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Optimal Speed Control of Hybrid Electric Vehicles

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Abstract

The main objective of this paper is to control the speed of Nonlinear Hybrid Electric Vehicle (HEV) by controlling the throttle position. Various control techniques such as well known Proportional-Integral-Derivative (PID) controller in conjunction with state feedback controller (SFC) such as Pole Placement Technique (PPT), Observer Based Controller (OBC) and Linear Quadratic Regulator (LQR) Controller are designed. Some Intelligent control techniques e.g. fuzzy logic PD, Fuzzy logic PI along with Adaptive Controller such as Self Organizing Controller (SOC) is also designed. The design objective in this research paper is to provide smooth throttle movement, zero steady-state speed error, and to maintain a Selected Vehicle (SV) speed. A comparative study is carried out in order to identify the superiority of optimal control technique so as to get improved fuel economy, reduced pollution, improved driving safety and reduced manufacturing costs.

Key Words: Fuzzy logic control, Linear Quadratic Optimal Controller, Observer Based Controller, PID Controller, Pole-Placement Technique, Self Organizing Controller, Vehicle

I. INTRODUCTION

In recent years increasing concern of environment and economy has made the use of electric vehicle indispensable and ubiquitous in nature. The exhaust emissions of the conventional internal combustion engine vehicles (ICEVs) are the major source of urban pollution that causes the green house effect, which in turn leads to global warming. Even from the economic standpoint that is inherent in the poor energy conversion efficiency of the internal combustion (IC) engines, electric vehicle is more viable. Though efficiency calculated on the basis of conversion from crude oil to traction effort at wheels for electric vehicles (EVs) is not significantly higher yet, it does make a difference. The regulation of emission due to power generation at remotely located plant is much easier than those emanating from IC engine vehicle that are individually maintained and scattered all over the world. Furthermore, electric power used for the battery of EVs can also be generated using non conventional sources which are environment friendly [1], [2]. Electric vehicles have no emissions and therefore are capable of tackling the pollution problem in an efficient way. Consequently electric vehicles are the only zero-emissions vehicles (ZEVs) available now days. The limited range of battery powered electric vehicles led the researchers and auto industry players to search for alternatives. The assiduous and aggressive efforts by the industry led to the prodigious development of hybrid electric vehicles (HEVs).The HEVs use both electric machines and an IC engine for delivering the propulsion power [1], [2]. With the burgeoning popularity of EVs and HEVs in the market bewildering varieties of energy management system in the hybrid drive train is devised. As pioneers of intelligent energy management in HEVs some authors have proposed an extensive classification and overviews of state of the art control strategies for the same [2]–[7].

The modern electric vehicle performance depends very much on automation systems applied. The conventional control methods have been found not so adequate and many control problems have come up due to imprecise input output relation and unknown external disturbances. Many new controllers such as fuzzy logic controller (FLC) have been suggested in near past to address such problems. FLC provides an efficient method to handle inexact information on a basis of reasoning. With FLC it is possible to convert knowledge expressed in uncertain form to an exact algorithm. Application of FLC and self tuning fuzzy PID controller have been used for the design of four wheeled drive EV yaw stability and industrial hydraulic actuator respectively [8], [9]. A new scheme known as self organizing fuzzy logic controller for wheeled mobile robot using evolutionary algorithm has been suggested by Kim et. al [10]. As fuzzy controller alone was not able to provide many features of adaptive controller both were together used for different control problems [11]–[14].

Next the state feedback control technique such as LQR controller of optimal control segment came up with beautiful features to improve dynamic as well as steady state performance [15]–[22]. The speed control in HEVs are mainly achieved controlling the servo motor which in turn controls the throttle position for smooth torque and speed control of

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Optimal Control Of Hybrid Vehicles

Bram de Jager,Thijs van Keulen,John Kessels

Optimal Control Of Hybrid Vehicles:

