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Performance Improvement of AC Adjustable Speed Drives During Voltage Sag Events

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1. Introduction

In the field of high-performance electric drives, especially in applications with tracking accuracy requirements for position, speed or torque regulation, numerous problems were detected caused by the deviation of the continuous, sinusoidal supply voltages.

Solutions based on additional devices for supply voltage conditioning or hardware modifications of industrial devices are unacceptable for most users due to price reasons.

2. Sensitivity of Vector Controlled ASDs

Disturbances caused by voltage sags in the case of a passive diode bridge lead to a reduction of the mean DC voltage and/or increase of DC voltage ripple. Main consequences are: reduction of the available motor torque, torque ripple, vibration and the speed deviation from the set point.

Rotor Field Oriented (RFO) control

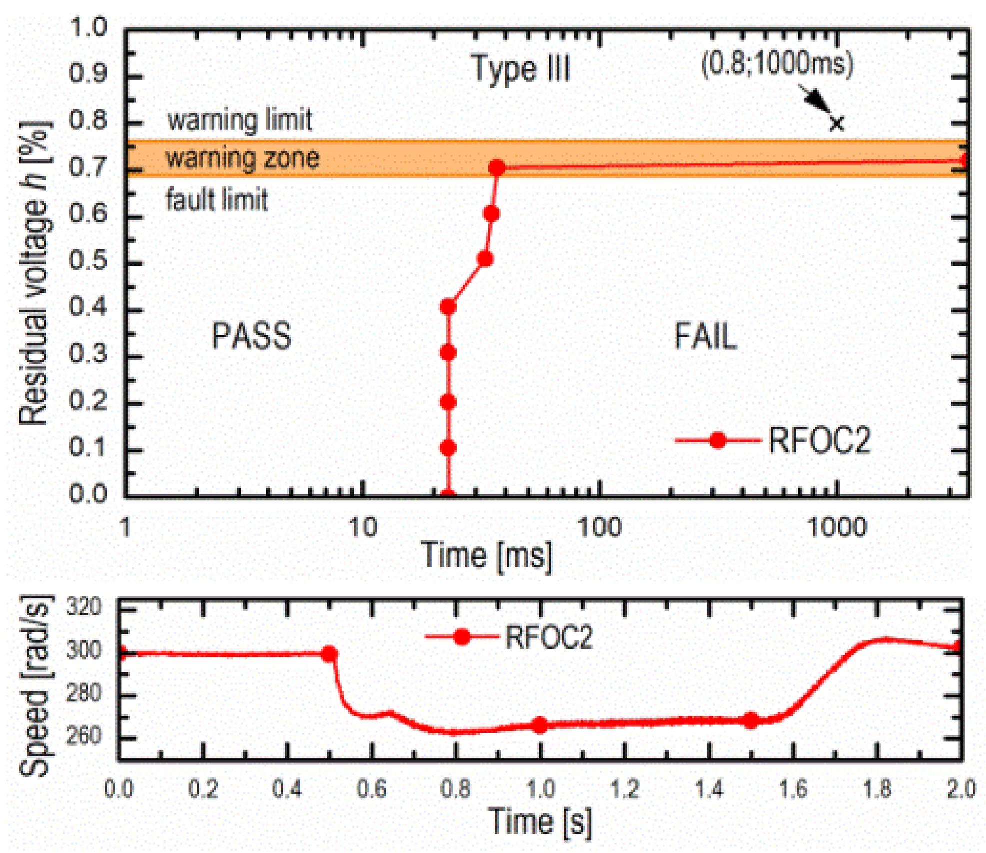


Fig. 3. Voltage tolerance curves for industrial 1.5kW ASDs (marked as RFOC2 [14]) for voltage sag type III (top); Speed response under voltage sag with $h = 0.8$ and $\Delta t = 1000$ ms (bottom).

Direct Torque Control (DTC)

