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CONDITION MONITORING OF THE POWERTRAIN

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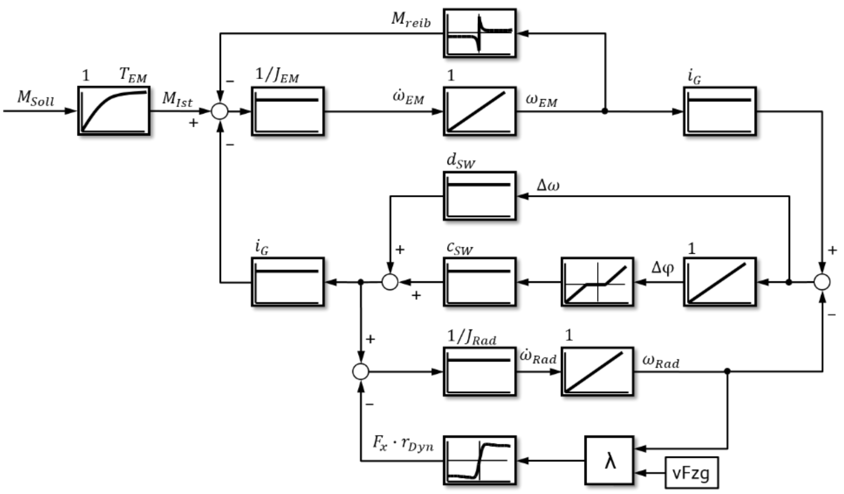
Technical task:
Observer as virtual sensor for the torsion angle.
The friction of the EM and the transmission can be estimated.

Initial Situation:
Torsion angle is rarely determined during development with external measurement technology - not at runtime or in customer operation. Wheel torque is not measured. Motor torque (= air gap torque / internal torque) is measured indirectly via current measurement and then calculated.

Actual torsion is unknown at runtime. Only the air gap torque of the drive is known, but not the torque at the wheel. This is calculated taking into account the losses and transmission ratios. The calculation of the wheel torque from the air gap torque is only correct if there is no change in these conditions.

Solution:
The block diagram of the controlled system "side shaft

Modell Regelstrecke Drehzahlregler



has been simplified to the model description

$$\begin{bmatrix} \dot{\omega}_{Rad} \\ \dot{\omega}_{EM,R} \\ \Delta\omega \end{bmatrix} = \begin{bmatrix} 0 & 0 & \frac{c_{SW}}{J_{Rad}} \\ 0 & 0 & \frac{-c_{SW}}{J_{EM,R}} \\ -1 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \omega_{Rad} \\ \omega_{EM,R} \\ \Delta\varphi \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{J_{EM,R}} \\ 0 \end{bmatrix} \cdot M_{Ist} + \begin{bmatrix} \frac{-1}{J_{Rad}} \\ 0 \\ 0 \end{bmatrix} \cdot F_x \cdot r_{Dyn}$$

$$\begin{bmatrix} \omega_{Rad} \\ \omega_{EM,R} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \omega_{Rad} \\ \omega_{EM,R} \\ \Delta\varphi \end{bmatrix}$$

The neglected effects, such as the friction torque, were compensated by the I-component of the PI-ZR.
The basis for this invention is again the observer for estimating the torsion angle and the disturbance torque.

Beobachter-Modell

Messung

$$\begin{bmatrix} \dot{\omega}_{Rad} \\ \dot{\omega}_{EM,R} \\ \Delta\omega \\ \dot{F}_x \cdot r_{Dyn} \end{bmatrix} = \begin{bmatrix} 0 & 0 & \frac{c_{SW}}{J_{Rad}} & \frac{-1}{J_{Rad}} \\ 0 & 0 & \frac{-c_{SW}}{J_{EM,R}} & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \omega_{Rad} \\ \omega_{EM,R} \\ \Delta\varphi \\ F_x \cdot r_{Dyn} \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{J_{EM,R}} \\ 0 \\ 0 \end{bmatrix} \cdot M_{Ist}$$

Schätzung

$$\begin{bmatrix} \omega_{Rad} \\ \omega_{EM,R} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \omega_{Rad} \\ \omega_{EM,R} \\ \Delta\varphi \\ F_x \cdot r_{Dyn} \end{bmatrix}$$

Störmodell Lastmoment = Sprung
→ konstant über eine Zykluszeit

At constant acceleration, the torsion angle can be estimated from the observer with high accuracy and thus also the shaft torque M_sw. The electric machine speed and the electric machine torque are available as measured values anyway.

The equation derived from the graphic "Model controlled system speed controller

$$\dot{\omega}_{EM} \cdot J_{EM} = M_{Ist} + M_{reib} + M_{SW}$$

can be solved with this information and the friction torque of the drive (EM and gearbox) is known.

Advantages:

- Torsion profiles about customer usage can be obtained using BigData approaches. The design of the components can be optimized on the basis of utilization cycles.
- The knowledge about friction can be used for safety functions by ensuring that the torque of the electric machine reaches the wheel in a known manner.
- It can be used for service and maintenance: if increased friction in EM or transmission is detected, the driver can be informed and visit a workshop before the transmission locks up in the worst case.