Introduction to the UNIPOWER family

Table of contents

1 Introduction

Within the industrial sector, it has become increasingly important to monitor processes and machinery for the purposes of supervision, control and quality assurance. Examples of measurement parameters used for these purposes include temperature, pressure, flow, current, voltage, revolutions etc. In addition, more advanced properties such as color, pH, conductivity and the components of gaseous mixtures are measured without difficulty.

A fundamental parameter for monitoring almost any process is energy consumption as reflected by the variables **torque** and **power consumption**.

Most industrial applications use some type of electric-motor to deliver power, in the form of torque, to run the process or actuate the machinery. Electrical power is delivered to the motor where it is converted to torque; the torque then provides the work energy required by the process or machinery.

Through the measurement of the supplied torque, therefore, it is possible to monitor the process to see if it runs as expected. Continuous measurement of the motor-torque makes it possible to control or stop the process if it becomes unstable or lies outside some predefined limits.

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, subject to overload damage and used only with very expensive machinery.

Torque, however, is **easily obtained from motor power consumption**. Using the motor itself as a torque sensor is fast and accurate and has the added advantages of requiring no mechanical modification to install the sensor and the sensor is extremely robust - overloading of the mechanical elements of the system will, in no way, damage the power sensor.

The proportionality between power and torque is well known and this article describes the functions and applications of the **Unipower** family of **Intelligent Power-Control Units** for supervision, control and process feedback in a wide range of industrial applications.

2 Power measurement

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

1. True Power must be measured using the formula: $P = \sqrt{3} \times U \times I \times \cos\varphi$.

2. Measurement accuracy must be high; especially repeatability.

3. 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 system must 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 criteria are realized within the **Unipower** family.

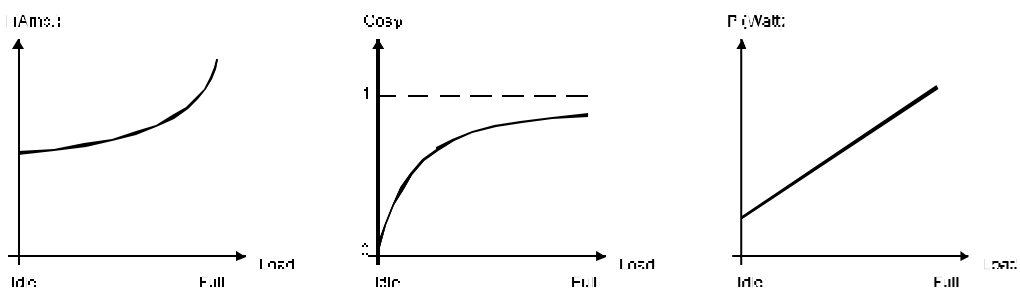
The **Unipower HPL** series units are designed for use with fixed frequency motors but can all be used equally effectively in front of fequency inverters in variable frequency installations. This ability is due to the advanced measurement circuitry which integrates the current for each half cycle even for non-sine shaped currents.

In addition, the **Unipower PWM** series sensors use even more advanced power measurement techniques to accommodate measurement at variable frequencies, i.e. measurement between a frequency inverter and an induction motor.

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

2.1 The Importance of True Power - Power vs Current vs Phase Angle

A number of load limiting units have been offered which are based on phase angle cosφ or pure current (I) measurement. 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.



Current measurement is hugely non-linear with respect to torque - the current practically does not change from idle to about 50% load.

The phase angle φ and cosφ exhibit a similar limitation with high sensitivity at low loads and then extremely low sensitivity at higher loads.

Both of these variables are also susceptible to changes in mains voltage. Repeatability using either current or phase angle measurement would only be achieved with a constant mains voltage, which is not often available. When the mains voltage changes, the power factor (cosφ) and/or current adjust such that the required torque is maintained. Mains fluctuations, therefore, result in measurement errors which may lead to false alarms etc. when using simple current or power factor measurement techniques.

For monitoring purposes, therefore, the measurement of true power using the formula $P = \sqrt{3} \times U \times I \times \cos\varphi$ is absolutely critical for reliable performance.

2.2 Compensating for Idle Power

Mains voltage fluctuations influence, though to a lesser extent, the proportionality between motor power and torque.

The power meter measures the total input power consumption of the motor which is P1 = Po + P2 where P1 is total power input, Po is the idle power and P2 is the load power. P2 is not related to mains voltage fluctuations, but Po changes quadratically with respect to ΔU.

