Voltage feedforward

Translation of the "Original Dokumentation"

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Change	**Letter symbol**
• New Document	STL

Previous version: -/-

Product version:

Product (AMK part no.)	Firmware Version (AMK part no.)
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KW-R24 (O901)	AE-R24 V2.03 2015/06 (205587)
KW-R24-R (O954)	AE-R24-R V2.11 2016/46 (206643)
KW-R25 (O902)	AE-R25 V2.03 2015/06 (205588)
KW-R26 (O903)	AE-R26 V2.03 2015/06 (205589)
iX / iC / iDT5 /	iX V1.03 2013/18 (204515)
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1 Voltage feedforward

Supported hardware:	KW-R06 / KW-R16 / KW-R07 / KW-R17 / KW-R24 / KW-R24-R / KW-R25 / KW-R26 / iX / iC / iDT5 / iX(-R3) / iC(-R3) / iDT5(-R3) / ihXT /

By means of voltage feedforward, the correlations between currents and voltages of a permanent magnet excited synchronous motor can be presented in a d/q coordinate system.

The current controller generates the voltages u_d and u_q which force the currents i_d and i_q.
If the phase resistance, the direct and quadrature axis inductances and the magnetic flux, are known, the voltages can be fed forward. Thus, the current controller is relieved and the controller dynamics increases.

The currents and voltages of a permanent magnet excited synchronous motor in a field-orientated d/q coordinate system are correlated according to the following equations:

$$u_d = R_s \times i_d - \omega \times L_q \times i_q + L_d \times \frac{di_d}{dt}$$

$$u_q = R_s \times i_q + \omega \times L_d \times i_d + L_q \times \frac{di_q}{dt} + \Psi \times \omega$$

The following assumptions are taken into account:

- The differential parts $L_d \times \frac{di_d}{dt}$ and $L_q \times \frac{di_q}{dt}$ are ignored.
- The angular speed ω meets the actual speed value n_{act}.
- The currents i_d and i_q are replaced with the setpoint values $i_{d,set}$ und $i_{q,set}$.
- The magnetic flux Ψ meets the voltage constant K_e.

This results in the following simplified calculation of the feedforward voltages:

$u_{d,fwd} \approx R_s \times i_{d,set} - n_{act} \times L_q \times i_{q,set}$

$u_{q,fwd} \approx R_s \times i_{q,set} + n_{act} \times L_d \times i_{d,set} + K_e \times n_{act}$

2 Parametrization

Relevant parameters

Parameter	Name	Meaning See document 'Parameter description' (AMK part no. 203704)
ID32773 [1)]	'Service bits'	Bit 26: activate voltage feedforward See 'ID32773 'Service bits' bit 26' on page 7.
ID34045 [1)]	'Inductance path D'	Direct axis inductance L_d (see motor data sheet)
ID34046 [1)]	'Inductance path Q'	Quadrature axis inductance L_q (see motor data sheet)
ID34233 [1)]	'Phase resistance'	Phase resistance R_s of the motor winding [2)]
ID34234 [1)]	'Voltage constant Ke'	Voltage constant K_e, corresponds to magnetic flux (see motor data sheet)

1) The parameter value must be set specific to the application

2) The phase resistance R_s can be calculated from the terminal resistance R_{tt} of the Motor (ID34164 'Terminal resistance', see motor data sheet):

Motor winding in star connection: $R_s = 0,5 \times R_{tt}$
Motor winding in delta connection: $R_s = 1,5 \times R_{tt}$

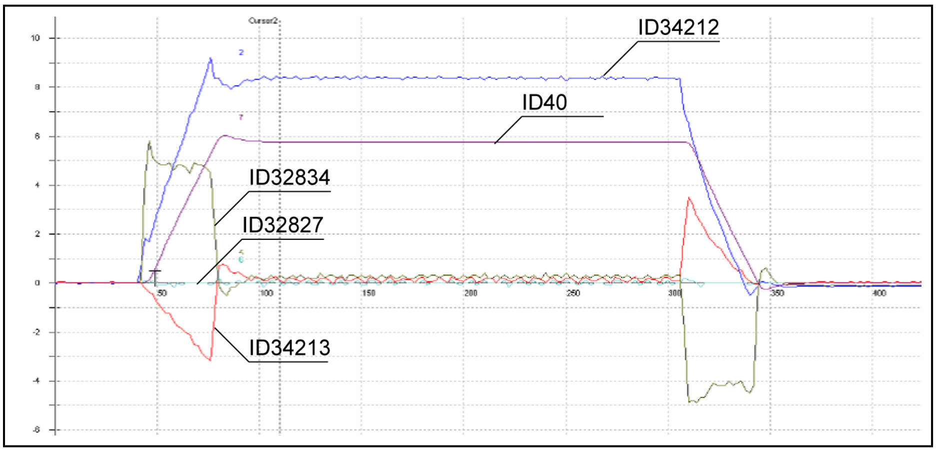
3 Startup instructions

The feedforward voltages ID34231 'Feed forward control voltage path Q' and ID34232 'Feed forward control voltage path D' shall be adjusted to the voltages of the path d (ID34213 'Voltage path D') resp. the path q (ID34212 'Voltage path Q').

