UNIVERSITI PUTRA MALAYSIA

REGENERATIVE BRAKING STRATEGY FOR ELECTRIC VEHICLES USING IMPROVED ADAPTIVE GENETIC ALGORITHM

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FK 2018 59

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By

HUSSEIN TALEGHANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

October 2017

DEDICATIONS

To my loving and patient wife, Fatemeh, and my beloved parents. This work could not have been completed without their support.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in
fulfillment of the requirement for the degree of Master of Science

REGENERATIVE BRAKING STRATEGY FOR ELECTRIC VEHICLES USING IMPROVED ADAPTIVE GENETIC ALGORITHM

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October 2017

Chairman : Associate Professor Ir. Mohd Khair Hassan, PhD
Faculty : Engineering

An electric vehicle (EV) is a clear alternative compared to the conventional internal combustion engine (ICE) vehicles which are powered using fossil fuels. One of the fundamental advantages of EVs compared to conventional vehicles is the regenerative braking mechanism. Using this technique, some portion of the kinetic energy of the vehicle can be recovered during regenerative braking by using the electric drive system as a generator. Either parallel or series regenerative braking systems can be used to harvest the braking energy. Studies have shown that the amount of regenerated energy using a series (co-operative) system is more than the energy that a parallel system can harvest. A co-operative regenerative braking strategy should perform two tasks.

Firstly, it distributes the brake forces between front and rear axles of the vehicle. This braking force distribution affects vehicles stability while braking. If rear wheels lock prior to the front wheels, the vehicle would be unstable and start to skid. In order to keep vehicle's stability, the required braking force should be distributed according to the Economic Commission for Europe (ECE) regulations.

Secondly, it distributes the brake forces between regenerative braking and frictional braking systems. This braking force distribution affects the amount of harvested energy during braking. There are different algorithms used as a regenerative braking strategy. It is a time-consuming task to model and develop a regenerative braking strategy. Genetic Algorithm (GA) performance is flexible; it does not require many changes to be used in a different vehicle configuration. However, there are still issues remain to address such as increasing driving range and braking efficiency. Two GA based regenerative

braking strategies are proposed in this study. One uses Standard Genetic Algorithm (SGA), the second strategy uses Improved Adaptive Genetic Algorithm (IAGA). IAGA is able to solve complex and none-liner problems while providing faster convergence speed. In addition, SGA is prone to be stuck in local optimums when compared to IAGA. The performance of the proposed regenerative braking strategy is evaluated using Advanced Vehicle Simulator (ADVISOR) which is created in MATLAB/Simulink environment.

In order to illustrate the contrast between different regenerative braking strategies, three various strategies' performances are compared along with an EV configuration that does not utilize regenerative braking. The first regenerative braking strategy is the ADVISOR's Embedded Braking Strategy. The second strategy is based on Standard Genetic Algorithm (SGA). Lastly, the third strategy is utilizing Improved Adaptive Genetic Algorithm (IAGA). Four standard drive cycles are selected in order to evaluate each braking strategy performance under different driving conditions. 1015 drive cycle has been used in Japan to investigate on emissions and fuel economy for light duty vehicles. The Highway Fuel Economy Test (HWFET or HFET) cycle is a chassis dynamometer driving schedule developed by the US Environmental Protection Agency (US EPA) for the determination of highway fuel economy of light duty vehicles. The Urban Dynamometer Driving Schedule (UDDS) simulates an urban rote to evaluate urban fuel economy rating. Lastly, US06 drive cycle represents an aggressive, high speed and/or high acceleration driving behavior with rapid speed fluctuations. The results on these four driving cycles show a superior performance of IAGA in compare with other strategies. IAGA is able to improve braking efficiency up to 90% while increasing driving range up to 25%. However, the amount of available energy to recover is depended on driver's behavior.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

STATEGI REGENERATIF SISTEM BREK MENGGUNAKAN ALGORITMA GENETIK

Oleh

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Oktober 2017

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Kenderaan elektrik (electric vehicle, EV) merupakan pilihan yang lebih baik berbanding kenderaan enjin pembakaran dalaman (internal combustion engine, ICE) lazim yang menggunakan bahan api fosil. Salah satu kelebihan asas EV berbanding kenderaan lazim ialah mekanisme brek penjanaan semula. Dengan menggunakan teknik ini, sebahagian daripada tenaga kinetik kenderaan tersebut boleh dikumpul semula semasa brek penjanaan semula dengan menggunakan sistem pemacu elektrik sebagai penjana elektrik. Kedua-dua sistem brek penjanaan semula, sama ada selari atau bersiri, boleh digunakan untuk mengumpul tenaga brek. Beberapa kajian telah menunjukkan bahawa jumlah tenaga yang dijana semula menggunakan sistem bersiri (bekerjasama) adalah lebih banyak berbanding tenaga yang dapat dikumpul daripada sistem selari. Strategi kerjasama antara brek penjanaan semula perlu melakukan dua tugas.

