Introduction to the UNIPOWER family

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1 Introduction

Within the industrial sector it has become more and more important to measure a number of physical variables and use their values for control and regulation purposes. Examples of measured variables are temperature, pressure, flow, current, voltage, revolutions etc. In addition to this also pH, conductivity, oxygen and other gasses are measured without difficulty. However, a few very important variables exist, which have been almost ignored for supervision and control by the industry. These variables are **torque** and **power consumption**.

Most industrial applications use some type of electro-motor. The purpose of the motor is to supply the necessary torque transformed into linear translation, flow of current, pressure etc. Through the measurement of the supplied torque it is possible to monitor the process to see if it runs as expected. The continuos measurement of the motor-torque makes it possible to control or stop the process, if it becomes unstable or lies outside some predefined limits.

The direct measurement of torque through the use of strain gauges mounted on a rotating shaft is usually quite an expensive task and a mechanical challenge as well. Various types of rotational-torque measurement systems exist, but they are expensive, not very robust and used only with very expensive machinery. The torque is however easily obtained indirectly from a fast and accurate measurement of the motor power consumption. The proportionality between power (P2) and torque is well known and this paper is going to argue for the power consumption measurement as an invaluable feedback in a great number of industrial applications. We are going to make a number of references to the **Unipower family** (**HPL**- and **APM**-units) of **Intelligent Power-Control Units,** which is developed and manufactured by **Hydria Elektronik ApS**.

2 Power measurement

In order to use the power consumption measurement as an indirect torque measurement the following facts must be taken into account.

1. Power must be measured through the use of the formula: $P = \sqrt{3} \times U \times I \times \cos\varphi$.
2. The measurement must be accurate; especially the repetition accuracy must be high.
3. The reaction time must be short. The shortest possible reaction time is equal to one half voltage period = 10 ms at 50 Hz.
4. The measurement must be valid also for non sine-shaped currents, as is for instance seen with measurement before frequency inverters, which generate very high and short current peaks (Crest factor up to 10).
5. The measuring unit should include support functions such as: start timer, automatic zeroing, peak-detector for Max./Min. load, possible voltage compensation and Po correction.

All the above-mentioned items are realised in the **Unipower** family, as well as the HPL400-series has an analogue output, 4 - 20 mA and includes phase-order supervision.

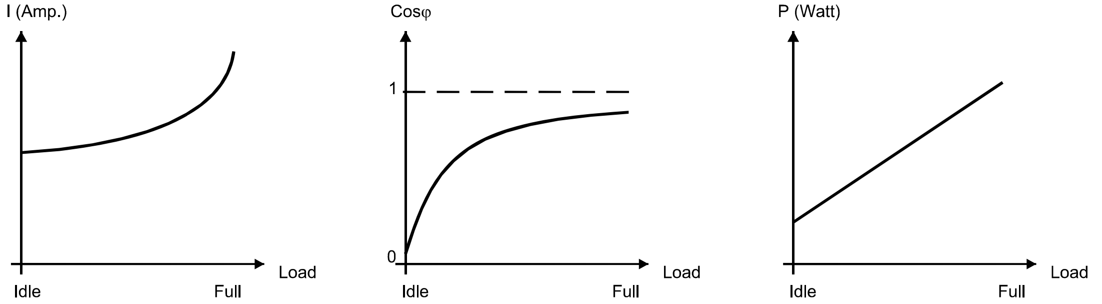
The Unipower family is built around powerful microprocessors that made it possible to implement all the above-mentioned functions. The fast and accurate measurement was achieved through the use of a specially developed 4-quadrant multiplier. This measurement principle makes the kW measurement accuracy independant of the shape of the voltage and current signals. It also accepts high crest factors.

Besides the accurate measurement mentioned here the **Unipower** family includes a number of control functions, which are useful to the industry.

2.1 Power- versus cosφ- and current- measurement

Most of the existing power consumption measurement devices supplied to the industry have been used to register the total power consumption, kWh, and have typically a very long reaction time and are thus not very useful for machine supervision/control.