Record the following parameters by means of the AIPEX PRO oscilloscope function.
(The following oscillograms are generated with a laboratory model.)

Parameter ID	Parameter name	Formula symbol	Colour in the following oscillograms
ID40	'Velocity feedback value'	n_{act}	purple
ID32827	'Magnetising current feedback'	$\approx i_{d,set}$	light blue
ID32834	'Torque current feedback'	$\approx i_{q,set}$	grey
ID34212	'Voltage path Q'	u_q	blue
ID34213	'Voltage path D'	u_d	red
ID34231	'Feed forward control voltage path Q'	$u_{q,fwd}$	magenta
ID34232	'Feed forward control voltage path D'	$u_{d,fwd}$	light green

Initial situation:

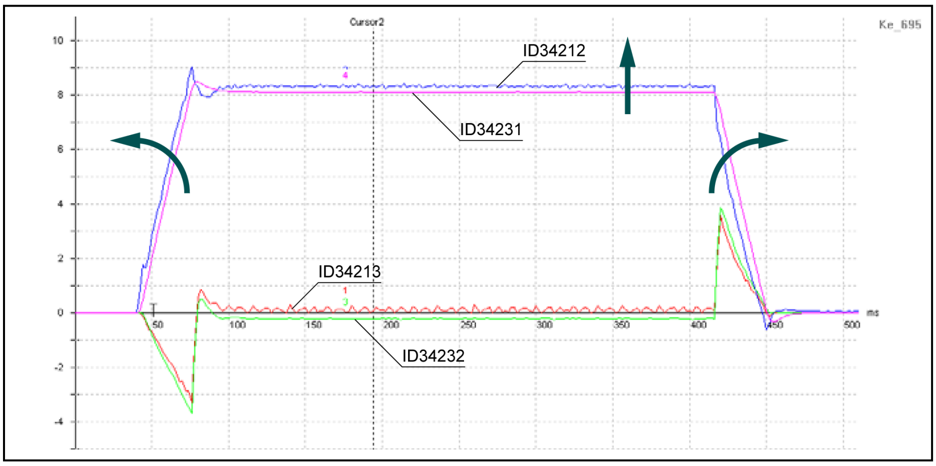


Optimising the feedforward

If the parameters ID34045 'Inductance path D', ID34046 'Inductance path Q', ID34233 'Phase resistance' resp. ID34164 'Terminal resistance' and ID34234 'Voltage constant Ke', are known from the motor data sheet, you can start with these values.

If the values are unknown, start with 0 for ID34045 'Inductance path D', ID34046 'Inductance path Q' and ID34233 'Phase resistance' and with ID34234 'Voltage constant Ke' = 1 V/1000min^{-1}

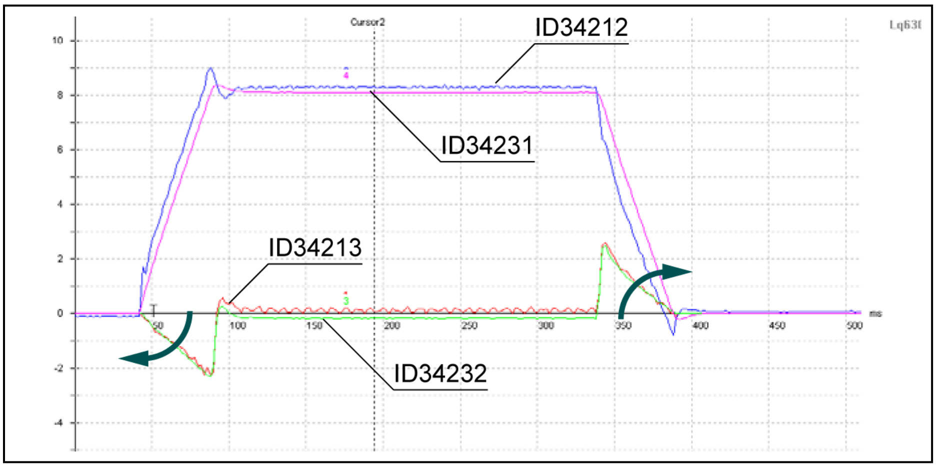
1. ID34234 'Voltage constant Ke'



$$u_{q,fwd} \approx R_s \times i_{q,set} + n_{act} \times L_d \times i_{d,set} + \mathbf{K_e \times n_{act}}$$

($u_{q,fwd}$ ~ K_e x n_{act} => By modifying the voltage constant K_e, the curve of ID34231 'Feed forward control voltage path Q' is moved vertically in the range of constant speed and the flanks are slanted.)