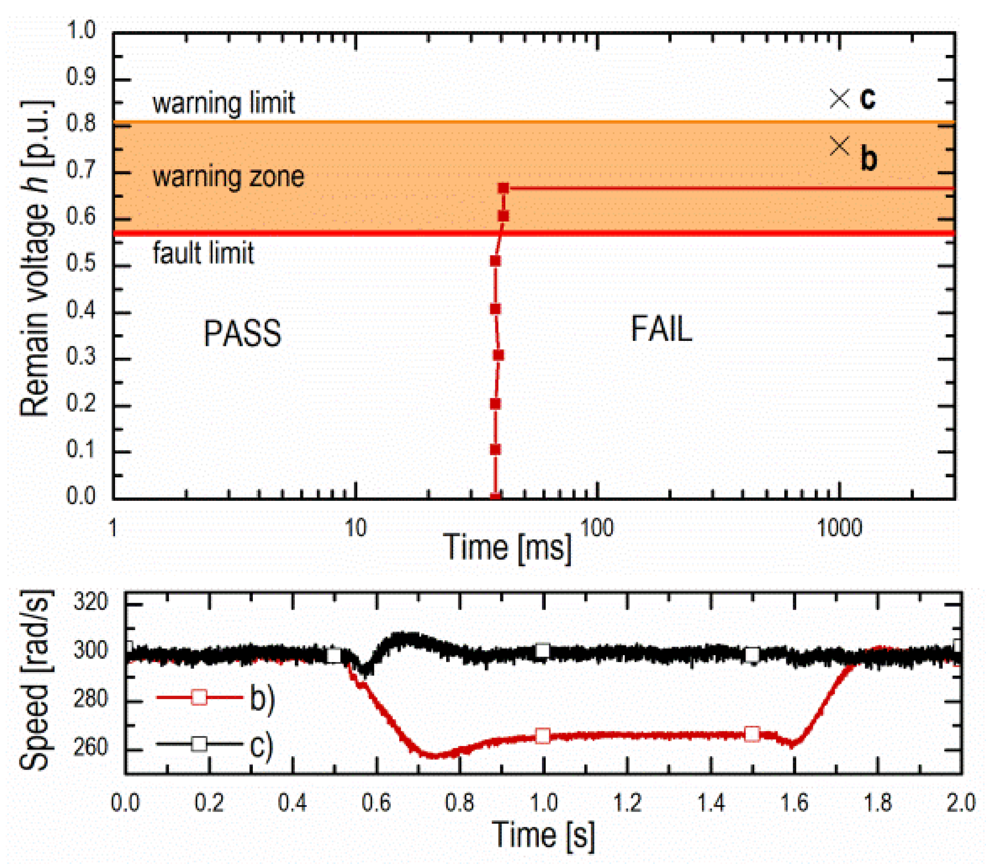


Figure 5. Voltage tolerance curves for industrial 1.5kW DTC drive ([16]) for voltage sag type III (top); Speed response under voltage sag with $h = 0.75$ and $h = 0.86$ and $\Delta t = 1000$ ms (bottom).

3. ASDs Drop in Speed and Torque Reduction

The voltage limit

$$u_{qs}^2 + u_{ds}^2 \le V_{\max}^2,$$

The current limit

$$i_{qs}^2 + i_{ds}^2 \le I_{\max}^2,$$

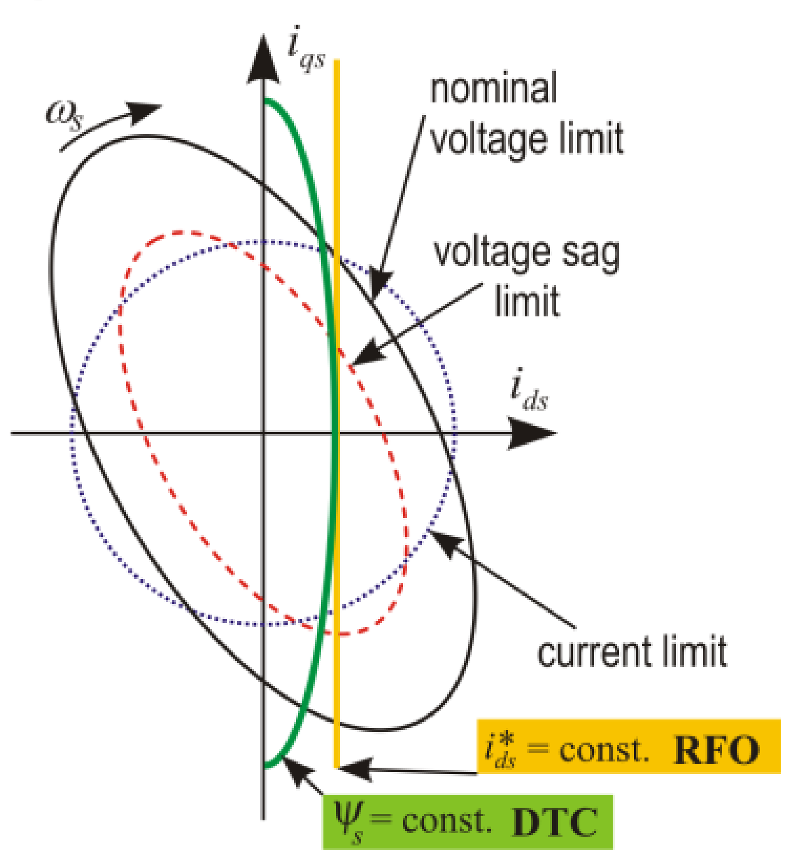
Rotor Field Oriented (RFO) control:

