Design of a State-Predictive and Robust Control of Energy Storage Units for Smart Power Grids

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1.Introduction

Battery management systems are ubiquitous in the industrial world today, along with the need for an accurate measurement of the internal characteristics of batteries. Various techniques are used to remove the process and observation noises from the internal sensor, and a widely used filter is the Kalman filter. In this paper, we investigate how two versions of the Kalman filter (KF) estimate the state of charge of Lithium-Ion batteries.

3.Prediction Algorithms

Extended KF

The Extended Kalman Filter is an industry standard for nonlinear state estimations, that handles a system's Gaussian noises by using Jacobian matrices to do linear approximation of the system. With each measurement and error feedback, the EKF corrects its gain matrix and update the error, giving a new prediction the next time that may be better than the last.

Unscented KF

The Unscented Kalman Filter is proposed to be an improvement over the EKF, using probability density with weighted sigma points approximated by the sampling of data. This in turn represents how Gaussian noises affects the data sample. The update cycle would then affect the sigma points for better future prediction.

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2.System model

The example battery model (Figure 1) utilizes a waveform generator to produce an input signal. A measurement function is used to capture the voltage of the battery. A state function monitors the measured current, temperature and capacity. The two Kalman Filter prediction algorithms predict SoC. To simulate the battery system, we utilize two MATLAB-Simulink systems to generate the input charge and output voltages and SoC.

4.Results

The storage battery system illustrates the difference between UKF and EKF most clearly, as in all three test sequences the UKF achieved closer results to the actual SoC. The filters perform best when the battery is in the state of driving. The result is displayed in Figure 2. The degrading battery system produces excellent estimation of SoC using EKF and UKF. The difference between real and estimated SoC is less than 1%, which is a success. The result is shown in Figure 3.

5.Discussion

Our investigation shows that UKF has high potential for estimating SoC in battery management systems, and EKF only lacks behind the former a small amount. The implementation of Kalman filters in energy storage units for power grids have great prospective for engineering and control of the system. Further studies of SoC estimation with prediction algorithms in batteries may include more dimensional measurements to consider the performances of the filters in more complex simulations.

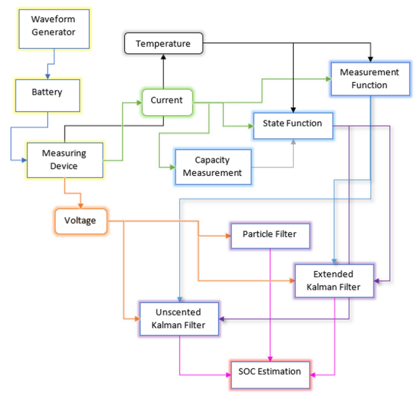

Figure 1 System model

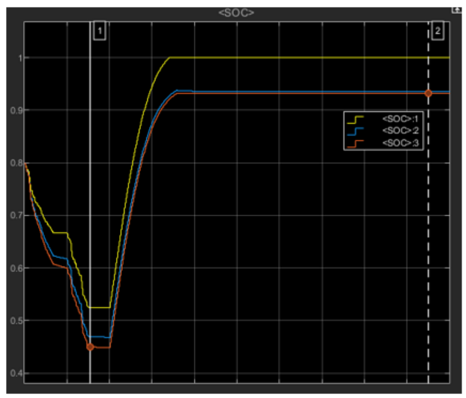

Figure 2 Storage Battery SOC (1-Actual, 2-UKF, 3-EKF)

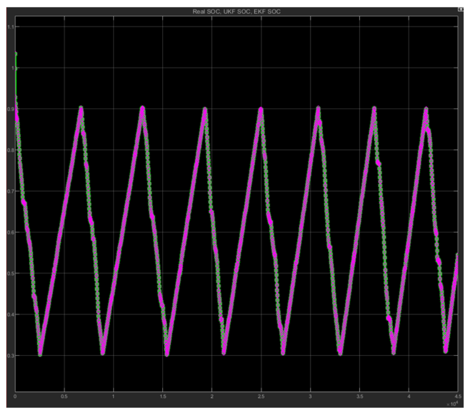

Figure 3 Degrading Battery SOC (Green-UKF, Magenta-EKF)