist Competitive Algorithm (ICA) and Cuckoo Optimization Algorithm (COA). Then we will propose the discussion and simulation results to compare the performance of each method with several indexes. Finally conclusion proposed in the last section.

II. ELECTRIC VEHICLES STRUCTURE

Today Electric Vehicles with the simpler structure are popular for short distance trips especially in urban areas. Each EV has a physical structure such as Fig.1. consisting of a battery, charger, electric motor and its driver and so on.

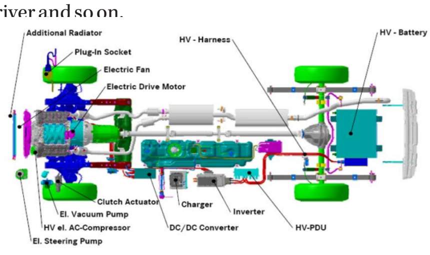

Fig. 1 An electric vehicle typical CAD

We can control all of the vehicle components using the ECUs. Each component has its local processor and they are connected to a main processor for management of all components with CAN BUS [5].

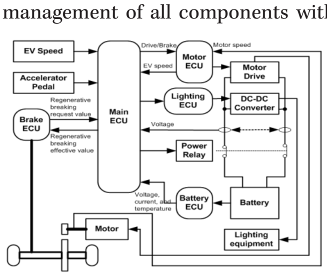

Fig. 2 Electric vehicles control system schematic

The motor ECU collects the data from motor sensors such as shaft speed and output torque. The most popular motors in Electric Vehicles are permanent magnet DC motor, separately excited DC motor, permanent magnet synchronous motor and inductive motor. The most important advantage of DC motors is the simple drive system [6]. We can control its speed and the generated torque using the applied voltage on the armature. So if we adjust the applied voltage on motor armature, we can control the speed of the vehicle. The goal of speed control system design is to achieve fast, smooth and error free response after vehicle driver commands [7-8]. Generally EV speed controller is a system consisting of a PWM signal generator and an H-bridge power electronic circuit [9].

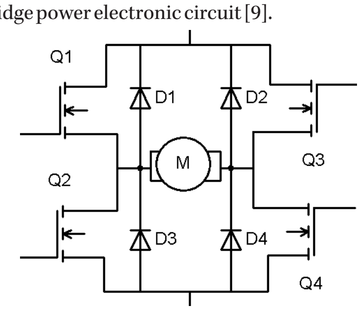

Fig. 3 H-bridge power electronic circuit

This method causes slow and non-smooth response. So we have to use intelligent controllers for better performance. In the next sections we will propose PID controller optimized with the GA, ICA and COA optimization techniques [10].

I. MODELING OF ELECTRIC VEHICLES MOTOR

In this section we will model separately exited DC motor of an Electric Vehicle. The armature and schematic of the motor are shown in Fig.4. In this case study we have voltage as input and the rotational speed of the shaft as output.

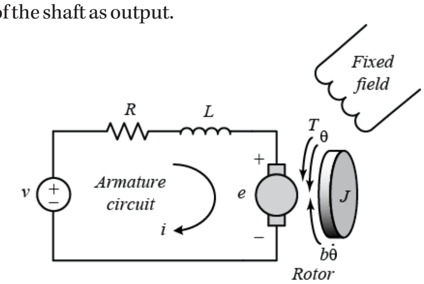

Fig. 3 H-bridge power electronic circuit

In a DC motor generated torque depends on applied armature current and the strength of magnetic field. In Electric Vehicles,

Volume - 7 | Issue - 1 | January - 2017 | ISSN - 2249-555X | IF : 3.919 | IC Value : 79.96

separately excited DC motors are the main and popular choice and we can assume that strength of magnetic field is constant. So the generated torque proportional to armature current and motor torque constant.

TABLE
MOTOR PARAMETERS

Parameter	description	Value
J [kg.m^2]	moment of inertia of the rotor	0.01
b [N.m.s]	motor viscous friction constant	0.5
Ke [V/rad/sec]	electromotive force constant	2
Kt [N.m/Amp]	motor torque constant	2
R [Ohm]	electric resistance	1
L [H]	electric inductance	0.005

$$T = K_t i \quad (1)$$

The back EMF generated in armature proportional to angular velocity of the shaft and electromotive force constant.

$$e = K_e \dot{\theta} \quad (2)$$

Generally the back EMF and motor torque constants are equal and we can use K to represent this parameter. With the aim of Newton's 2nd law and Kirchhoff's voltage law we can write the equations below.

$$L\frac{di}{dt} + Ri = V - K\dot{\theta} \quad (3)$$

$$J\ddot{\theta} + b\dot{\theta} = Ki \quad (4)$$

Using the Laplace transform we can express these equations in term of Laplace variable s.