Pertama, ia perlu mengagih daya brek di antara aci gandar hadapan dan belakang kenderaan. Pengagihan daya brek ini akan menjejaskan kestabilan kenderaan semasa membrek. Sekiranya roda belakang terkunci sebelum roda hadapan, kenderaan akan menjadi tidak stabil dan mula tergelincir. Untuk memastikan kestabilan kenderaan, daya brek yang diperlukan perlu diagihkan menurut peraturan-peraturan yang ditetapkan oleh Suruhanjaya Ekonomi untuk Eropah (Economic Commission for Europe, ECE).

Kedua, ia mengagihkan daya brek antara sistem brek penjanaan semula dan brek geseran. Pengagihan daya brek akan mempengaruhi jumlah tenaga yang dikumpul semasa membrek. Terdapat beberapa algoritma berbeza yang digunakan dalam strategi brek penjanaan semula.Walau bagaimanapun, tugas mencipta model dan membangunkan strategi brek penjanaan semula boleh memakan masa yang lama. Prestasi Algoritma Genetik (genetic algorithm, GA) adalah fleksibel; tidak banyak perubahan perlu dilakukan untuk menggunakan GA di dalam konfigurasi kenderaan yang berbeza. Namun, masih ada isu yang perlu ditangani, contohnya, meningkatkan jarak pemanduan dan kecekapan brek. Maka, kajian ini mencadangkan dua strategi brek penjanaan semula berasaskan GA. Satu strategi menggunakan sistem Algoritma Genetik Standard (Standard Genetic Algorithm, SGA), manakala strategi kedua menggunakan Algoritma Genetik Boleh suai Diperbaik (Improved Adaptive Gentic Algorithm, IAGA). IAGA mampu menyelesaikan masalah-masalah rumit dan tidak linear, di samping menyediakan kelajuan penumpuan yang lebih cepat. Selain itu, SGA lebih mudah tersekat dalam keadaan optimum terhad jika dibandingkan dengan IAGA. Prestasi strategi brek penjanaan semula yang dicadangkan ini dinilai menggunakan Simulator Kenderaan Maju (Advanced Vehicle Simulator, ADVISOR) yang dicipta di dalam persekitaran MATLAB/Simulink.

Untuk menggambarkan perbezaan di antara strategi-strategi brek penjanaan semula yang berlainan, prestasi tiga strategi yang berlainan telah dibandingkan, termasuklah satu konfigurasi EV yang tidak menggunakan brek penjanaan semula. Strategi brek penjanaan semula pertama ialah Strategi Membrek Terbenam ADVISOR. Strategi kedua pula adalah berdasarkan Algoritma Genetik Standard (SGA). Akhir sekali, strategi ketiga menggunakan Algoritma Genetik Boleh suai Diperbaik (IAGA). Empat kitaran pemanduan standard telah dipilih untuk menilai prestasi setiap strategi brek di dalam keadaan memandu yang berbeza. Kitaran memandu 1015 telah digunakan di Jepun untuk menyiasat pelepasan gas dan ekonomi bahan api untuk kenderaan ringan. Kitaran Ujian Ekonomi Bahan Api di Lebuhraya (Highway Fuel Economy Test, HWFET atau HFET) adalah jadual pemanduan dinamometer casis yang dibangunkan oleh Agensi Perlindungan Alam Sekitar Amerika Syarikat (US Environmental Protection Agency ,US EPA) untuk menentukan ekonomi bahan api di lebuh raya oleh kenderaan ringan. Jadual Pemanduan Dinamometer Bandar (Urban Dynamometer Driving Schedule, UDDS) pula menyerupai laluan dalam bandar untuk menilai kedudukan ekonomi bahan api dalam bandar. Akhir sekali, kitaran pemanduan US06 mewakili tingkah laku memandu yang agresif dan laju dan/atau pemecutan yang tinggi dengan penurunan-penaikan tahap kelajuan yang pantas. Keputusan daripada empat kitaran pemanduan ini menunjukkan prestasi unggul IAGA berbanding dengan strategi lain. IAGA mampu meningkatkan kecekapan membrek sehingga 90%, di samping meningkatkan jarak pemanduan sebanyak 25%. Walau bagaimanapun, jumlah tenaga yang ada untuk dikumpul semula bergantung kepada tingkah laku pemandu.

