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A STUDY ON ACCELERATED MODEL PREDICTIVE CONTROL FOR ELECTRIC VEHICLES

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Keywords

Electric Vehicle, Model predictive control, Energy management, Cost optimization, Performance management

Abstract

In this study, a detailed description of an accelerated model predictive control (MPC) for the electric vehicles has been evaluated. The discussion for different studies about this topic reveals that the benefits of this MPC system in developing an EV. The potential benefits of this system in sustainability and environmental protections are also discussed along with its significant optimization of resources and costs. The associated challenges regarding the implementation of this system are also included in this study. The data has been analyzed based on the identified themes from 10 most relevant literature.

1. INTRODUCTION

The model predictive control (MPC) is known as one of the promising domains for effective energy management and it deals with the system of multiple inputs and multiple outputs. The utilization of this MPC system in electric vehicles (EVs) enables efficiency in the total operational costs considering all the constraints and supply-demand market situations. In this research, a thorough study has been conducted based on the significant information available in the market. The findings and analysis have been evaluated in this study depending on various research resources from various scientific articles.

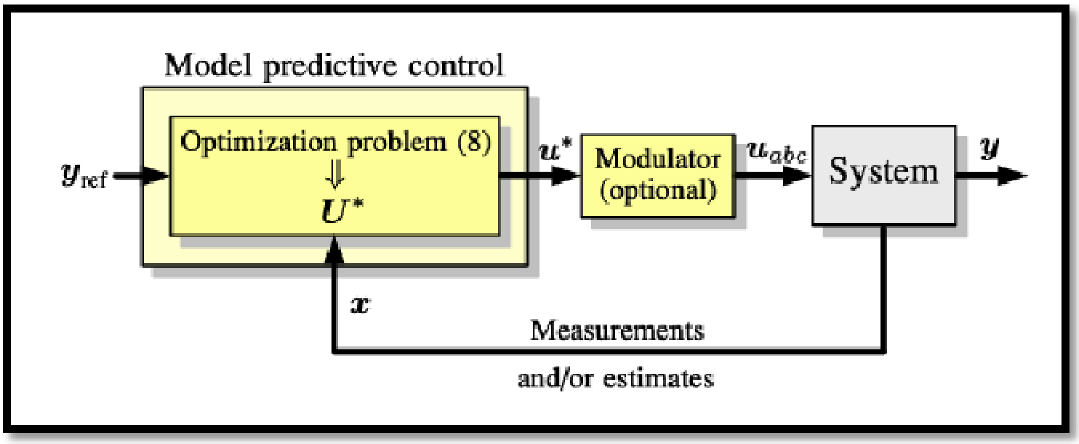

Figure 1: Block diagram for MPC(Karamanakos et al., 2020)

This research aims to study the MPC strategies in EV manufacturing focusing on the optimization of energy performance, range, and overall performance of the vehicles. It also addresses the potential challenges of the implementation of this system in real-time scenarios. Objectives include to review the existing literature about MPC systems tailored for EVs and to assess the overall computational efficiency of the MPC system.

2. BACKGROUND OF THE RESEARCH

The effective horizon strategies are employed in various MPC-based approaches by optimizing the overall operational costs and other significant constraints. According to the study of Guo et al., (2020) there are various variables involved in the prediction models regarding microgrids of the system and these variables include the energy prices, RES outputs, load demands, and other significant energy management elements. To handle various uncertainties in the parameters of EVs, MCP is designed effectively aligning with the solution of different optimization problems. However, there are the constraints of the controlling actions and states that are often not considered in the evaluation of the efficiency of this system. As depicted in the study of Amini, Kolmanovsky & Sun (2020), the conservative controls of the vehicles limit the effective implementation of this controlling system. While evaluating the performance of this control, the future states of the system are considered by making significant updates in the model and optimizing through effective algorithms in the predictive horizon. As opined by Lin, McPhee &

Azad (2020), the flexibility in control challenges formulations enables this system to be more effective in various time-varying and nonlinearities features in the vehicles. The initial implementation of MPC can be observed in the electronic stability program (ESP) in modern EVs.