A number of load monitors, which are based on cosφ or pure current (I) measurement have been made. As it is seen from the following figure these systems are inadequate for torque control because only the true power consumption is proportional to torque.



The current measurement shows a huge non-linearity with respect to torque because the current practically does not change from idle to about 50% load.

The angle φ and cosφ are apparently useful variables for control and supervision purposes. Unfortunately this is only true with a constant mains voltage, which is not often available. When the mains voltage increases the power factor (cosφ) decreases if the torque is constant. When the mains voltage decreases the opposite happens and may lead to false alarms etc.

The mains voltage fluctuations influence, though to a lesser extent, the proportionality between power and torque. The power meter measures the total power consumption of the motor P1 = Po + P2. P2 is of course not related to mains voltage fluctuations, but Po changes quadratically with respect to ΔU. This relation may become critical in some applications and therefore it is possible to make different types of Po compensations in the Unipower family. With cyclic operating machines (ex. tooling machines) it is a great advantage to zero out the idle power consumption Po for each cycle. This does not only compensate for slow mains voltage fluctuations but also for friction in bearings, gear oil temperature etc.

The units in the Unipower family have all been designed for supervision/control of motors etc. which appear as symmetric loads to the mains. The current is therefore only measured in one phase. The HPL-units have an internal current converter up to 8A and four programmable current ranges In = 1, 3, 5, or 8A. With currents greater than 8A an external N/1 or N/5 current converter is needed, more about this later.

3 Standard Unipower family features

Besides the power measurement and trip points a number of other control functions have been integrated into the Unipower family. These functions, which are all programmable from the keyboard, are necessary to implement a stand-alone supervision/control scheme. In the following sections a brief explanation of the programming of the units exists followed by a description of the functions.

3.1 Programming

The Unipower products are in general programmed by the use of only three keys located on the front panel (see figure 2). The mode key is used to switch the display from showing true kW or kW [%] to display one of the programmable parameters. The red mode LEDs are used to show which parameter may be altered. When a parameter has been selected by the mode key, its value is shown on the display and may be altered by the two arrow-keys. Parameters are stored in EEPROM and are thus still present if the unit has been turned off. Note that the function of the keys is repeated if held down continuously.

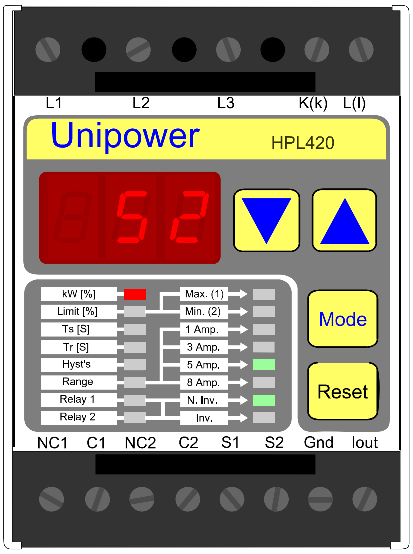


Figure 2. Typical front plate (here HPL420)

3.2 Measurement ranges

All units have an internal current transformer (C.T.), which measures current up to 8A. The units have four current ranges: 1, 3, 5 and 8A. When measuring currents above 8A an external C.T. N/1 or N/5 have to be used. If an N/1 C.T. is used the 1A current range should be selected and similar for an N/5 C.T. The display of power is in % of the measurement range. The power (P) in kW corresponding to 100% may be calculated as follows:
P = 1.73 x U x I, where
U: Nominel voltage.
I: Selected current range or primary current of the external C.T.
Example: Current range = 1A and nominal voltage 400VAC:
P = 1.73 x 400 x 1 = 0.692kW.
This means that 100% on the display corresponds to a consumption of 0.692kW. Then a display of 40% corresponds to a consumption of 0.4 x 0.692kW = 0.277kW.

