Doctoral Dissertation Abstract
Doctoral Program in Mechanical Engineering (35th Cycle)

All-wheel drive EVs:
from the modeling and validation to the development of a design tool and advanced control strategies

By

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Abstract

The electrification is a consolidated reality in the automotive industry, following technological advancements and pushed by always stricter emission regulations. The use of electric powertrains faces innumerous challenges but brings some interesting research opportunities. One interesting possibility is the use of **multiple independently controlled electric motors** to create a full electric drive. The addition of new degrees of freedom fosters the application of advanced control methods, to improve handling and energy efficiency.

Exploring this possibility is not new to the literature, in the past couple of decades several articles present classic control theory proposals based on Torque Vectoring, Direct Yaw Control and vehicle stability concepts. At the front of the state-of-the-art novel kinds of controllers, based on **Machine Learning** strategies, start to gain momentum in the literature, but its application to vehicle dynamics handling behavior is still timid. Additionally, the combination of lateral dynamics' controllers with detailed E-PWT description (including **electro-mechanical and thermal** features) is also a relevant gap.

With that in mind, this thesis contribution is focused on the modeling, validation, and implementation of advanced control systems to EVs. The research, done in the context of an **Industrial PhD program**, has a twofold objective: being at the edge of the scientific state-of-the-art, while generating outcomes that can be useful to the industry in a shorter timeframe.

There are three main parts composing the thesis:

The first where the **modeling** strategies are discussed, including lateral dynamics, longitudinal dynamics, electric machine modeling, battery modeling and thermal modeling of the main components of the E-PWT.

The second, where the "**PerfECT Design Tool**" is introduced and developed. This multi-step tool is created as a simulation platform able to support the first phases of design of new EVs (useful for the industry) and serve as basis for advanced control algorithms implementation (of scientific interest). The PerfECT Design Tool is validated through an **experimental campaign with track tests of a Tesla Model 3** and then it is used to design a novel version of the Model 3 with a E-PWT composed of **4 In-wheel motors**.

The third and last chapter explores the vehicle dynamics controllers, implementing and virtually testing the performance of a series of **classic control** algorithms (PID, SMC, LQR) and proposing a **Machine Learning based controller**, applied as base for the **Torque Vectoring** and for the **Torque Allocation** tasks.

The thesis achieves its goal by creating a useful and validated tool that can be readily employed in Industry setting endeavors related to EV design and simulation, while expanding the state-of-the-art with important steps towards advanced ML-based controllers supported by detailed E-PWT and vehicle dynamics modeling.