ACKNOWLEDGEMENTS

First of all, I would like to express my deep sense of respect and utmost gratitude towards my advisor, Assoc. Prof. Ir. Dr. Mohd Khair Hassan, whose constant encouragement, guidance and support has been invaluable to me. His patience, motivation, enthusiasm, and immense knowledge has helped me during the research and writing of this thesis. He has been a wonderful mentor all throughout my stay in UPM.

Next, I want to express my respects to my co-supervisory committee Assoc. Prof. Azura Che Soh and Dr. Ribhan Zafira Abdul Rahman for their advices and wonderful suggestions during the research time. My sincere gratitude is due to them.

Last but not the least, I would like to thank the ones closest to my heart, my parents and my wife. I owe them my everything.

I certify that a Thesis Examination Committee has met on 2 October 2017 to conduct the final examination of Hussein Taleghani on his thesis entitled "Regenerative Braking Strategy for Electric Vehicles using Improved Adaptive Genetic Algorithm" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

EV	Electric Vehicle
BEV	Battery Powered Electric Vehicle
ICE	Internal Combustion Engines
ESS	Energy Storage System
SOC	State Of Charge
ABS	Anti-lock Braking System
ESC	Electronic Stability Control
CAE	Computer Aided Engineering
DOE	U.S. Department of Energy
NREL	National Renewable Energy Laboratory
ADVISOR	Advanced Vehicle Simulator
IAGA	Improved Adaptive Genetic Algorithm
AGA	Adaptive Genetic Algorithm
SGA	Standard Genetic Algorithm
NiMH	Nickel-Metal Hydride
PM	Permanent Magnet Motor
IM	Induction Motor
SRM	Switched Reluctance Motor
IPM	Interior Permanent Magnet Motor
RBS	Regenerative Braking System
FEV	Fuel Cell Electric Vehicle
ECE	Economic Commission for Europe
FE-RBS	Fully Electrified Regenerative Braking System
MF	Membership Functions
GUI	Graphical User Interface
RC	Resistive-Capacitive
Rint	Internal Resistance
V_{OC}	open circuit voltage source
MC	Motor/Controller
NRB	An EV Without Regenerative Braking
AEBS	ADVISOR's Embedded Braking Strategy
HWFET	Highway Fuel Economy Test
HFET	Highway Fuel Economy Test
EPA	Environmental Protection Agency
UDDS	Urban Dynamometer Driving Schedule Test

LIST OF SYMBOLS

$\eta_{coulomb}$	Coulombic efficiencies
Ah_{max}	Battery maximum capacity
P	Electric power
$P_{m,req}$	Electrical power required by motor
$P_{m,out}$	Motor power output
$P_{m,loss}$	Motor power loss
τ_m	Motor torque
$\tau_{m,out}$	Motor torque output
$\tau_{m,req}$	Motor torque required
$\tau_{m,inertia}$	Motor torque needed due to inertial effect
ω_m	Motor angular speed
$I_{m,inertia}$	Motor inertia
z	Braking intensity
k	Adhesive utilization coefficient
β	Front axle braking force to the total braking force ratio
F_{bf}	Surface braking force of the front axle
F_{br}	Surface braking force of the rear axle
F_{zf}	Vertical load of the front axle
F_{zr}	Vertical load of the rear axle
L	Distance between the front and the rear axle
a	Distance from the center of the vehicle to the front axle
b	Distance from the center of the vehicle to the rear axle
h_g	Center of weight of the vehicle's high
F_t	Total braking force required
F_d	Braking force provided by drivetrain
F_f	Braking force provided by front axle
F_r	Braking force provided by rear axle
F_{dr}	Ratio of regenerative braking force to the total front axle braking force
i_n	Individual n-th in the population
r	Rolling radius of the wheels
i	Transmission ratio
η_{drive}	Drivetrain efficiency
η_{axle}	Axle efficiency
ϕ_i	Fitness of individual i.
P_{cr}	Crossover probability
P_{mt}	Mutation probability
ϕ_{max}	Maximum fitness in a population
ϕ_{avg}	Average fitness in a population
$\phi^{'}$	Maximum fitness between two selected parents