$$\psi_{dr} = \psi_r \Rightarrow i_{ds} = \text{const.}$$

Direct Torque Control (DTC):

constant stator flux (ψ_s) is with:

$$i_{ds} = \sqrt{(\psi_s^*)^2 - \sigma^2 \cdot L_s^2 \cdot i_{qs}^2 / L_s}$$



4. Flux Weakening Algorithm

IM vector control allows to adjust the flux values inside the appropriate limits, regardless of the motor load and speed. Maximizing torque per ampere, for the examples of the voltage sag type III, **torque-speed curves** are constructed with different reference flux values.

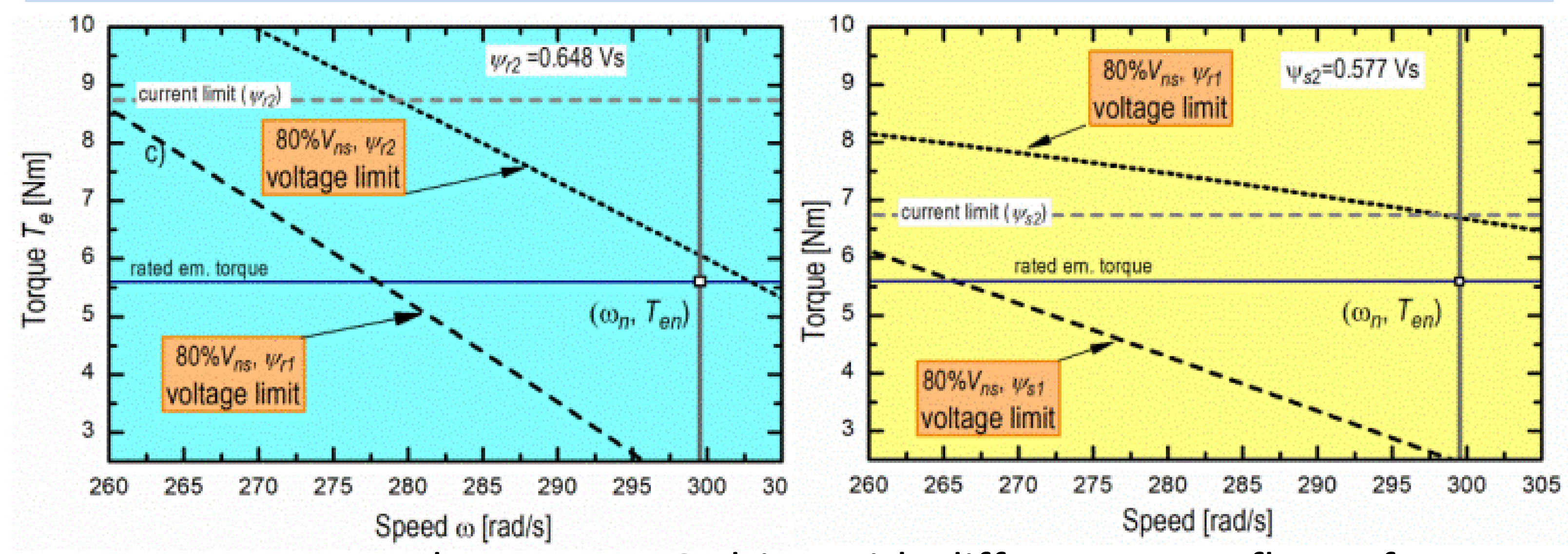


Fig. 8. Torque-speed curves: RFO drive with different rotor flux references and under reduced ($h = 0.8$) supply voltage (left); DTC drive with different stator flux references and under reduced (h=0.75) supply voltage (right).