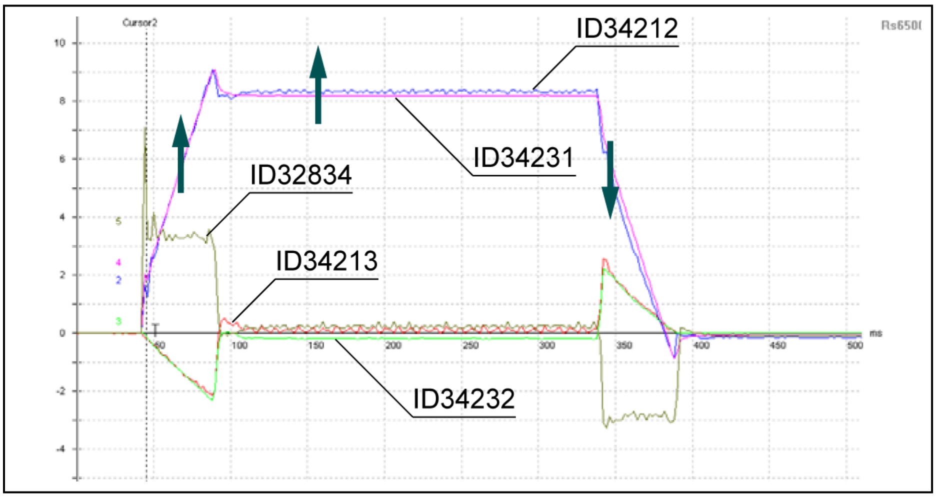
2. ID34046 'Inductance path Q'



$$u_{d,fwd} \approx R_s \times i_{d,set} - \mathbf{n_{act} \times L_q \times i_{q,set}}$$

($u_{d,fwd}$ ~ -L_q x n_{act} x $i_{q,set}$ => By means of the quadrature inductance L_q, the flanks of the curve of ID34232 'Feed forward control voltage path D' are slanted.)

3. ID34233 'Phase resistance'



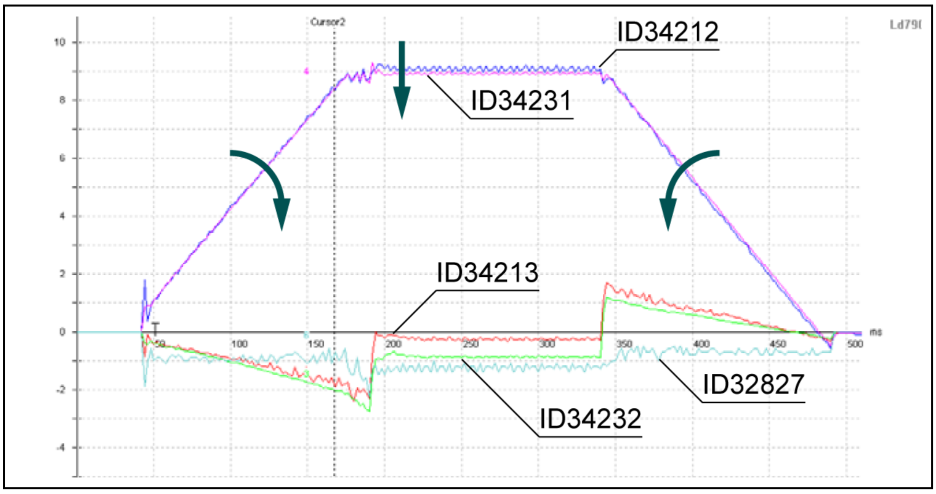
$$u_{d,fwd} \approx \mathbf{R_s \times i_{d,set}} - n_{act} \times L_q \times i_{q,set}$$

$$u_{q,fwd} \approx \mathbf{R_s \times i_{q,set}} + n_{act} \times L_d \times i_{d,set} + K_e \times n_{act}$$

($u_{q,fwd}$ ~ R_s x $i_{q,set}$; $u_{d,fwd}$ ~ R_s x $i_{d,set}$ => By means of the phase resistance R_s, the curves of ID34231 'Feed forward control voltage path Q' and ID34232 'Feed forward control voltage path D' are moved vertically.)

As the resistances of the supply lines, the terminals and the power semiconductors, are added, the determined value can differ from the value of the motor data sheet

4. ID34045 'Inductance path D'



$u_{q,fwd} \approx R_s \times i_{q,set} + \mathbf{n_{act} \times L_d \times i_{d,set}} + K_e \times n_{act}$

($u_{q,fwd} \sim L_d \times n_{act} \times i_{d,set}$ => By means of the direct inductance L_d, the curve of ID34231 'Feed forward control voltage path Q' is moved vertically in the range of constant speed and the flanks are slanted.)

Appendix

ID32773 'Service bits' bit 26

Bit no.	Condition	Meaning
26	0	Voltage feedforward inactive for synchronous machines
	1	Voltage feedforward active for synchronous machines The voltage feedforward in synchronous machines improves the dynamic properties and can be switched on independently of the application. Relevant parameters: (from the motor data sheet) ID34045 'Inductance path D' ID34046 'Inductance path Q' ID34233 'Phase resistance' ID34234 'Voltage constant Ke'