CHAPTER 1

INTRODUCTION

1.1 Background

At least one electric motor is used for propulsion in an electric vehicle (EV) which is also known as an electric drive vehicle. There are three main varieties of EVs including:

1. An external power station is used to directly power the EV.
2. An external power source is used to store electricity in an energy storage system on EV (BEV).
3. An on-board electrical generator, such as an internal combustion engine is used to propel the EV (hydrogen fuel cell or hybrid electric vehicles).

In response to regulations by governments, market interests, environmental issues, and economical concerns the automobile industry has been concentrating on developing clean, efficient and sustainable vehicles as a replacement for conventional vehicles which are propelled using internal combustion engines (ICE). The idea of battery powered electric vehicles (BEVs) works well with this trend due to high efficiency, quiet operation and zero emissions of EVs. However, energy storage is still an issue for EVs today due to the restrictions such as bulky size, heavy weight, long charging times, and expensive nature of current generation batteries.

Regenerative braking is an important and fundamental technique for increasing the driving range; it also compensates for battery capacity limitation of an EV with an energy storage system (ESS). With this method, kinetic energy is converted to electricity. The harvested electricity can be stored in an ESS such as a battery (or/and an ultra-capacitor) in order to be reused again while driving [Zhang and Mi, 2011]. With an appropriate control strategy, the electric motor that drives the wheels can be used as a generator [Cao et al., 2005] that provides braking torque when the brakes are applied while regenerating energy, by converting kinetic energy of the vehicle back into electricity which is then stored in the ESS. This technique can save considerable amount of energy also increasing the drive range [Ortmeyer and Pillay, 2002]. The provided braking force may not be guaranteed because of many limitations (including the driver's deceleration request, the state of charge (SOC) of the battery, the vehicle speed etc.). Therefore, friction brakes and a controller are required to ensure an active co-operative control with regenerative braking in response to driver's demands. Co-operative braking strategy that does not work properly may significantly affect the braking performance, energy harvesting, and braking feeling [Fujimoto et al., 2012].

Two types of regenerative braking systems can be used to harvest the braking energy, Either a parallel or a series (co-operative) system. In a parallel system, the brake pedal is connected mechanically to the friction brakes while the electric motor provides additional braking torque to reduces vehicle's speed. While, in a series system, the brake pedal is decoupled from the friction brakes. When the drivers braking demand is higher than the motor/generator's power capacity, the friction brakes are then applied. The amount of regenerated energy using series (co-operative) system is more than the energy that a parallel system can harvest [Von Albrichsfeld and Karner, 2009].

Whereas, the series regenerative braking system is more complicated due to the fact that the wheel pressure must be controlled without causing noise and vibration and also the braking system must response in real time [Nakamura et al., 2002]. This can be achieved by using an input device in order to determine brake demand and provide normal pedal feeling for the vehicle driver. In normal driving situations, the friction brakes provide the difference between the required torque demand and the available braking torque provided by electric motor. As the speed reduces, the regenerative torque increases until the speed drops to below the base speed of the motor. At low speed, the recovered energy is small and it is difficult to meet the drivers pedal feel expectations [Yeo and Kim, 2002], they found that the driver behavior in braking dramatically affects the harvested energy amount. For instance, if the brake demand is constantly high this causes the friction brakes to be continuously actuated from the start of braking, and a lower proportion of the braking energy can be harvested.

The main benefit of using a parallel regenerative braking system is its simplicity. Vehicles with parallel braking system can use a conventional braking system directly, resulting in a lower cost of the vehicle. The TATA ACE is a small electric truck which utilize a parallel regenerative braking system [Lukic et al., 2008]. Using a parallel regenerative braking system, the driver controls the pressure of the wheel cylinders of the both friction brakes of front and rear axle, while the electric motor which is in generator mode while braking, provides regenerative braking force in addition to the friction force. The electric motor limitations have a crucial impact on the amount of the regenerative braking force provided at any given speed. The driver have a perception on the vehicle deceleration rate based on the force he is applying to the brake pedal. However, due to the limitations of the motor that provides the regenerative braking force, the provided force is not fixed. When the driver is expecting the vehicle to decelerate with a certain rate, if the total braking torque is larger or smaller that what the driver demands, the driver would feel uncomfortable about the braking system. Moreover, modern EVs utilize other brake safety systems such as Anti-lock Braking (ABS) and Electronic Stability Control (ESC). Indeed, vehicle and passenger safety is critical in contrast with energy harvesting. Thus, regenerative braking system should be turned off while ABS or ESC systems are activated. Hence, a co-operation between regenerative braking system and the brake safety systems is required.