3.3 Trip points

The Trip points in the Unipower family are always programmed in % of the measurement range. Choosing the trip point may be done either theoretically or practically. The practical method is described in the paragraph about "Peak detectors".
Theoretically:

$$Md = \frac{P_2 \times 60}{2\pi n}$$, where

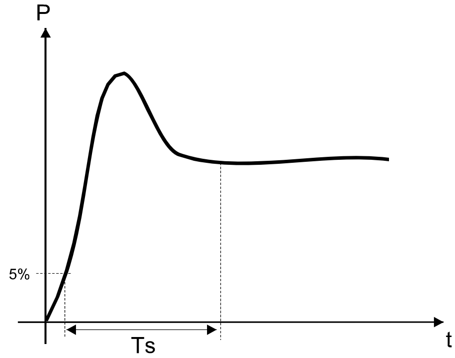
Md: Torque where an alarm is wanted.
P_2: Corresponding shaft power.
n: Revelations in rev/min.
$P_1 = P_2 + P_0$ (or from the motors efficiency curve)
Trip point [%] = 100 x P_1 / P, where
P: The unit's measurement range.

3.4 Peak detectors

Leave the machinery running with normal load for a suitable time duration. Read the Max. and Min. values by activating the arrow-keys in the kW-Mode; Arrow-up for Max. peak and arrow-down for Min. peak. Program the trip points with the appropriate tolerances into the Unipower module.

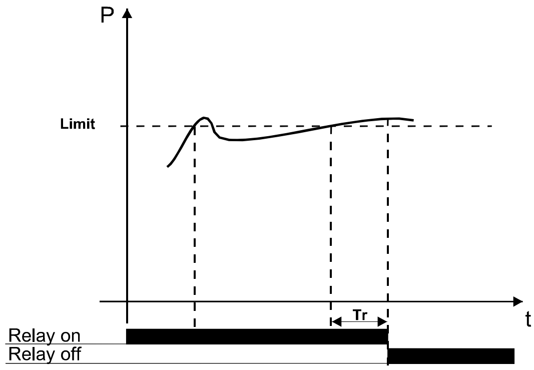
3.5 Start-timer, Ts

To avoid alarms generated by the start current, the supervision is not activated until the motor is running. This is done by the use of a start timer Ts, which typically is programmable from 0.1 – 25 sec. When the consumption exceeds 5% Ts is activated. After Ts expires limits, hysteresis, reaction timers etc. become active. If the consumption drops below 5% the supervision is disabled.



3.6 Reaction timer, Tr

By the use of reaction timers alarms generated by peaks in the power signal are avoided. If a Tr of for instance 1 sec is used an alarm is not generated unless the measurement has exceeded the trip point for 1 second. Tr may be programmed form 0.01 – 25 seconds typically.



3.7 Resetting alarms

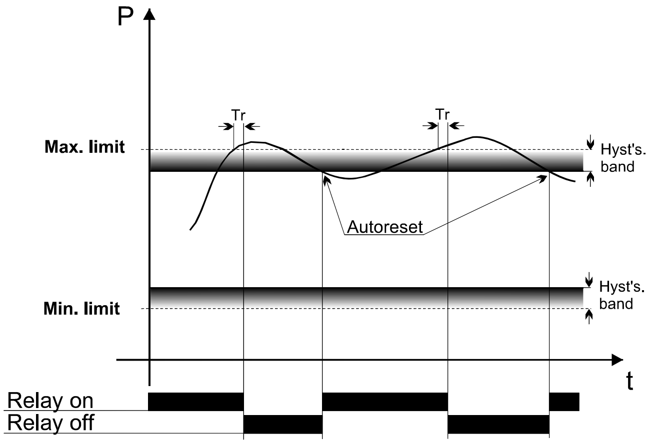
Alarms are reset either by the “Reset”-key on the front plate or via the digital input S1.

3.8 Reset input, S1

Through the digital input S1 an alarm may be reset either manually or automatically (Auto reset). Auto reset is enabled when the S1 is connected to Gnd by which the hysteresis function is activated.