Hybrid Systems, Optimal Control and Hybrid Vehicles Thomas J. Böhme,Benjamin Frank,2017-02-01 This book assembles new methods showing the automotive engineer for the first time how hybrid vehicle configurations can be modeled as systems with discrete and continuous controls These hybrid systems describe naturally and compactly the networks of embedded systems which use elements such as integrators hysteresis state machines and logical rules to describe the evolution of continuous and discrete dynamics and arise inevitably when modeling hybrid electric vehicles They can throw light on systems which may otherwise be too complex or recondite Hybrid Systems Optimal Control and Hybrid Vehicles shows the reader how to formulate and solve control problems which satisfy multiple objectives which may be arbitrary and complex with contradictory influences on fuel consumption emissions and drivability The text introduces industrial engineers postgraduates and researchers to the theory of hybrid optimal control problems A series of novel algorithmic developments provides tools for solving engineering problems of growing complexity in the field of hybrid vehicles Important topics of real relevance rarely found in text books and research publications switching costs sensitivity of discrete decisions and there impact on fuel savings etc are discussed and supported with practical applications These demonstrate the contribution of optimal hybrid control in predictive energy management advanced powertrain calibration and the optimization of vehicle configuration with respect to fuel economy lowest emissions and smoothest drivability Numerical issues such as computing resources simplifications and stability are treated to enable readers to assess such complex systems To help industrial engineers and managers with project decision making solutions for many important problems in hybrid vehicle control are provided in terms of requirements benefits and risks **Optimal Control of Hybrid Vehicles** Bram de Jager,Thijs van Keulen,John Kessels,2013-04-05 Optimal Control of Hybrid Vehicles provides a description of power train control for hybrid vehicles The background environmental motivation and control challenges associated with hybrid vehicles are introduced The text includes mathematical models for all relevant components in the hybrid power train The power split problem in hybrid power trains is formally described and several numerical solutions detailed including dynamic programming and a novel solution for state constrained optimal control problems based on the maximum principle Real time implementable strategies that can approximate the optimal solution closely are dealt with in depth Several approaches are discussed and compared including a state of the art strategy which is adaptive for vehicle conditions like velocity and mass Three case studies are included in the book a control strategy for a micro hybrid power train experimental results obtained with a real time strategy implemented in a hybrid electric truck and an analysis of the optimal component sizes for a hybrid power train Optimal Control of Hybrid Vehicles will appeal to academic researchers and graduate students interested in hybrid vehicle control or in the applications of optimal control Practitioners working in the design of control systems for the automotive industry will also find the ideas propounded in this book of interest **Vehicle Propulsion Systems** Lino Guzzella,Antonio

Sciarretta,2007-09-21 In this book the longitudinal behavior of road vehicles is analyzed The main emphasis is on the analysis and minimization of the fuel and energy consumption Most approaches to this problem enhance the complexity of the vehicle system by adding components such as electrical motors or storage devices Such a complex system can only be designed by means of mathematical models This text gives an introduction to the modeling and optimization problems typically encountered when designing new propulsion systems for passenger cars It is intended for persons interested in the analysis and optimization of classical and novel vehicle propulsion systems Its focus lies on the control oriented mathematical description of the physical processes and on the model based optimization of the system structure and of the supervisory control algorithms This text has evolved from a lecture series at ETH Zurich Prerequisites are general engineering topics and a first course in optimal control theory Optimal Control of Hybrid Electric Vehicles for Real-world Driving Patterns Christopher Vagg,2014 Regenerative Braking and Stability Optimal Control in Hybrid Vehicles ,2009 **Hybrid Vehicles** BADIN François,2013-07-04 The fast growth in world population and the associated energy requirements the announced depletion of fossil fuel resources the continuing rise in greenhouse gas GHG emissions with the induced climatic changes represent some of the major challenges to be taken up in the coming years and decades Hybridization therefore typically represents a transition technology which can significantly improve the energy and environmental performance of current vehicles without radically changing their use typologies while opening the way to new propulsion modes for the longer term It is nevertheless a complex subject requiring a multidisciplinary approach This book which is intended to be exhaustive considers the vehicle its components their association and their control as well as the global balances determined over the vehicle lifetime It starts with a general presentation of the various conditions of use of vehicles to give readers an understanding of the stakes related to the development of hybrid vehicles and the methods used to compare the performance of the various solutions The principles and the various types of internal combustion engine and electrical drives onboard energy storage systems principles architectures specific components and operation of hybrid drivetrains as well as the energy management in these vehicles are developed A global analysis of the various drivetrains life cycle assessment LCA total costs and availability of sensitive materials is also provided This book is intended for everyone involved in the design manufacture and implementation of hybrid drive vehicles and their components It will also be of interest to students teachers and researchers wishing to acquire or further their knowledge in all fields impacted by drivetrain electrification More globally after consulting this book readers will be in a position to evaluate the technologies related to the concept of drivetrain hybridization their implementation balances and generalization conditions This book is available in French Under the title V hicules hybrides Contents 1 Vehicle use 2 Internal combustion engines 3 Electric drivetrain 4 On board energy storage systems 5 Hybridization 6 Control of hybrid vehicles 7 Comparative study of hybrid vehicles greenhouse gas emissions energy consumption and cost Appendixes **Optimal Control and Design of Hybrid-electric Vehicles** Olle

