Current and voltage measurement

The current and voltage measurement function is handling the measurement of converter dc current, converter output voltage and the main network ac voltage.

EMF-feedback calculation

The DCVOCAXX function is a part of the automatic field weakening system. The main function is to rescale the motor e.m.f.feed back signal.

EMF-reference calculation

The e.m.f. control is performed by the control system of the field exciter where conventional field weakening etc. is performed. See description for field exciter program.

There are functions for improved motor utilisation via motor field control, which is implemented in the converter program, see section optimal utilisation control" below.

Optimal motor utilisation control

The purpose of this function is to operate the motor as optimal as possible, with respect to the power factor of the motor, requirement for control dynamics, power losses and also the reactive power consumption of the line converter. The method is specially developed for rolling mill applications where a wide field weakening range is common and where control dynamics is of utmost importance.

The function consists of two parts; BETA-calc and PHIREF-calc. Where BETA-calc is controlling the magnetisation of the motor and thus the motor voltage level.

The machine converter thyristor firing is controlled to the smallest value of the firing angle βm, signal BETAM, that gives a required commutation margin, parameter CMARG plus the percentage of the current rate of change. To change the ability to commutate current by increasing the firing angle βm is lowered and the power factor of the machine is increased. The motor voltage is kept at the highest possible level with respect to the requirements for the current control.

The action of these two functions can be easier to understand when we look at the formula for the motortype.

$$\text{Mmotor} = \frac{\text{Pmotor}}{\text{Wm}} = k\frac{\text{Umotor}}{\text{Wm}} \text{ I x } \cos\varphi$$

Where $\frac{\text{Umotor}}{\text{Wm}}$ is controlled by PHIREF-calc

cosφ is controlled by BETA-calc

I is controlled by current control

K is a constant

The function BETA-calc is optimising the cosφ of the motor by controlling the firing angle βm (BETAM) and the function PHIREF-calc is optimising the cosφ by controlling the magnetic flux reference ϕ-ref (PHIREF).

The optimisation is activated for loads > 75% of nominal load.

The optimal utilisation control works closely together with the function IDMAX-calc described in section "Maximal motoring current limiter".

Figure 1 shows the speed and load variation of the motor magnetisation and emf.

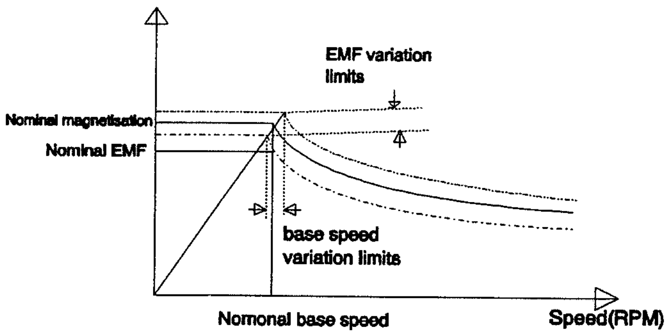

Figure 1, High utilisation control.

Adaptation of e.m.f. and base speed are made according to line voltage variations. This will give a constant relation between line voltage and motor e.m.f.. Reactive power consumption will be minimised.

Torque direction and mode change control

The control of Torque direction change over operation is a part of converter control system. The module contains following functions:

- Control of torque direction change over operation
- Mode change, forced to natural commutated machine converter
- Current reference limiter

The main function is to supervise and to control the torque direction change over procedure. In an LCI-drive is the torque direction determined by the sign of the dc-link voltage, signal UDVOLT (PD 324). The dc-link voltage is proportional to the cosine of the machine converter firing angle βm, signal BETAM (PD 364). Torque dir = sign (cos βm) where βm = 180° -ψm. (ψm is the firing delay angle of the machine converter).

When the current reference, signal IDREF, changes sign this is detected by a special level detector,(see below), and which output signal CONVDIR is activating the torque direction change over operation by the signal IREFCHS. This procedure is started by retarding the current control by the signal BRCHRET and blocking the thyristor firing of the line converter by the signal BRCHBLOC. When this is performed the machine converter firing angle βm is changed by a signal MOTOMODE, where "1" means motoring mode. When ψm is changed form a small value, generating mode (ψm<90°), to motoring mode (ψm>90°) the inversion of the dc-link voltage takes a certain time depending on the frequency of the motor voltage. This time is a necessary delay time until the new value of β m is transferred to a new "stationary" value of the dc-link voltage. The frequency varying delay time is calculated by a function TDEL-CALC. When the delay time is passed out the blocking signal BRCHBLOC is cleared the current control is released when the signal BRCHRET is cleared.

Torque direction

The level detector controlling bridge change is implemented with a special hysteresis function. The hysteresis to transient changes of current reference, signal IDREF, can be set by parameter ILEVBRCM. By integration of the reference this hysteresis to transients will be a function of the reference actual mean value. The steady state hysteresis will by this principle be zero. This principle will efficiently prevent unnecessary bridge changes due to transients, but at the same time allow for bridge change for small and steady reference changes.

At low speed of an LCI-drive, when the motor emf. is not high enough to commutate the machine converter, the dc-link is forced to zero with a pulse of short duration, signal PHASERET. At the same time as a new firing pattern of the machine converter is released. This mode of operation is named forced commutation and disabled at higher motor speeds, signal MODE2="1".

There is an internal current reference limiter controlled by the signal MOTOMODE. The purpose is to limit the regenerated current at braking to a safe value represented by the parameter IDBEMAX.

Armature current controller

The armature, or the main machine stator, current control consists of several parts, all implemented in software. The software realisation gives several advantages since problems related to electrical noise disappears and the inductance of the main circuitry can vary within a wide range without causing problems.

The control part of the current controller is represented by the converter model. The converter model is handling system gain calculation, current prediction and linearisation of current control at discontinuous current. This last task is very important since a linear current control over the full current range is needed for a fast and robust speed control, demanded in rolling mill applications.

The current predictor is "measuring" a current feedback before it actually can be measured. This is needed for a fast current control since the digitalisation of the current measuring and control is introducing a time delay.

The system gain calculation is a function that makes the tuning of the current control a setting of OMEGA_L and N_OMEGAL to a very simple matter, see the commissioning instruction. The real system gain is depending on the actual voltage level and for that reason the gain of the current controller is compensated for line voltage variations.

The current control also contains an automatic tuning function that is determining the characteristics of the main circuitry, which is presented as output signals, OMEGALT and NOMEGALT.

The converter mode is determining the mode of operation, continuous or discontinuous current control mode, and performed by the signal I_CONT ("1" means continuous current).

The signal I_CONT is adapting the characteristics of the current controller.

The current controller generates an output signal, DELTAUS, in order to minimise the deviation between current reference and the predicted current feedback. The gain of the controller is a product of the system gain and the setting of parameter IAGAIN.

The controller output, DELTAUS, is added to a signal EMFREL, that corresponds to the counter emf of the machine converter, to a form a control signal USREL that represents an internal voltage of the line converter. At continuous current mode the firing angle ALPHA_C is generated as an arc-cosine function by the signal USREL. By discontinuous current some more signals are influencing the firing angle ALPHA_C by the working principles is the same.

The current feedback is measured by current transformers of the a.c. side of the line converter.

The output from the current controller is the control angle to the firing pulse equipment. The current control contains also a firing delay angle limitation.