3.9 Hysteresis

From the figure to the right it is evident how a Maximum or Minimum hysteresis band is placed relative to the trip points. The hysteresis band is always placed below a Max. limit and above a Min. limit. The size of the band is programmed in % of the measurement range. This means that with a Max. limit of 80% and a hysteresis band of 10% the consumption must drop below 70% before the relay is On again. The hysteresis function is activated, when a trip point is exceeded and the external Reset is active. By means of the hysteresis a 2(4) point control may be established.



3.10 Alarm blocking, S2

If during the supervision cycle a short predictable over load or under load occurs an alarm may be avoided by informing the unit about the incident. This is done through the digital input S2, which must be activated as long as the alarm condition is present or should be ignored. This is also the case if a motor is stopped intentionally when using a Min. limit. If nothing is done the unit will generate a Min. alarm as the Min. limit is exceeded.

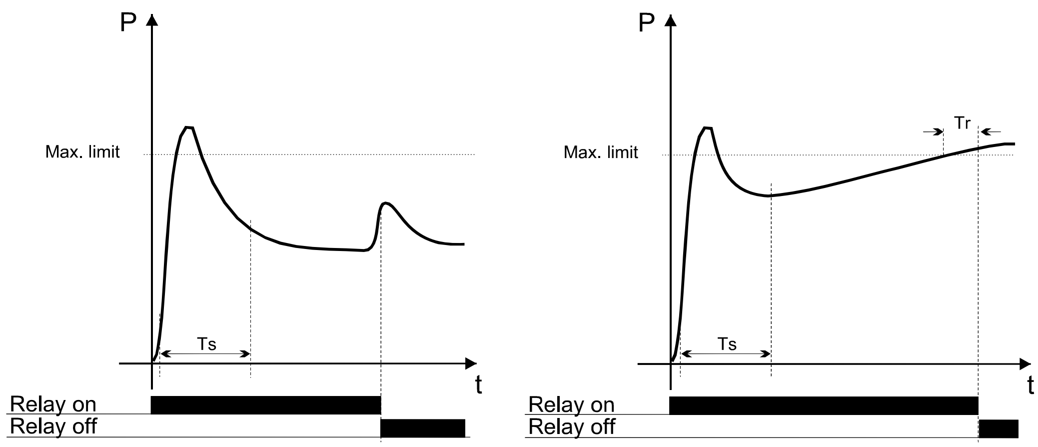
3.11 Relay polarity

Should a need of using inverted relays occur the units have the opportunity of programming the relays to be inverted. Please be aware of the fact that inverted relays are Off during normal operation, i.e. the ability of self-supervision is lost which generally is not advisable. Therefore the user is advised to use non-inverted relays where possible.

Besides the mentioned functions some special functions only exist in unique units in the Unipower-family:

3.12 dP/dt supervision (HPL430)

The principle of dP/dt supervision is to monitor the changes in the consumption rather than the absolute values, which in some cases are inadequate for an efficient supervision. An example of this is the supervision of conveyor belts or bucket conveyors with variable static load. The variable load makes it impossible to use a static trip point, where as a dP/dt supervision may solve the task. Note that the dP/dt limit is programmed in % of the measurement range. This means, that a high measurement results in a sensitive supervision and vice versa.
Example: The power lies on 10% and the dP/dt-limit is 10%. The measurement signal must rise to double the normal load (10% + 10%) within 20ms before the relay trips, as the dP/dt-limit is not relative to the actual measurement but to the measurement range.
Besides the dP/dt-limit naturally the HPL430 also contains a Max.-limit as a slowly increasing load must be detected also.