Sundström,2009 Energy Efficiency Improvements in Smart Grid Components Moustafa Eissa,2015-04-22 This book is intended for academics and engineers who are working in universities research institutes utility and industry sectors wishing to enhance their idea and get new information about the energy efficiency developments in smart grid The readers will gain special experience with deep information and new idea about the energy efficiency topics This book includes lots of problems and solutions that can easily be understood and integrated into larger projects and researches The book enables some studies about monitoring management and measures related to smart grid components Energy Efficiency Improvements in smart grid components and new intelligent Control strategies for Distributed energy resources boosting PV systems electrical vehicles etc It included optimization concepts for power system promoting value propositions protection in power system etc The book also has some recent developments in solar cell technologies LEDs and non thermal plasma technology As I enjoyed preparing this book I am sure that it will be very valuable for large sector of readers **Hybrid Electric Vehicles** Simona Onori,Lorenzo Serrao,Giorgio Rizzoni,2015-12-16 This SpringerBrief deals with the control and optimization problem in hybrid electric vehicles Given that there are two or more energy sources i e battery and fuel in hybrid vehicles it shows the reader how to implement an energy management strategy that decides how much of the vehicle s power is provided by each source instant by instant Hybrid Electric Vehicles introduces methods for modeling energy flow in hybrid electric vehicles presents a standard mathematical formulation of the optimal control problem discusses different optimization and control strategies for energy management integrating the most recent research results and carries out an overall comparison of the different control strategies presented Chapter by chapter a case study is thoroughly developed providing illustrative numerical examples that show the basic principles applied to real world situations The brief is intended as a straightforward tool for learning quickly about state of the art energy management strategies It is particularly well suited to the needs of graduate students and engineers already familiar with the basics of hybrid vehicles but who wish to learn more about their control strategies *Predictive Optimal Control Based Energy Management of Hybrid Electric Vehicles* Temiloluwa Jegede,2022 *Constrained Optimal Control Applied to Fuel Cells and Vehicle Systems* Ardalan Vahidi,2005 *A Multiobjective Optimization Framework for Online Stochastic Optimal Control in Hybrid Electric Vehicles* ,2015 The increasing urgency to extract additional efficiency from hybrid propulsion systems has led to the development of advanced power management control algorithms In this paper we address the problem of online optimization of the supervisory power management control in parallel hybrid electric vehicles HEVs We model HEV operation as a controlled Markov chain and we show that the control policy yielding the Pareto optimal solution minimizes online the long run expected average cost per unit time criterion The effectiveness of the proposed solution is validated through simulation and compared to the solution derived with dynamic programming using the average cost criterion Both solutions achieved the same cumulative fuel consumption demonstrating that the online Pareto control policy is an optimal control policy

