Consideration of the energy efficiency of a plant by means of energy measurement

The measurement of energy consumption variables in the connected circuit is possible using the KL3403 Bus Terminal and the EL3403 EtherCAT Terminal: the terminals directly output the effective values for voltage, current and active power and total up the energy consumption internally; further parameters can be calculated on the basis of the values determined.

Approach

Energy costs belong to the operating costs of a plant and are accounted for as overheads in lump sum shares to all cost centres, since they cannot be attributed to any particular originator. In order to increase profits by reducing energy costs, the costs must primarily be attributed to a particular consumer. This could similarly be entire plants or buildings or also individual segments. If the consumption can be attributed, the optimisation of operating conditions is easier to implement and, in case of doubt, their benefit also proven. By means of a transparent supply network, savings potentials can be specifically implemented and the success of individual measures can also be observed in the long term. Furthermore, the financial expenditure for the production of a certain lot size can be adopted into the cost calculation, since the energy throughput per production lot can be determined as a result.

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As a rule, the following are starting points that need to be addressed in order to reduce energy costs:
- reduction in electricity costs: total active energy obtained, reactive power costs and also costs for peak loads
- stabilisation of manufacturing processes and avoidance of production losses
- identification of 'energy hogs'
- lowering of maintenance costs
- extension of the service lives of electronic and electrical equipment
- cost centre allocation

Both the EL3403 EtherCAT Terminal and the KL3403 Bus Terminal provide the hardware for the analysis and localisation of energy consumption. In addition to the important data from a three-phase supply network, they also record any energy peaks occurring over a selectable time period and total up the energy consumption internally, so that different modes of operation or shifted peak usage times can be judged even after just one production cycle. In addition to a general consideration of energy efficiency, the quantity of energy used for the production of a particular lot size can be determined in order to adapt the price per unit accordingly or to optimise manufacturing costs.

Function of the KL3403 Bus Terminal

The KL3403 Bus Terminal enables analysis via the fieldbus of the energy consumption of the connected plant or building segment or, quite specifically, the key energy data of individual consumers. The voltages of the three phases and neutral can be measured by directly wiring the individual cables to the terminal. In order to measure current, the current of the three phases L1, L2 and L3 is fed in via simple current transformers. The measured current and voltage values are output as effective values. From the effective values for voltage (U) and current (I), the KL3403 calculates the effective power (P), the energy consumption (W) and the power factor ($\cos \varphi$) for each phase. The apparent power (S) and the phase shift angle (φ) can be derived from these values.
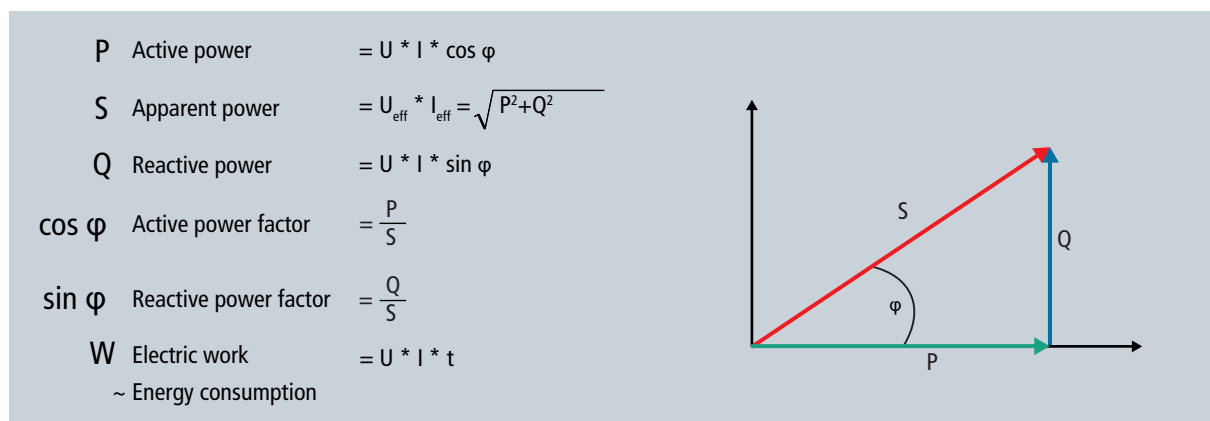
P	Active power	$= U * I * \cos \varphi$
S	Apparent power	$= U_{eff} * I_{eff} = \sqrt{P^2 + Q^2}$
Q	Reactive power	$= U * I * \sin \varphi$
$\cos \varphi$	Active power factor	$= \dfrac{P}{S}$
$\sin \varphi$	Reactive power factor	$= \dfrac{Q}{S}$
W	Electric work	$= U * I * t$
~	Energy consumption	