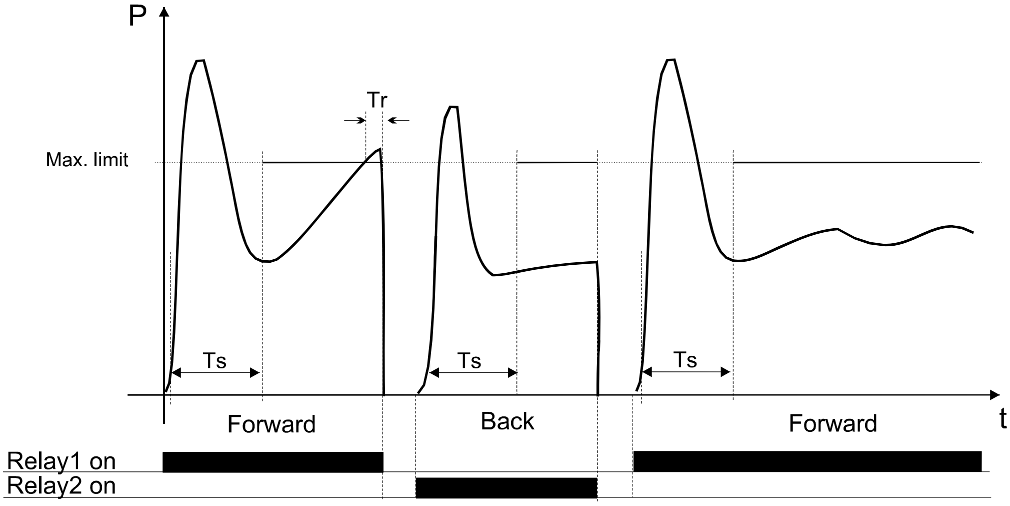


dU/dt supervision

If during the dP/dt-supervision voltage alterations (dU/dt) are not taken into account fault alarms will occur, since the idle power in the motor changes quadratically in proportion to the voltage alterations. An increase in the voltage will therefore cause a power increase and eventually an alarm, even though the shaft power (torque) hasn't changed. HPL430 therefore contains a “dU/dt-supervision”, which ignores a dP/dt-alarm if the voltage change has been greater than a certain level programmed by the user.

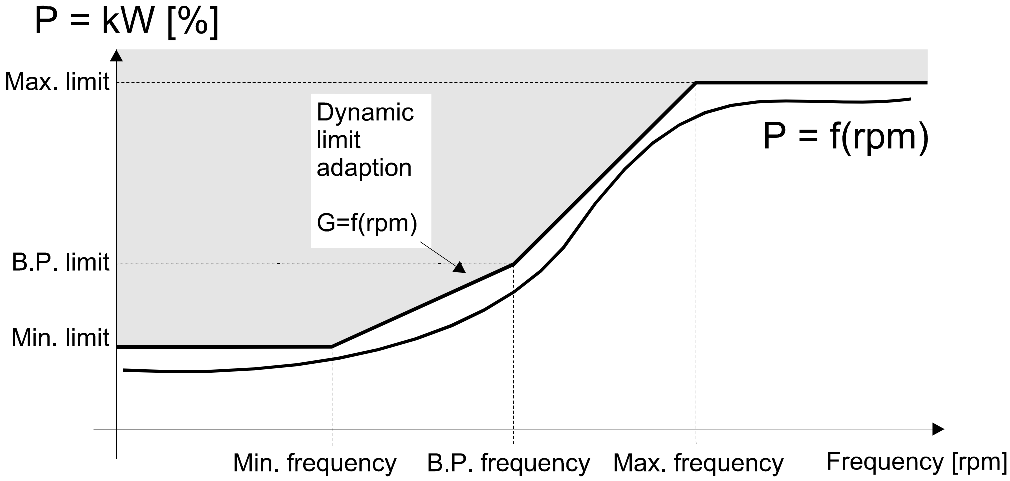
3.13 Reversing (HPL440)

The most advanced “stand alone”-control in the Unipower-family is the HPL440, which by it self without connection to a PLC is able to reverse a conveyor and by doing so perhaps remove a blocking. The reversing time and number of reversing attempts are programmable.



3.14 Frequency adapted trip point (HPL450)

In connection with for instance mechanical variable gear a power measurement on the motor may not without further ado be used as a measurement for the shaft power. Here it is necessary to adjust for the revelations (frequency). For this purpose the HPL450-series is developed. Besides the power measurement a frequency signal (4-20mA, 0-10V, 5-1000Hz square or Namur) is connected to the unit. The unit then adjusts the trip point from user-programmed coordinates (Min, Break Point, Max) depending on the frequency.