6. Experimental Results

This ASD laboratory prototype with 1.5kW IM supplied with an industrial converter, dSpace control system and constant load emulator. The experiments are examined the operation of RFO and DTC drive under type III voltage sag

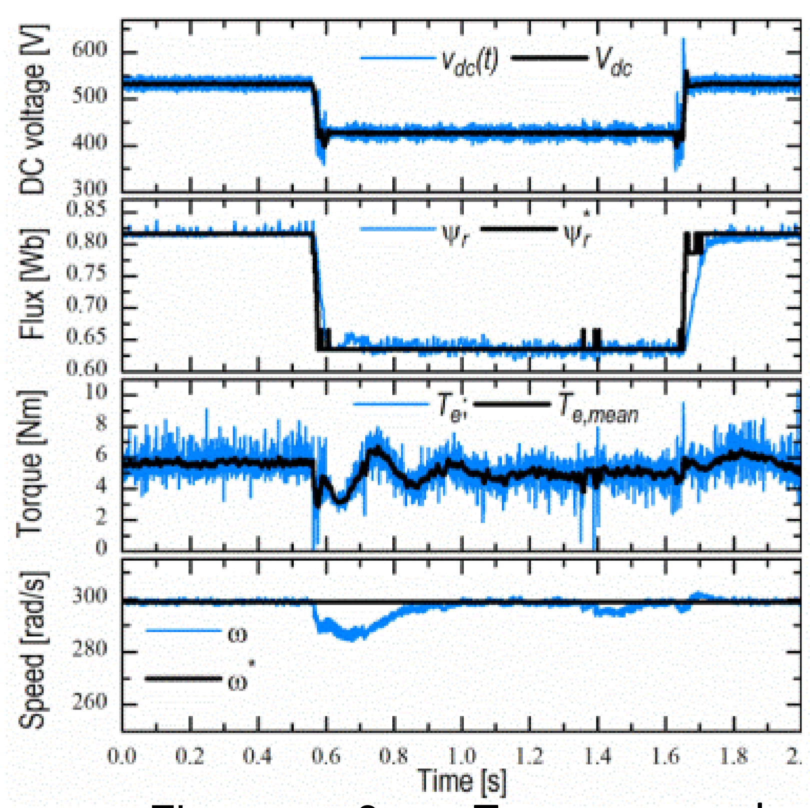


Figure 9. Torque-speed curves of DTC drive with different stator reference fluxes and under reduced ($h = 0.75$) supply voltage.

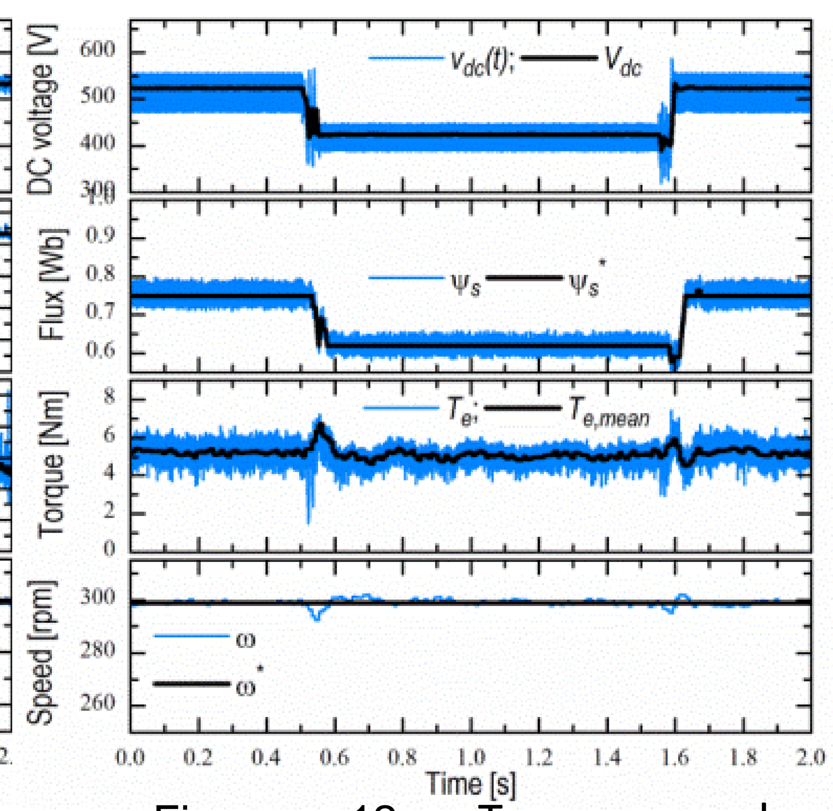


Figure 12. Torque-speed curves of DTC drive with different stator reference fluxes and under reduced ($h = 0.75$) supply voltage.

6. Conclusion

Main contributions of this work:

- Flux weakening during voltage supply reduction have great potential in minimizing speed drop through increasing available torque under voltage limitation;
- Simple for implementation - do not require intensive calculations and can be implemented simultaneously with the control parameters identification;
- Suitable for upgrade of the existing vector controlled drives – no hardware modification.
- Field weakening is particularly effective in DTC drives and therefore the speed deviation is minimal.

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