3. RESEARCH METHODOLOGY

3.1 Systematic Review

For conducting this research study, a systematic review of the existing literature has been made. Different databases including ProQuest and Google Scholar are used to find significant literature resources about the topic of MCP systems for EVs. As per the opinion of Zhou, Ravey & Péra (2021), for the review process, a comprehensive strategy for searching has been followed with the relevant keywords regarding acceleration techniques, electric vehicles, energy optimization, and MPC systems. Moreover, the inclusion and exclusion criteria for the relevant resources have been applied to this research to choose the most relevant literature based on the relevance of the topic, methodology, and publications. The following table highlights different keywords and their Boolean operations with significant search results.

Table 1: Boolean operation and the database

Keyword		Keyword		Keyword	Search results
Model Predictive Control	AND	Electric Vehicles	AND	Acceleration	ProQuest- 3088
Performance	AND	Accelerated MPC	AND	Electric Vehicles	ProQuest- 11543
Computational Efficiency	OR	Real-time MPC system implementation	AND	EVs	ProQuest- 81565
Optimization Algorithms	OR	Computational Algorithms	AND	MPC System in Electric Vehicles	ProQuest- 87036

4. RESEARCH FINDINGS

From the collected information, there have been identified several findings. Depending on the relevance of the data and other significant data validation, the exclusion and inclusion criteria are applied. After eliminating the irrelevant literature, the findings are formulated in the following table.

Table 2: Summary of the data searches

Steps	Search results	Excluded literature and reason
Identification	Identified resources: From database 1: (n=50) From database 2: (n=30)	Duplicate literature (n=40)
Screening	Screened resources (n=40) Eligible resources (n=10)	Excluded for duplicity of the literature (n=40) Resources excluded based on the relevance of information about Accelerated MPC systems, EVs, energy, and cost optimization (n=30)
Final inclusion	Included studies in this review (n=10)	

From the relevant information, the following articles are evaluated in the below table-3.

Table 3: Theme identification from the relevant literature sources

Source	Codes	Sub-codes	Theme
Guo et al., (2020) Amini, Kolmanovsky & Sun (2020) Lin, McPhee & Azad (2020)	MPC system, Electric Vehicles	Nonlinear MPC model, Adaptive predictive control, optimization of EVs	Real-time MPC system optimizes the adaptive, distributive, and integrated EV drives.
Zhou, Ravey & Péra (2021) Chen et al., (2020) Tang et al., (2020)	Cost minimization, energy optimization, Hybrid Electric Vehicles	Energy management, predictive control, power-efficient technology	MPC for energy management enhances the energy and cost efficiency of Electric Vehicles.
Karamanakos et al., (2020) Altan & Hacıoğlu (2020) Mariano-Hernández et al., (2021) Ding, Wang & Zhang (2020)	MPC system, Accelerations, EVs	Real-time MPC challenges, Energy management system, optimization, demand management, acceleration regulations	MPC strategies are tailored to build an effective energy management system.

5. DATA ANALYSIS

5.1 Thematic Analysis

5.1.1 Real-time MPC system optimizes the adaptive, distributive, and integrated EV drives.

MPC has a significant impact in developing effective technologies in energy management for EVs and this system is developed for optimizing the consumption of energy fuels reducing the carbon footprints in the environment. According to Chen et al., (2020), in the integration of renewable energy resources, this system is effectively implemented as distributed energy generations which have been accelerated by the extensive demands for energy. Various issues regarding the utilization of renewable energy solutions can be resolved by this system.

