Real-time parameter estimation of EMI modelling of AC cables in automotive electric drive systems

Mohammadreza **BAGHERIBAVARYANI**, Niklas **LANGMAACK;** Technische Universität Braunschweig, (Germany), mohammadreza.bagheribavaryani@tu-braunschweig.de, N.Langmaack@tu-braunschweig.de

☒**Young Researcher** (Proved full-time engineering and science university researchers and Ph.D. students under 35 YO)

ABSTRACT

This paper presents a real-time cable model using a Kalman filter-based method to estimate the parasitic elements of an AC cable in an Electric Drive System (EDS) that uses WBG semiconductors. Accurate modelling of cables is crucial for EMI studies, but offline modelling does not reflect the actual high-frequency characteristics of cables under real operating conditions. The proposed method is shown to effectively handle uncertainties in parameter estimation and can be used for condition monitoring and EMI filter design, particularly for mobile applications like electric vehicles where changes in parasitic capacitance can occur while the vehicle is operating.

KEYWORDS

cables, electric vehicles, electric drive systems, electromagnetic interference, Kalman filter, parasitic elements, WBG devices

INTRODUCTION

The use of wide band gap (WBG) semiconductors in mobile applications such as electric vehicles has significantly improved the performance of electric drive systems (EDS) by allowing for higher switching frequencies and downsizing of the inverters. However, the use of such high-frequency devices has introduced new challenges, especially Electromagnetic Interference (EMI) problems, which can lead to malfunction or system shutdown if not properly addressed [1], [2]. Cables in an EDS play a critical role in conducting EMI, making accurate modeling of cables for high-frequency analysis essential when tackling EMI problems in mobile applications [3-5].

The parasitic characteristics of cables, especially in Silicon Carbide (SiC)-based drive systems, are highly sensitive to mechanical and electrical stress, resulting in Unceasing changes in the high-frequency characteristics of the cables, particularly in automotive applications [6], [7]. Thus, offline models of cables created for given electrical and mechanical conditions do not reflect the actual high-frequency characteristics of cables under real operating conditions, leading to significant errors in EMI studies or inevitable over-design in EMI filters, resulting in additional weight and volume in the entire EDS, which in turn, leads to less efficiency of the whole vehicle. Therefore, real-time modeling of the parasitic capacitance of the cables is essential for accurate EMI studies in mobile applications. Hence, it is of high importance to have the value of the parasitic capacitance of the cable in real time.

The estimation of parasitic capacitance in cables has gained significant attention in recent years due to its impact on the performance and reliability of electronic circuits. Several research studies have been conducted to develop accurate and efficient methods for estimating parasitic capacitance. One such method, described in [8], employs a least-square based approach combined with measurement setups to estimate parasitic capacitance offline. While this method is effective, it requires measurements to be taken on an offline basis, which can be time-consuming and limit its practical applicability. To address this limitation, online estimation of parasitic capacitance was first introduced [9]. In this study, the authors proposed the use of the Unscented Kalman Filter (UKF) to estimate the parasitic capacitance in a dc-dc buck converter. This method takes into account the stochastic nature of electromagnetic interference (EMI) in a dc-dc converter, which can be challenging to model accurately. However, it is important to note that the method in [9] considers a simplified equivalent circuit for EMI studies, where all parasitic elements are summed up into a single capacitance. This approach may not be suitable for more complex systems where multiple parasitic elements exist. Additionally, the computational burden of the UKF method can be high, which may limit its practical applicability in real-time applications.

This paper presents a method for estimating the parasitic capacitance of an AC cable in an EDS in real-time using an Extended Kalman filter (EKF) approach. Unlike previous methods, this proposed method considers the various parasitic elements present in the EDS and distinguishes between them to estimate the parasitic capacitance of the AC cable, which has the most significant impact on common mode EMI in the system. The EKF approach used in this study has several advantages, including faster convergence to the true value of the parasitic capacitance and a lower computational burden compared to the Unscented Kalman filter (UKF) method. The proposed model is used to simulate the high-frequency current flow in the AC cable based on measurable quantities in real-time, such as voltage and current in the EDS. The parasitic elements of the derived model are then estimated in real-time using the EKF approach.

The effectiveness of the proposed method is verified through simulations using MATLAB/Simulink software. The proposed method has potential applications in condition monitoring of EMI in EDSs and can be used to record data on parasitic elements in cables over a long period to provide a better overview for EMI filter design and develop more efficient filters.