It would lead too far to describe all the units of the Unipower family thoroughly but it should be noted that the HPL403 is a pure measurement transducer for kW and kWh and is usually used as a PLC-interface unit. The unit measures/displays kW in % or absolute value. The HPL410-430 and the HPL110 implements different types of trip points used for various types of supervision and control purposes. The TMS-units are used for the supervision of cutting tool machinery for tool-break and tool-blunt conditions.

4 Applications

An almost infinite number of applications of the Unipower family exist, which may be divided into supervision- and control tasks as well as tool monitoring tasks. The tool monitoring tasks will not be treated here, but interested readers will be referred to the company's home page: www.unipower.dk

4.1 Supervision

In must be stated here that it is **not the motor, but the machinery** that normally requires supervision. That at the same time a supervision of the motor is established may be a valuable acquisition.

1. The Unipower modules replace friction clutches, breaking bolts, tacho controllers etc. in connection with conveyor belts, screws, elevators, ventilators, pumps etc. Depending on the application a type with one, two or even more trip points is used. Both a Max. and a Min. trip point is often useful together with ventilators and pumps. With two-speed motors two trip points are used, one for each speed. With transport elevators in the food processing industry a unit with both a Max. trip point and a dP/dt-Max. limit is often used. The HPL440 is used with screw-transporters and is able to change the revolution direction of the screw for a certain time period and a specific number of times.

2. Examples of specific applications of the Unipower family are: Coal-transporters on power-plants (Austria, Denmark), conveyor belts in industrial washing machinery (Sweden), elevators and transporters in automatic computer controlled stock systems (Switzerland & Belgium), cleaning plants and pumps (Denmark), internal transport and gate-supervision (Germany). Supervision of motor/gear in a reactor control on a nuclear power plant. Because of the very fast reaction time the Unipower modules have even been used as end-stops as well.

4.2 Control

A number of relatively simple control tasks are implemented by the Unipower alone. The more complex control schemes must be established by a PLC with the assistance of one or more Unipower modules. As stand-alone controllers the Unipower modules are used as two- or four-point controllers with a suitable hysteresis band. A couple of examples.

a) Control of flow of material.
The power consumption of a grinding mill, which is working with stone/coal/etc., is measured with the Unipower HPL410. The material is supplied to the mill from a conveyor belt, which in case of continuos operation is going to fill the mill totally (and probably overfill it). The Max. trip point of the HPL410 is programmed to e.g. 80% and a hysteresis-band of 10% is selected. While the mill is being filled its power consumption slowly increases and when it reaches 80% the HPL410 Max. trip point relay changes state. The relay is used to stop the conveyor belt (feeder) and the power consumption of the mill decreases and when the value 80% - 10% is reached the relay activates the feeder again. There are a great number of equivalent applications. Please note that if the motor consumption is below 50% of nominal load and the hysteresis band is very narrow (5-10%), it might be necessary to use the Po compensation. It is especially necessary where huge mains voltage fluctuations exist.

b) Supervision of pumps.
Depending upon the construction of the pump, breakdown may occur if the pump runs dry. To prevent this an HPL110 with a Min.-limit is widely used.

c) Controlling mixer.
The power consumption of the mixer is a measure of the viscosity of the mixture. If the consumption reaches a certain Max. trip point the relay changes and should be used to start the flow of the low viscosity material to the mixer.

This system is currently used in the ice-cream industry (Denmark).

d) Controlling number of revolutions.
The inverted analogue output signal (4-20 mA) might be used to control a frequency inverter in a way that makes it possible to keep the power consumption of the machine at a constant

level by changing the revolution speed. The same is achievable, within certain limits, with mechanical variable gears using Max. and Min. trip points plus hysteresis.

The examples above are only meant as general information about the many possibilities that lies in measuring the torque indirectly by means of a power measurement.