$$(Ls + R)I(s) = V(s) - Ks\theta(s) \quad (5)$$
$$s(Js + b)\theta(s) = KI(s) \quad (6)$$

Finally we can propose the transfer function of electric vehicle DC motor such as below.

$$\frac{\dot{\theta}(s)}{V(s)} = \frac{K}{(Js+b)(Ls+R)+K^2} \quad [\frac{rad/sec}{V}] \quad (7)$$

State-space equations are expressed as below.

$$\frac{d}{dt}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} = \begin{bmatrix}-\frac{b}{J} & \frac{K}{J}\\ -\frac{K}{L} & -\frac{R}{L}\end{bmatrix}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} + \begin{bmatrix}0\\ \frac{1}{L}\end{bmatrix}V \quad (8)$$

$$y = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} \quad (9)$$

IV. IMPERIALIST COMPETITIVE ALGORITHM
Fig.5 shows the flowchart of the Imperialist Competitive Algorithm (ICA) [11]. Like other evolutionary algorithms, ICA starts with an initial population called initial countries. Some of the best countries in the population are selected to be the imperialists according to some predefined indexes. All the colonies of initial population are divided among the imperialists based on their profit value then these colonies start moving toward their relevant imperialist country. The power of each imperialist grows depending on number of its colonies members. ICA models this fact by defining the total power of an empire by the power of imperialist country added by a percentage of mean power of its colonies. Then the imperialistic competition begins among all the empires. Any empire that is not able to succeed in this competition and can't increase its power (or at least prevent decreasing its power) will be eliminated from the competition. The imperialistic competition will gradually result in an increase in the power of powerful empires and a decrease in the power of weaker ones. Weak empires will lose their power and ultimately they will collapse. The movement of colonies toward their relevant imperialists along with competition among empires and also the collapse mechanism will hopefully cause all the countries to converge to a state in which there exist just one empire in the world and all the other countries are colonies of that empire. In this ideal new world colonies, have the same position and power as the imperialist.

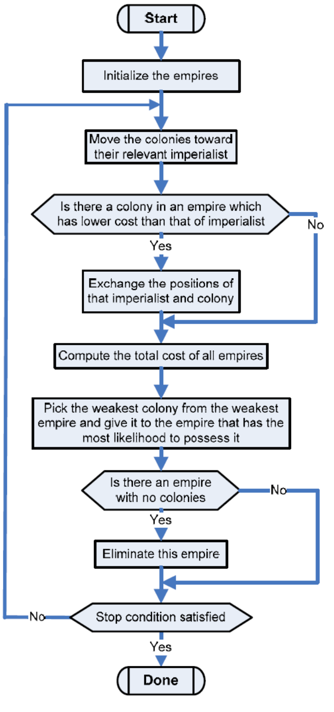

Fig. 5 Imperialist Competitive Algorithm flowchart

V. CUCKOO OPTIMIZATION ALGORITHM
In Fig.6, the flowchart of cuckoo optimization algorithm (COA) is seen [12]. Cuckoo Optimization Algorithm will begin its work with an initial population. The cuckoo population has a number of eggs that will host them in the nests of other birds. Some of these eggs that more closely similar to the host bird's eggs will mature into cuckoo. The number of mature eggs shows the suitability of the nest in that area. The situation in which most eggs are saved is the mode that COA is trying to optimize. Cuckoos seek to the best area to maximize their survival eggs. After the chicks were hatched and were mature into cuckoo, they form groups of themselves. Now each group has its specific residence for living. The best residence for all groups will be next destination for the cuckoos in the other groups. Hence, all groups migrate to the best current available area. According to the number of eggs that every cuckoo will lay and also the distance of cuckoos from the current optimal region for residence, a number of radiuses lying is calculated and formed. Then cuckoos start to randomly lay eggs in the nests inside its egg laying radius (ELR). The same algorithm was used in many application to predict the response of various physical systems [13]-[14].

This process continues to reach the best place to egg laying (the region with the highest profit value). This optimum location is where the most number of cuckoos get together.

Volume - 7 | Issue - 1 | January - 2017 | ISSN - 2249-555X | IF : 3.919 | IC Value : 79.96

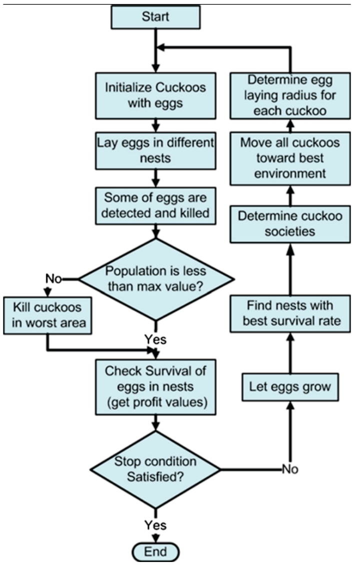

Fig.6 Cuckoo Optimization Algorithm flowchart

VI. SIMULATION RESULTS

A. *Response without Utilizing Intelligent Controllers*

Fig.7 illustrates the open loop response of EV motor.

