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Energy Procedia 104 (2016) 538 – 543

Energy Procedia

CUE2016-Applied Energy Symposium and Forum 2016: Low carbon cities & urban energy systems

Distributed Drive Electric Vehicle State Estimation based on Extended Kalman Filter

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Abstract

This paper researched an estimation method based on Extended Kalman Filter (EKF) for distributed drive electric vehicle states. A 7 DOF closed-loop vehicle simulation platform including driver model of preview follower method and 'Magic formula' tire model was established. A general 2-input – 1-output and 3 states estimation system was established, considering the white Gauss measurement noise. The estimation algorithm was applied to a four-motor-driven vehicle during a double-lane-change process. The results showed that EKF estimator could effectively estimate the states of distributed drive electric vehicle with varying speed under simulative experimental condition.

Peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, CUE2016: Low carbon cities and urban energy systems.
Key words: state estimation；distributed drive electric vehicle；Extended Kalman Filter

1. Introduction

The vehicle state estimation is crucial for vehicle active safety control technology as stability control system intervene vehicle according to the vehicle state. In reference [1], EKF and UKF have been applied to estimate the yaw rate and sideslip angle. However, the change of longitudinal velocity has been neglected. Reference [2] has introduced a wide variety of methods to estimate vehicle state. Reference [3] has researched an estimation method based on the Minimum Model Error (MME) and criterion combing with the EKF for 4WD vehicle states.

The longitudinal dynamics control of the vehicle depends on the accurate estimation of the longitudinal velocity and the lateral dynamics control depends on the sideslip angle and yaw velocity. These state variables can be directly measured by sensors but a few key parameters of vehicle state cannot be measured by sensors accurately and directly under the factors of testing techniques and cost of measurement and so on. So it is necessary to use vehicle state estimation to accurately calculate the requi-

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Peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, CUE2016: Low carbon cities and urban energy systems.
doi:10.1016/j.egypro.2016.12.091

red but unmeasurable state parameters. Currently, distributed drive electric vehicle is rapidly developed， so it is crucial to research state estimation method for this kind of vehicle.

2. The modeling of the 4WD electric vehicle

2.1. 'Magic tire Formula' model

The tire force calculation is significant for vehicle dynamics model. The tire force can be calculated by certain tire models like 'Magic Tire Formula 'and ' Dugoff tire model' etc.[4].In this paper we use 'Magic Tire Formula' to calculate the tire forces. The general expression of the model is given as follows:

$$\begin{cases} Y(x) = D\sin\left\{C\arctan\left[Bx - E\left(Bx - \arctan Bx\right)\right]\right\} + S_v \\ x = X + S_h \end{cases} \tag{1}$$

$$\begin{cases} F_x = \dfrac{\sigma_x}{\sigma}F_{x0},\ F_y = \dfrac{\sigma_y}{\sigma}F_{y0} \\ \sigma_x = \left|\dfrac{\lambda}{\lambda+1}\right|,\ \sigma_y = \left|\dfrac{\tan\alpha}{\lambda+1}\right|,\ \sigma = \sqrt{\sigma_x^{\ 2} + \sigma_y^{\ 2}} \end{cases} \tag{2}$$

where Y represents the tire forces to be calculated; X is the overall independent variables considering the camber angle, the vertical load and the slip ratio or slip angles. B , C , D , E , S_v , S_h are the stiffness, shape, peak, curvature, vertical drift and horizontal drift factors respectively. Eq. (2) is used to calculate the tire forces at combined (longitudinal and lateral) slip conditions.

When vehicle drives on a curve， the tire has both the longitudinal and lateral sideslip[5].Under this condition, the relationships between the longitudinal force, lateral force and the slip ratio are shown in Fig.1(a) and (b) respectively.

2.2. Driver model

In the vehicle simulation system, a driver model was designed to follow the desired trajectory and speed by adjusting the steering angle, driving or braking pedals. The driver model includes two parts: a PI speed tracker and a trajectory tracker which is based on the 'Preview-follower Theory' developed by K.Guo[6]. Fig.2(a) and (b) show a typical curve of driving pedal angle and steering wheel angle during the double-lane-change process.

3. The modeling of the vehicle state estimation system based on EKF

3.1. The 2-input－1-output and 3 states estimation system

Due to limited available model parameters and calculation burden restriction for real time application, after a series of assumptions and simplifications, a 3DOF vehicle body model including the longitudinal displacement, the lateral displacement and the yaw angle displacement is used for the distributed drive electric vehicle state estimator.

(1)Input vector