Fig. 1:   Calculation of the important energy consumption variables

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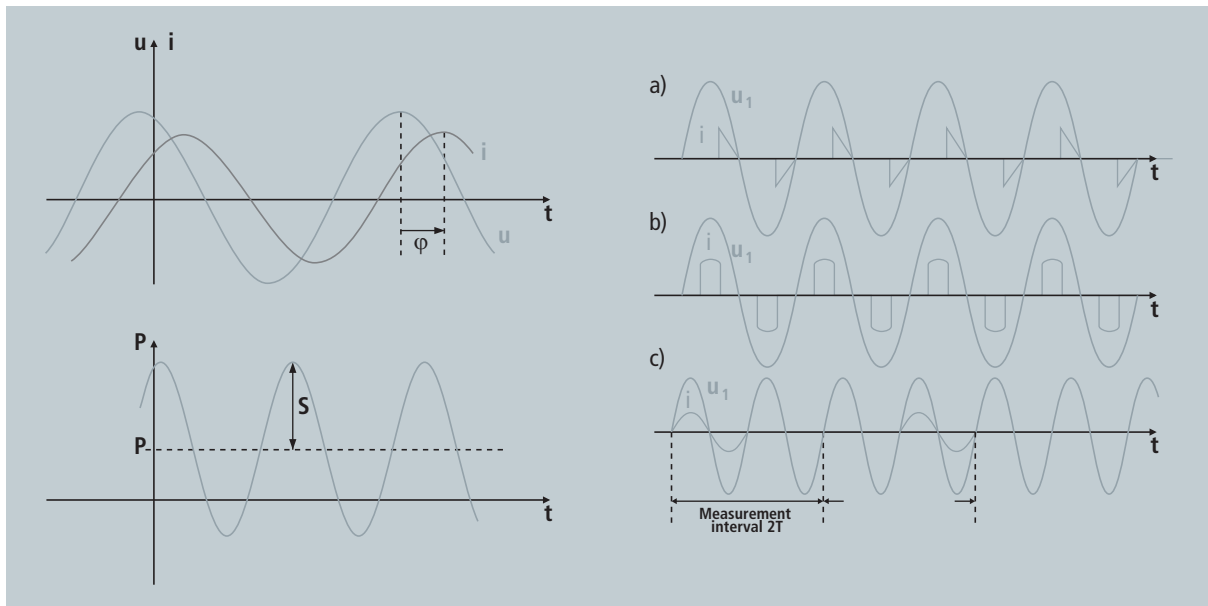## Application Note DK9222-1209-0007
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Fig. 2:   Left: typical current-voltage curve, right: types of current that can be measured

The following types of current can be measured with the KL3403: current and voltage curve for phase control (a), pulse duration control (b) and burst firing control (c); the measurement interval is set analogous to the control interval.

Integration of the KL3403 Bus Terminal
Internal pre-processing of the KL3403 provides rms values in the process image, without requiring high computing capacity on the controller. The terminal outputs the measurement data in a 3 x 3-byte block, i.e. three bytes for each phase. Two bytes per phase are pure process data, while one byte transmits the different status bits. The measured total energy performance is written to the terminal's internal non-volatile memory in a 15-minute cycle, so that these data are also available after a loss of power. The recorded measurement values are transmitted to the controller via an arbitrary fieldbus (integration of the terminal via bus coupler) and are available to the higher-level control system (BDE, ERP or the like) for continuous energy monitoring. In order to achieve fast, cost-optimised and reliable communication of the energy data, the terminal can be integrated in existing network architectures via different bus couplers.