Towards Optimal Control of Fuel Cell Hybrid Electric Vehicles Philipp Kemper,2019 **Optimal Control of Li-Ion Hydrogen Fuel Cell Hybrid Vehicles** Michael Karpinski-Leydier,University of Waterloo. Department of Mechanical and Mechatronics Engineering,2012 Hydrogen fuel cells are poised to become the next major power generation technology for the automotive industry Fuel cell hybrid vehicles have similar power trains to conventional series hybrid electric vehicles The underlying hybrid control concepts used for conventional hybrid vehicles are still valid although it is unknown how well they will perform on fuel cell based vehicles since the fuel cell is a fundamentally different power source This thesis reviews several control strategies for fuel cell vehicles including a mode switching rule based control strategy a constant fuel cell output strategy and an adaptive variation of the equivalent consumption minimization strategy A ECMS which has been modified for fuel cell vehicles These strategies are implemented in simulation and evaluated against optimal strategies The optimal strategies have been determined using convex optimization problem solving techniques The mode switching and constant fuel cell strategies have also been evaluated in real world testing on a fully functional road safe fuel cell powered SUV The test vehicle was designed and built by the University of Waterloo Alternative Fuels Team UWAFT for the EcoCAR competition The simulation results demonstrate that near optimal fuel economies can be achieved through operating the fuel cell at near peak efficiency while the battery manages all major transients in the power demand The constant fuel cell strategy demonstrates the highest fuel economy of all the tested strategies since it operates continually within this high efficiency region The mode based strategy showed the worst results since the fuel cell would follow the transients of the power demand pushing it out of the peak efficiency region The simulation results were validated by the experimental results which showed similar relationships The A ECMS provided good results although they were lower than the constant fuel cell strategy Hydrogen fuel cell vehicles have the real potential to become the next major vehicle technology Only by continuing to research every aspect of these vehicles needed to make them viable for consumer use can these vehicles ever replace the gasoline powered vehicles we use today **Intelligent Control and Smart Energy Management** Maude Josée Blondin,João Pedro Fernandes Trovão,Hicham Chaoui,Panos M. Pardalos,2022-05-28 This volume aims to provide a state of the art and the latest advancements in the field of intelligent control and smart energy management Techniques combined with technological advances have enabled the deployment of new operating systems in many engineering applications especially in the domain of transport and renewable resources The control and energy management of transportation and renewable resources are shifting towards autonomous reasoning learning planning and operating As a result these techniques also referred to as autonomous control and energy management will become practically ubiquitous soon The discussions include methods based on neural control and others as well as distributed and intelligent optimization While the theoretical concepts are detailed and explained the techniques presented are tailored to transport and renewable resources applications such as smart grids and automated vehicles The reader will grasp the most important theoretical concepts as

well as to fathom the challenges and needs related to timely practical applications Additional content includes research perspectives and future direction as well as insight into the devising of techniques that will meet tomorrow s scientific needs This contributed volume is for researchers graduate students engineers and practitioners in the domains of control energy and transportation **Vehicle, Mechatronics and Information Technologies** X.D. Yu,2013-08-30 Selected peer reviewed papers from the 2013 International Conference on Vehicle Mechanical Engineering and Information Technology VMEIT 2013 August 17 18 2013 Zhengzhou Henan China *ASME Technical Papers* ,1982 **Proceedings of the ASME Advanced Energy Systems Division** American Society of Mechanical Engineers. Advanced Energy Systems Division,2004 Proceedings ,1980 Application of Energy Optimal Control to Energy Management of Hybrid Vehicle Hiroshi Uchida,2011

Unveiling the Power of Verbal Art: An Mental Sojourn through **Optimal Control Of Hybrid Vehicles**

In a global inundated with monitors and the cacophony of instant interaction, the profound energy and psychological resonance of verbal beauty usually fade into obscurity, eclipsed by the constant onslaught of noise and distractions. However, nestled within the lyrical pages of **Optimal Control Of Hybrid Vehicles**, a fascinating work of literary brilliance that impulses with organic emotions, lies an unforgettable trip waiting to be embarked upon. Penned with a virtuoso wordsmith, this mesmerizing opus manuals viewers on a mental odyssey, gently exposing the latent potential and profound affect embedded within the complex web of language. Within the heart-wrenching expanse of the evocative evaluation, we will embark upon an introspective exploration of the book is main subjects, dissect its charming publishing design, and immerse ourselves in the indelible impression it leaves upon the depths of readers souls.

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