In the scenario of trailing actuator fail-hard, the generated residuals for the leading actuator are almost similar to the normal condition, while the faulty actuator for the trailing wheelset generated higher residuals compared to the normal condition.

In order to extract features for fault detection and isolation, the root mean square or standard deviation of the residuals can be considered, but in this study the latter is preferred as per the fail-hard mode, as an actuator may lock-up at different positions rather than just at the zero position.

A. Fail-soft detection and isolation

The actuator in the event of fail-soft can lead to system instability, and therefore the residuals generated by the observer in either Strategy 1 or Strategy 2 will be expected to show an oscillation—or a limit cycle if the non-linearity of the wheel-rail profiles is considered. Figures 14, 15, 16 and 17 compare the generated residuals of the both actuators when Strategy 1 is used for developing the KF. It shows the generated residuals of motor rotational speed and motor current between the normal condition, and when the leading actuator fails in soft mode at the time of zero. They clearly show that the generated residuals' signals of the leading actuator significantly increased, as the faulty actuator is not able to deliver any torque to the wheelset. Although the generated residuals of the trailing actuator which functions properly increase, the gain is slow and an abnormal change in actuator can be identified within less than 500 (m.sec); therefore, it is necessary to enable the controller to be re-scheduled to cope with the identified fault. Similar results can be gained when the trailing actuator fails soft. It seems that the use of residuals is sufficient to detect the actuator fail-soft and to identify whether the fail-soft occurs at either the front or rear actuators.

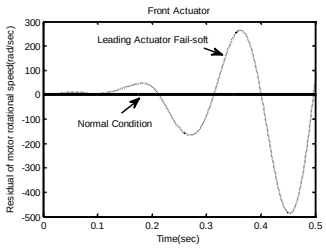

Figure 14:Residuals from motor rotational velocity – leading actuator

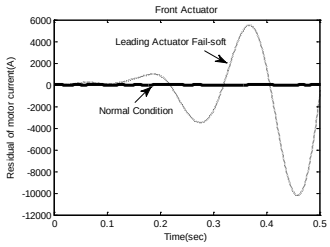

Figure 15: Residuals from motor current – leading actuator

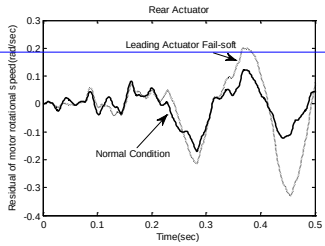

Figure 16: Residuals from motor rotational velocity – trailing actuator

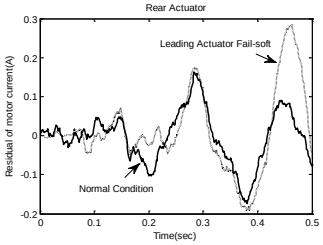

Figure 17: Residuals from motor current – trailing actuator

If the KF is developed through Strategy 2, where the actuator is equipped with three sensors, the fault detection and isolation of the actuator with soft failure can be achieved through the residuals' evaluation. Figures 18, 19, 20, 21, 22 and 23 compare the generated residuals for both the actuators between normal condition, and when the leading actuator fails soft at the time of zero. They clearly show the level of the residuals is significantly magnified for the leading actuator as it fails in soft mode. In the scenario of trailing actuator fail-soft, the generated residuals of the trailing actuator are significantly increased compared to the normal condition. In order to detect the actuator in the hard failure from the soft failure when Strategy 2 is used, the generated residual from the motor rotational velocity can be considered due to the fact that the magnitude of those generated residuals does not exceed 4(rad.sec^{-1}) in the fail-hard condition (Figure 8), whereas it will increase significantly in the event of fail-soft (Figure 18).

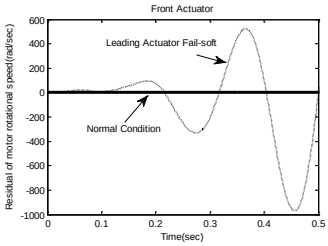

Figure 18: Residuals from motor rotational velocity – leading actuator

Comment [B1]: Change to either:

almost identical
similar

Comment [B2]: Or, as a singular compound adjective:

generated residual signals

Comment [B3]: Meaning unclear. Possible correction:

In order to detect the difference(s) between the actuator in the hard failure and the soft failure when Strategy 2 is used, …