Computer Aided Engineering (CAE) has been playing a significant and crucial role throughout the process of vehicle design in order to increase the efficiency and accuracy of automotive design. With the increase of computing power, manufacturers are now able to design, test, and optimize the vehicle through computer simulation, all prior to the actual manufacturing of the vehicle. Similar to other areas of automotive research such as vehicle dynamics and crash worthiness, numerous software packages are developed in order to evaluate the energy efficiencies of electric vehicles. One particular example is a software originally developed by the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) called ADVISOR (Advanced Vehicle Simulator). ADVISOR was later acquired by AVL Powertrain Engineering, Inc. This software which is based on MATLAB/Simulink, can be used to simulate and analyze various types of vehicles, including electric and hybrid vehicles, where it allows the user to customize the power components such as internal combustion engines and electric motors to study the effect on fuel efficiency and vehicle performance on different drive cycles.

1.2 Problem Statement

While a conventional ICE (internal combustion engine) vehicle brakes, the kinetic energy of the vehicle is wasted as heat due to friction in the brakes. An energy storage system (ESS) provides energy to the electric motor to run in an EV. Regenerative Braking is an energy recovery method which tries to harvest the braking energy before it is wasted as heat. Energy recovery in a regenerative braking system is performed by using the motor as a generator. While decelerating, the motor converts mechanical energy to electricity and thus charging the ESS. It has been pointed out by [Xu et al., 2011] that the regenerative braking system (RBS) is capable of increasing the driving range as much as 8%-25%. The advantages of regenerative braking by co-operative braking systems has been theoretically and experimentally validated in various kinds of EVs, for instance for battery electric vehicle (BEV) by [Han et al., 2014; Zhou et al., 2012], fuel cell electric vehicle (FEV) by [Lv et al., 2015] and hybrid electric vehicle (HEV) by [Li et al., 2016]. Although, there are few concerns remained to be investigated, including how to improve energy efficiency, driving range and also braking safety [Fujii and Fujimoto, 2007; Chan, 2007]. Two types of regenerative braking systems can be used to harvest the braking energy, Either a parallel or a series system. The amount of regenerated energy using a series (co-operative) system is more than the energy that a parallel system can harvest [Fujimoto et al., 2012; Von Albrichsfeld and

Karner, 2009].

A co-operative braking control strategy has two parts:

1. To distribute braking force between front and rear axle brakes
2. To distribute the demanded braking force between regenerative braking toque provided by drivetrain and mechanical friction brakes

The former, affects vehicles stability while braking. If rear wheels lock prior to the front wheels, the vehicle would be unstable and start to skid. In order to keep vehicle's stability, the required braking force should be distributed according to the Economic Commission for Europe (ECE) regulations [ECE, 2014; Chu et al., 2011].

The latter, affects the amount of harvested energy during braking. There are different algorithms used as a regenerative braking strategy. Some studies have utilized a rule-based strategy [Xu et al., 2017; Zhang and Gohlich, 2016; Chu et al., 2009; Zhang Jingming et al., 2008; Mutoh et al., 2007], they use look-up tables or rules to distribute braking force in a vehicle. Usually it is a time-consuming task to model and develop rules for these systems, it demands performing tests on the actual vehicle to build this type of braking strategy and also experts needs to perform these time-consuming tests on every different types of vehicle. Other studies have been using a Fuzzy logic based strategy [Qin, 2015; Xu et al., 2011; Jing-ming et al., 2009; Peng et al., 2008; Bathaee et al., 2005]. However, Fuzzy based approaches are heavily depended on the membership functions one designs for each system and these algorithms are also not flexible enough to distribute braking force if the driver's behavior varies. Few studies has suggested using a Genetic Algorithm (GA) algorithm [Li et al., 2017; Fengjiao and Minxiang, 2015; Guo et al., 2009] to optimize braking distribution strategy in order to harvest maximum energy possible. However, there are still issues remain to address. An Improved Adaptive Genetic Algorithm (IAGA) based braking strategy is proposed in this study to maximize the recovered energy while following the rules for stability. Generally Genetic Algorithm (GA) performance is more flexible than other rule-based or fuzzy algorithms [Haupt and Haupt, 2004], it does not require many changes to be used in a different vehicle configuration. Two GA based regenerative braking strategies are proposed. One uses Standard Genetic Algorithm (SGA), the second strategy uses Improved Adaptive Genetic Algorithm (IAGA). IAGA is able to solve complex and none-liner problems while providing faster convergence speed. And also, SGA is prone to be stuck in local optimums when compared to IAGA [Fan and Chen, 2017; Wang et al., 2014; Huang, 2012; Xu et al., 2010].