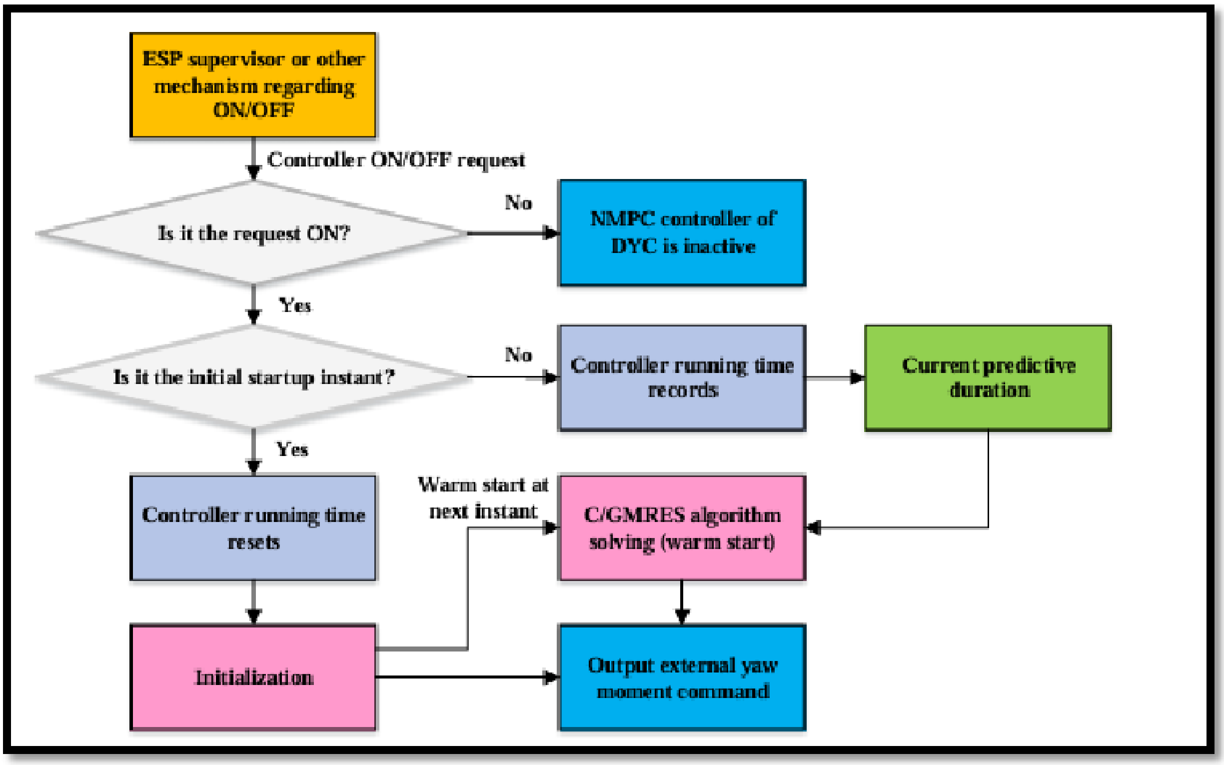

Figure 2: Operations of MPC controller within EVs (Guo et al., 2020)

5.1.2 MPC for energy management enhances the energy and cost efficiency of Electric Vehicles.

Effective management of energy resources and related costs is based on the optimization algorithms of the system, system size, system numbers, and its robustness. Although the initial cost for implementation of MPC could be high because of the requirements of skilled staff, specialized software, and hardware systems, it has long-term benefits in cost-cutting and energy efficiency. As depicted by Tang et al., (2020), MPC systems can be significantly installed within the hybrid EVs with a super capacitor and battery solving the energy management issues through optimizing the battery capacities and its range with nonlinear and time-varying techniques.

