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Research on motor rotational speed measurement in regenerative braking system of electric vehicle

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ABSTRACT

Rotational speed signals acquisition and processing techniques are widely used in rotational machinery. In order to realized precise and real-time control of motor drive and regenerative braking process, rotational speed measurement techniques are needed in electric vehicles. Obtaining accurate motor rotational speed signal will contribute to the regenerative braking force control steadily and realized higher energy recovery rate. This paper aims to develop a method that provides instantaneous speed information in the form of motor rotation. It addresses principles of motor rotational speed measurement in the regenerative braking systems of electric vehicle firstly. The paper then presents ideal and actual Hall position sensor signals characteristics, the relation between the motor rotational speed and the Hall position sensor signals is revealed. Finally, Hall position sensor signals conditioning and processing circuit and program for motor rotational speed measurement have been carried out based on measurement error analysis.

1. Introductions

Due to the limited capacity of electric vehicle energy storage system, the driving range of the pure electric vehicle is limited, thus the widespread use of electric vehicle is under constraint. If the kinetic energy of electric vehicle can be transformed into electrical energy by the regenerative braking system and recovered into the storage system during vehicle braking process, the energy efficiency of the electric vehicle will be improved, and the driving range of the electric vehicle will be extended. Previous studies show that the energy efficiency of electric vehicle can be enhanced about 8–25% by the regenerative braking system [1]. During the regenerative braking process, effective measures are utilized to realize the energy recovery, the vehicle longitudinal dynamics stability is also needed to maintain. In vehicle dynamic control research, rotational speed, sideslip angle as well as other dynamic parameters can be estimated by indirect methods or directly measured by sensors. Many current research works in state estimation have made great progress, various methods were utilized to estimate the state of control system and the dynamics response of vehicle, mode-dependent estimator is used in the nonlinear systems [2,3], uncertain linear-parameter-varying (LPV) system model were established to estimate the sideslip angle of four wheel independent drive electric vehicle. In the vehicle lateral dynamic control, the longitudinal velocity is not constant but varying within a range, as the longitudinal velocity is corresponding to the rotational speed of

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the motor, the rotational speed is the key input parameter of the electric vehicle motor control system, thus it is very important to measure the rotational speed accurately [4]. During the braking process the braking torque and the vehicle speed need to be controlled in real time and accurately, the regenerative braking system control unit of electric vehicle is also required to obtain the accurate motor rotational speed signal [5].

Rotational speed sensor usually output signal in analog mode, analog signal is conditioned by circuit and suitable for measurement applications, it can be programmed to match the design specifications of a measurement system and adapt it to be used with a class of sensors with different output signal characteristics [6]. Based on the mechanism of data acquisition, the measurement of rotational speed can be categorized into two groups: timer/counter-based methods and ADC-based methods [7]. Timer/counter-based methods are conceptually either measuring the elapsed time between successive pulses or counting pulses during the prescribed time. ADC-based methods treat angular speed signals as ordinary analog signals. Multiple channels of speed signal can be measured simultaneously using a multi-channel ADC board, the ADC converts the analog speed signal into digital data during the measurement process. The digital data are recorded at a fixed sampling rate, so they record the time and amplitude information about the speed signal [8, 9]. Analog signal conditioning was primarily used in motor rotational speed measurement, and was applied to rotational speed measurement of generators. The digital tachometer system based on micro-controller has been widely used in the motor control system for its advantages of processing capability, low cost and high reliability.

In contrast to previously published works, this paper investigates methods for the measurement of three-phase instantaneous rotational speed of motor in electric vehicles. The methods require no specialized device but make maximum use of general data acquisition systems and computer resources. Therefore, this paper focuses on general signal conditioning circuit based method and a programming method. These two techniques aim at providing good measurement accuracy over a wide instantaneous rotational speed range so that they can be applied to regenerative braking process control of electric vehicles and other applications. The next section provides a description on principles of motor rotational speed measurement in the regenerative braking systems of electric vehicle. The paper then presents ideal and actual Hall position sensor signals characteristics, the relation between the motor rotational speed and the Hall position sensor signals was revealed. Consequently, Section 3 describes Hall position sensor signals conditioning and processing circuit, based on analysis of measurement error, program for motor rotational speed measurement was carried out. The paper concludes in Section 4 that, based on the analysis, the proposed methods can be applied to regenerative braking control of electric vehicle and other applications that require instantaneous rotational speed measurement with wide range and multiple channels.

2. Principles of motor rotational speed measurement

2.1. Structural and principle of regenerative braking system

Structure and principle of regenerative braking control system is shown in Fig. 1. Regenerative braking control unit acted as the central controller in the control system, it is relatively independent from the motor control unit, and these two control units work in mutual coordination states. Functions implemented by regenerative braking control system include

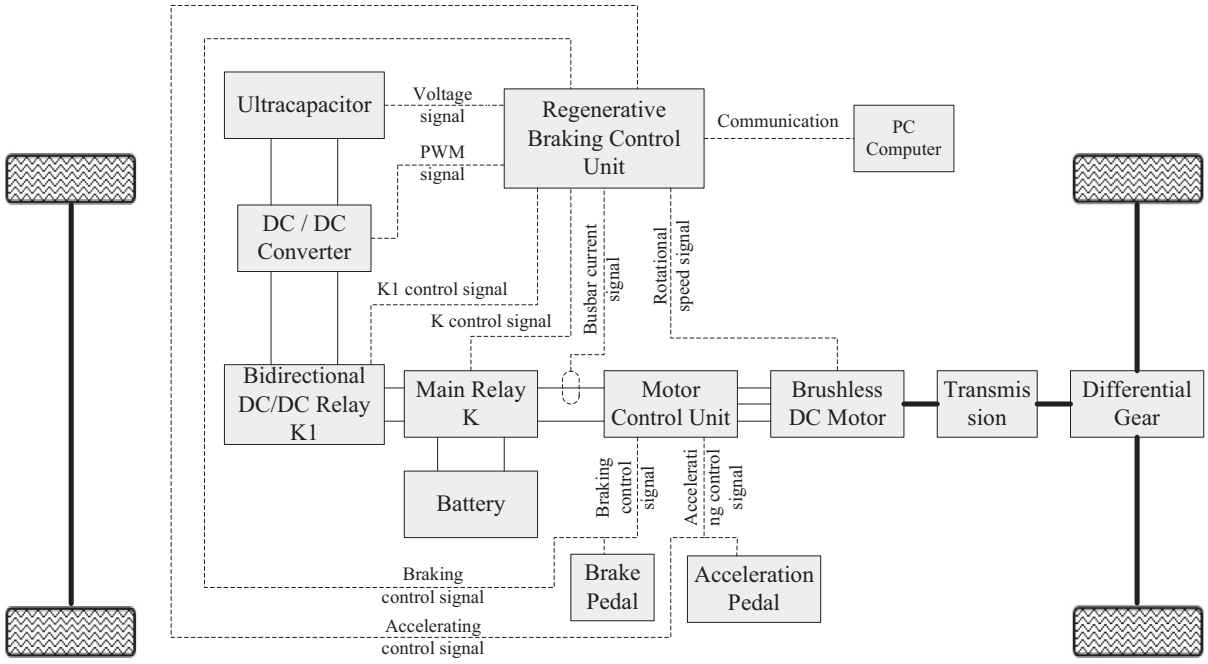

Fig. 1. Structure diagram of regenerative braking control system.