1.3 Objectives

The overall aim of this research is to improve driving range of EVs and also to increase braking efficiency for co-operative regenerative braking, i.e. regenerative braking with friction braking. The research objectives are as follows:

i. To develop a fitness function to simulate the main elements of a co-operative braking system

ii. To improve driving range of EV using an IAGA based co-operative braking strategy that considers the brake demand from the driver, vehicle constraints and vehicle stability rules

iii. To compare performance of SGA and IAGA as a co-operative braking strategy

1.4 Thesis Scope

This dissertation demonstrates a braking distribution strategy based on Improved Adaptive Genetic Algorithm (IAGA) for a medium-small four-wheel electric vehicle, whereas different parts' mathematical model has been investigated to harvest regenerative braking energy and distribute braking force for regenerative and friction brakes. The braking strategy is designed to perform on a wide range of driving cycles harvesting maximum energy while keeping the vehicle stable. Generally, there are two main regenerative braking approaches: the first system is a parallel approach in which the brake pedal is connected to the friction brakes mechanically and motor provides an additional braking torque, the second system is a series configuration where the friction brakes are decoupled from the brake pedal, the friction brakes are applied when the braking demand is higher than the motor's braking torque. The series configuration is the sole interest of this study for the proposed braking strategy design.

Developing a braking strategy based on IAGA, particularly on a strategy development that can handle mix-mode braking distribution successfully is emphasized on this study. Nevertheless, there are numerous difficulties can be encountered in obtaining that goal which influences harvested energy and stability. One of these problems is the adopting of genetic algorithm suitable for this situation. The braking strategy should handle different driving behavior which is applied to the system via drive cycles with a suitable efficiency regardless of the situation. The strategy should be integrated with ADVISOR to make the seamless evaluation process possible.

This study focuses on these issues only for series regenerative braking configuration. Therefore, the gapes this study is trying to cover are adopting effective genetic algorithm based braking strategy and also developing robust distribution strategy that can perform under different driving behavior and situations.

1.5 Contribution

The focus of this study is to design a braking strategy that can operate and harvest maximum energy in a wide range of drive cycle types which represent different driving situations. Therefore, the main contribution of this study can be pointed out as:

- Increasing driving range of the proposed EV.
- Increasing braking efficiency
- Developing a braking distribution strategy based on improved adaptive genetic algorithm
- Comparing different braking strategies and their behavior under different driving situations

1.6 Thesis Organization

The remaining parts of this thesis are organized as follows:

- Chapter 2: This chapter provides the literature review. Starting with different energy storage systems followed by electric motor types used for EVs. Followed by introducing Advanced Vehicle Simulator's (ADVISOR) structure and its data flow and also mathematical modeling of motor and energy storage system. Afterwards, a literature review about Genetic Algorithm is provided. Finally, reviewing literature on braking distribution strategies in electric and hybrid vehicles.
- Chapter 3: Presents adopted methodology for the braking strategy design. Initially, it starts by introducing flowchart of the study followed by presenting regenerative braking strategy as an optimization problem. Afterwards, two braking strategies are presented: first, a strategy based on Standard Genetic Algorithm (SGA). Followed by the second strategy which is based on Improved Adaptive Genetic Algorithm (IAGA).
- Chapter 4: Reveals and discusses simulation results of the braking strategies, their performance and operating behavior. The analysis and investigation includes simulation in ADVISOR in MATLAB/Simulink environment on four different standard drive cycles.
- Chapter 5: Presents the conclusion on this study as well as the proposed future work.

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