5 Panel instruments

If the unit needs to be panel mounted, the Unipower family also includes units with housing according to DIN43700 with standard dimensions 72x72mm. The HPL110A and the HPL130A are stand alone units (i.e. contain both measuring- and control ability), whereas the d10 and d382 are unable to measure and threfore need an APM110 and an APM382 respectively.

5.1 HPL110A

HPL110A is functionally identical to HPL110. Additionally the unit is available with 0-20mA analogue input and 4-20mA analogue output.
HPL110A may be supplied for single phase. (Measurement and/or supply)

5.2 HPL130A

HPL130A includes dP/dt-supervision besides the standard control functions. The unit is available with 0-20mA analogue input and 4-20mA analogue output.
HPL130A may be supplied for single phase. (Measurement and/or supply)

5.3 d10

The Unipower d10 is a display/control unit for the APM110. When connected the APM110 only functions as measuring- and relay unit. The d10 is connected via only two wires. All control functions are taken over by the d10. If correctly set up the d10 will display the power measurement as either kW, HP or kW%. Also the limit setpoints may be set in kW, HP or kW%. The d10 has an analogue output, which is either 4-20mA proportional to the power measurement or a separate alarm output.

5.4 d382

The APM382 may also be connected to a display unit for a readout of the measured power. This unit is called d382 and is connected to the APM382 via the same serial connection as used by the APM382 to connect to a PC. So an APM382 cannot be connected to a PC and a d382 at the same time. d382 is only able to display the measured power or programme the APM382. All control functions are performed by the APM382.

5.5 d382-dA

To accomodate demands of data acquisition the display unit d382 comes in a version with extra memory. Besides the functions of the d382 the d382-dA contains settings for data acquisition; Sampling interval, automatic or manual start of acquisition as well as a trigger function. The sampling interval lie between 20ms and 1s. The d382-dA has a capacity of 1mill. measurements.

6 The APM-family

The APM-family consists of compact units without a built-in display and includes measurement transducers and load monitors. The units are briefly described below. The functions described in the previous chapters naturally also apply to the APM-units.

6.1 APM100B

The APM100B is a 3-phased measurement transducer for symmetrical loads. The unit's measurement range may be setup in steps of 0.1kW from 0.1kW to 80kW. The analogue outputs are 0(4)-20mA and 0(2)-10V. Also an S0-1 output for kWh-pulses is included.

6.2 APM110

The APM110 is a 3-phased load monitor for symmetrical loads. The measurement range may be setup in steps of 10W from 0.01 – 80kW. The unit has a Max- and a Min-limit with a common output relay. The Max-limit equals the measurement range and the Min-limit is set in % of the measurement range. The unit has the necessary timers etc. to achieve a functional load monitor.

6.3 APM300B

The APM300B is a 3-phased asymmetrical measurement transducer to be connected to external current transformers. The analogue outputs are 0(4)-20mA and 0(2)-10V. Furthermore an S0-1 output is present for kWh-pulses.

6.4 APM380

The APM380 is a replacement of the previous PWM325. It measures power on 3-phased asymmetrical loads – also after frequency inverters. The unit has built-in CTs for currents up to 80A. The supply voltage is 24V= and the unit may be connected to mains voltages from 3x230V to 3x575V. The voltage range is setup on the unit's frontplate where also the current range is chosen from 1A to 80A. The analogue outputs are 0(4)-20mA and 0(2)-10V. Furthermore one of 4 analogue filters with short time constants may be chosen as well as one of 4 digital with long time constants. The APM380 is primarily used as measurement transducer for our Tool Monitors (TMS) in connection with tooling machines, but may be used in any application where a need for measuring power after frequency inverts exists.

6.5 APM382

The APM382 is identical to APM380 with respect to measurement principles, but includes also control machines for limits etc. Programming of the units is done with the PC-software 382Mon or with the display unit d382 (see paragraph about panel instruments).

This concludes the examination of the Unipower products. Please bear in mind that Hydria Elektronik ApS is a company in constant development, which means that new units are developed frequently. If an application needs modifications to an existing unit, do not hesitate to contact us to discuss the new requirements. At this point a variety of customer specific units exist and new requirements emerge all the time.