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230 V AC, 50 Hz

L1
L2
L3
N
PE

KL3403
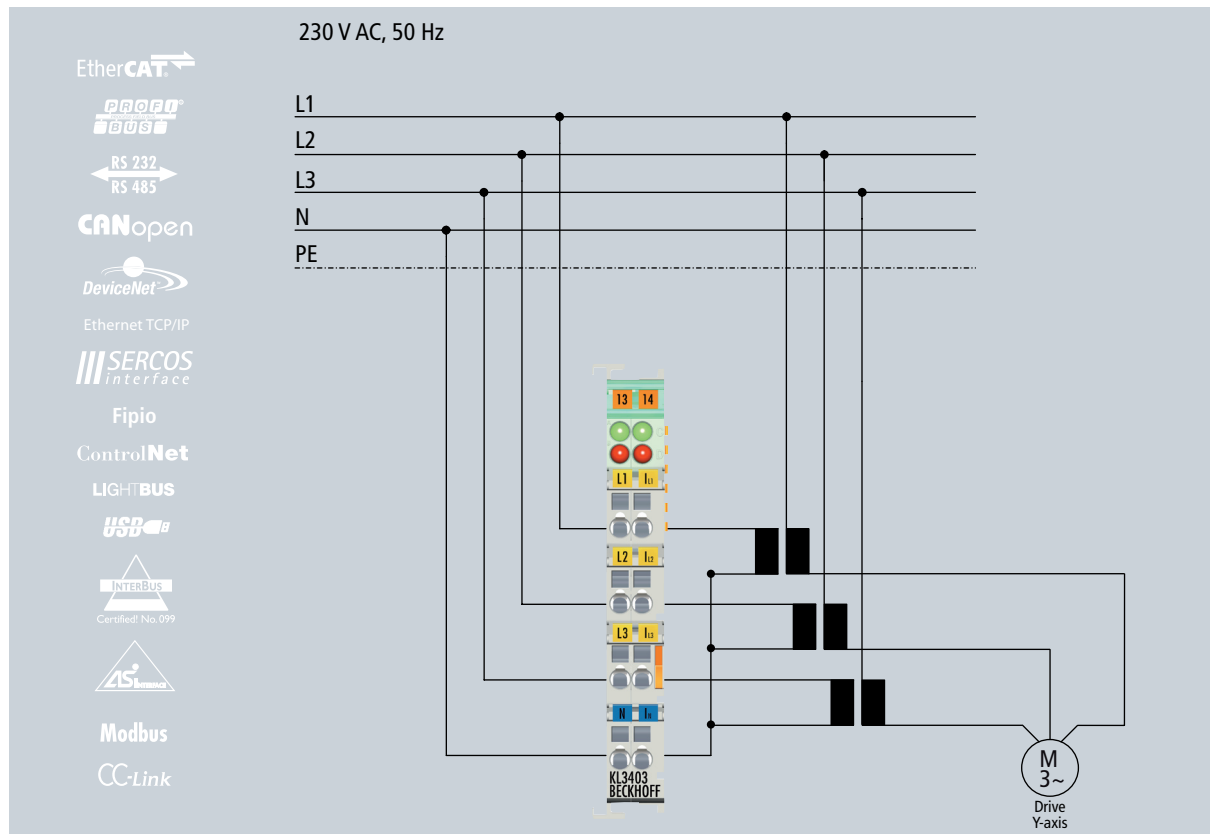BECKHOFF

M
3~
Drive
Y-axis

Fig. 3: Integration in any fieldbus environment as Bus Terminal or EtherCAT Terminal

Differences between EL3403 and KL3403

In principle, the EL3403 EtherCAT Terminal has the same range of functions as the KL3403 Bus Terminal, but is optimised for measurements in the 50/60 Hz mains network. Significant differences are briefly listed here; further information and specific details on the respective terminals can be taken from the documentation at www.beckhoff.com. EtherCAT Terminals are integrated via EtherCAT Couplers, Bus Terminals via Bus Couplers.

Unlike the KL3403, the value for reactive power is also calculated internally in the EL3403. The energy consumption is totalled up per sign, since different tariffs often apply to drawing out and feeding in.

As opposed to the KL3403, the EL3403 offers a considerably higher measurement value resolution. The standard version of the KL3403 achieves a measurement value resolution of 1 mA, whereas the EL3403 enables a resolution of down to 1 µA. Both values have a tolerance of 0.5 % FS (see documentation for details and further terminal variants). The EL3403 uses EtherCAT as the transmission medium with a high data transmission rate, with which it is possible to read out all essential measurement values in parallel if need be.

The EL3403's measurement range for frequency measurements is narrower, but considerably more accurate. However, the KL3403 can also be used for DC measurements. The measurement cycle is also optimised to the 50/60 Hz mains network in the case of the EL3403: the measurement range automatically snaps to one period of the mains frequency. A multiple of the period

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can also be selected.

Further details on technology and configuration can be taken from the documentation. Program examples for the use of the KL3403 in combination with other controllers are available on request.

– 3-phase power measurement terminal **www.beckhoff.com/KL3403**
– 3-phase power measurement EtherCAT Terminal **www.beckhoff.com/EL3403**
– Bus Terminal **www.beckhoff.com/BusTerminal**
– EtherCAT Terminal **www.beckhoff.com/EtherCAT-Terminal**
– Documentations **www.beckhoff.com/documentations**