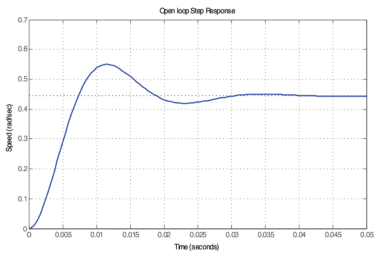

Fig. 7 Open loop response of EV motor speed

As shown in Fig.7 the open loop response has a big value in maximum Overshoot, undershoot, settling time, raise time and steady state error.

B. Response after Utilizing Intelligent Controllers

As shown in simulation result of GA method after 150 iterations in Fig.8, GA method corrected the overshoot of response but response has a big value in settling time and raise time and it is not acceptable for an Electric vehicle to have a long delay time between driver command and changing in speed value. According to Fig.9, the response of ICA and COA methods looks the same but the settling time and raise time of COA method is better than ICA. Other important parameters that make COA method most powerful than ICA are in number of algorithm iteration and elapsed time for calculation. The needed time for ICA method calculation is 1195sec. in 150 iterations even though needed time for COA method calculation is 22sec. in 8 iterations.

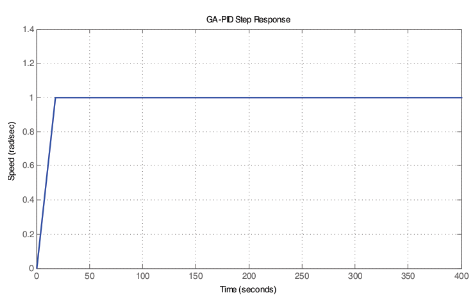

Fig. 8 Genetic Algorithm response

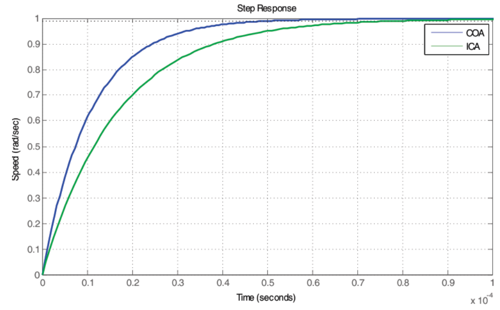

Fig. 9 COA and ICA response comparison

Fig.10 illustrates the convergence of Cuckoo Optimization Algorithm and Fig.11 illustrates the convergence of Imperialist Competitive Algorithm.

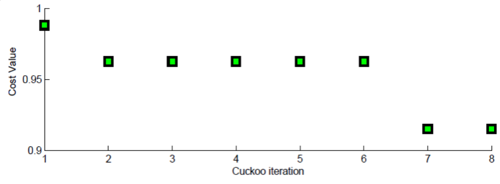

Fig. 10 Convergence of Cuckoo Optimization Algorithm

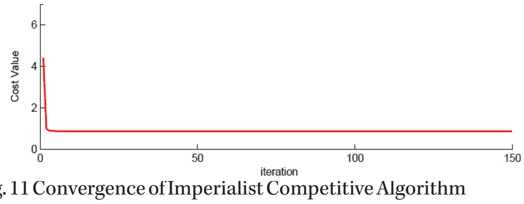

Fig. 11 Convergence of Imperialist Competitive Algorithm

Finally Table II indicates comparison between all utilized methods and non-controlled system step response performance with several indexes.

VII. CONCLUSION

In this paper a novel intelligent method for speed control of electric vehicles was proposed based on Cuckoo Optimization Algorithm. To show the high performance and effectiveness of the proposed technique, we simulate and compare its performance with two other optimization techniques including Imperialist Competitive Algorithm (ICA) and Genetic Algorithm (GA) with several indexes. The results indicate that COA method can operate for fast and smooth response in electric vehicle speed control system.

TABLE II

INTELLIGENT SPEED CONTROLLERS PERFORMANCE COMPARISON WITH NON CONTROLLED RESPONSE

Parameter	Open Loop	COA	ICA	GA
RiseTime [Sec]:	0.0059	2.9318e-005	4.5891e-005	15.9701
Settling Time [Sec]:	0.0280	3.7242e-005	5.8372e-005	17.3897
Overshoot [%]:	23.6556	0.9152	0.8760	1.8718e-011
Peak	0.5496	0.9978	0.9975	1.0000
PeakTime [Sec]:	0.0113	8.2463e-005	1.2884e-004	17.7446

Volume - 7 | Issue - 1 | January - 2017 | ISSN - 2249-555X | IF : 3.919 | IC Value : 79.96

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