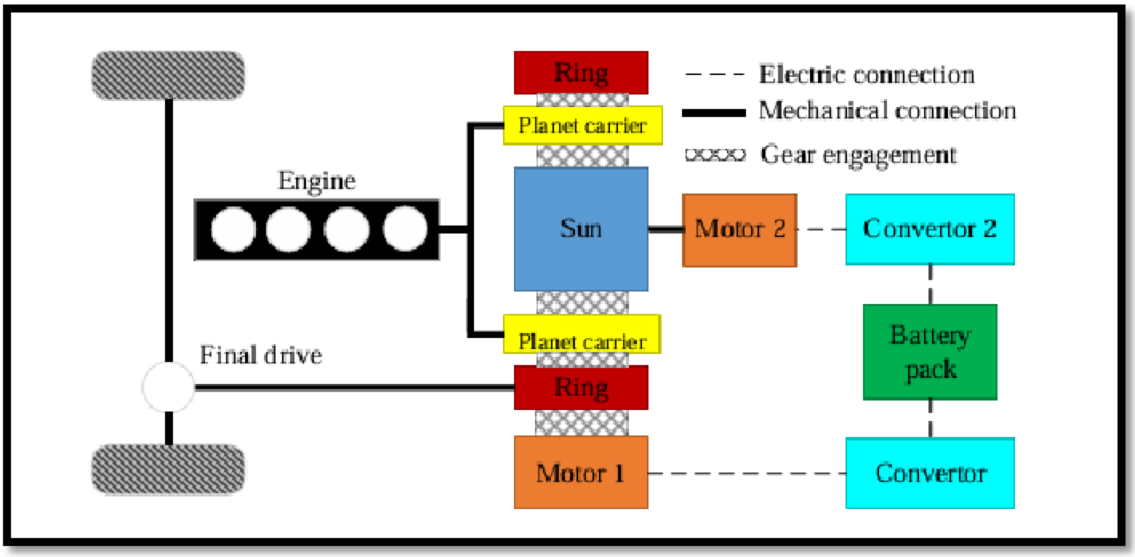

Figure 3: Power efficient framework of the vehicles (Guided by Chen et al., 2020)

5.1.3 MPC strategies are tailored to build an effective energy management system

While implanting this effective control system in EVs, a significant challenge occurs in the computational complexities regarding the optimization system. As per the study of Karamanakos et al., (2020), it leads to the involvement of specialized computational software in the MPC system increasing the costs. Another significant challenge involves the design complexities of an MPC controller to increase its robustness and effectiveness for the system.

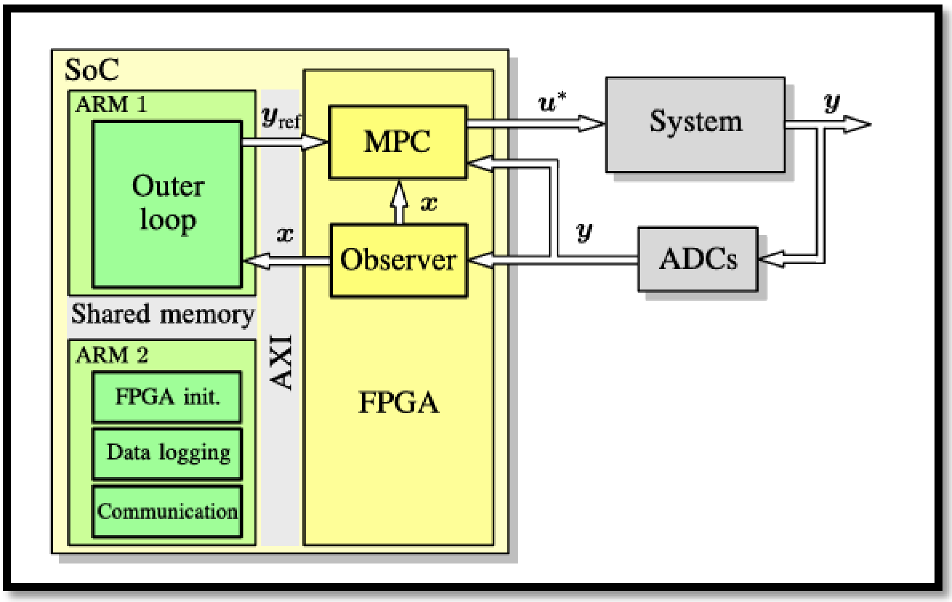

Figure 4: Structure of implementation for direct MPC (Karamanakos et al., 2020)

6. CONCLUSION

In conclusion, the above study, the accelerated MPC system has a profound impact on enhancing the performance of EVs. Although there are significant challenges in the initial investments and implementation process, the long-term impacts of this system could bring effective management to energy resources and environmental sustainability.

7. LIMITATIONS

While studying the topic, the limitation of primary data sources has been faced along with the implications of separating relevant literature which is primarily focused on the development of EVs through the MPC system.

8. FUTURE SCOPE

The findings of this study will effectively contribute to future research about the development of sustainability and energy efficiency through electric mobility. With the evolving landscape of the EV sector, these insights will offer valuable guidance for producing the accelerated MPC for EVs.

9. CONFLICT OF INTEREST: Nil

10. SOURCES OF FUNDING: This research work is not funded by any government organization.

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