This relation becomes critical in some applications and therefore it is possible to make two types of Po compensations in the Unipower family.

The first form of mains compensation is used in units offering dP/dt "shock load" trip points. In these units, a compensation is made to the dP/dt calculation when a sudden mains fluctuation is detected thereby eliminating false alarms which could otherwise occur.

The second is commonly used with cyclic operating machines (ex. tooling machines) where it is a great advantage to zero out the idle power consumption Po for each cycle. This does not only compensate for mains voltage fluctuations but also for friction in bearings, gear oil temperature etc.

The units in the Unipower family have 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 whereas the mains voltage is calculated as an average of the three voltages: $(U_{L1} + U_{L2} + U_{L3})/ 3$. The 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.

Exceptions to these rules are the PWM family which measures all three currents as well as voltages (allows installation after frequency inverters).

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. For purposes of simplicity, these discussions are based around the standard **HPL400 series** Unipower units.

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.

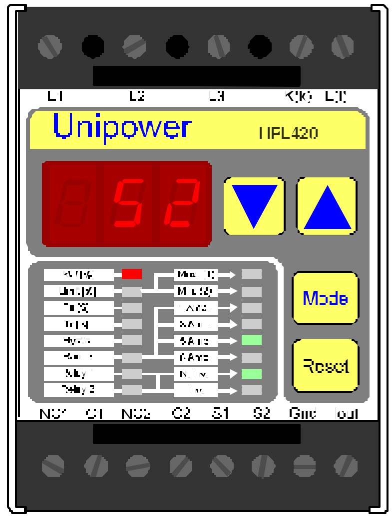


Figure 2. Typical front plate (here HPL420)

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: Nominal voltage.
I: Selected current range or primary current of the external C.T.

<u>Example:</u> Current range = 1A and nominal voltage 460VAC:

P = 1.73 x 460 x 1 = 0.796kW.

This means that 100% on the display corresponds to a consumption of 0.796kW. Then a display of 40% corresponds to a consumption of 0.4 x 0.796kW = 0.318kW.

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 Unipower philosophy is based on the practical method as described in the paragraph about 'Peak detectors".

To set the trip points theoretically, it is necessary to convert the desired shaft torque or power to input motor power as measured by the Unipower unit. This can be achieved as follows:

First, determine desired shaft power for alarm - P_2' - in terms of the alarm torque - Md:

$P_2' = 2.p.n.Md \div 60$, where

Md: Torque where an alarm is wanted,
$P_{2'}$: Corresponding shaft power, and

n: Revelations in rev/min.

Second, convert shaft power for alarm to input power at motor by compensating for idle power:

$P_1' = P_2' + P_0$ (or from the motor's efficiency curve), where

P_1': Input power for desired alarm point, and
P_0: Idle power offset.

Finally, convert the input power for desired alarm point to a Trip point in units of %kW:

Trip Point [%kW] = 100 x P_1' / P, where

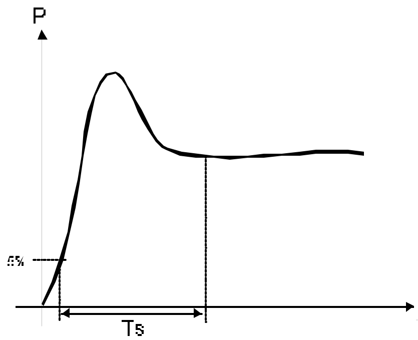
P: The unit's measurement range.

3.4 Peak detectors

To set alarm limits using 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.

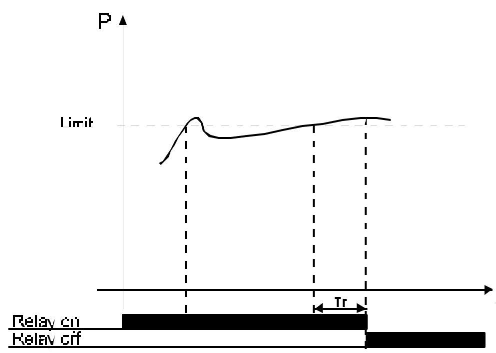
3.5 Start-timer, Ts

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

The reaction timers allow alarm sensitivity to short duration peaks in the power signal to be adjusted such that false alarms 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

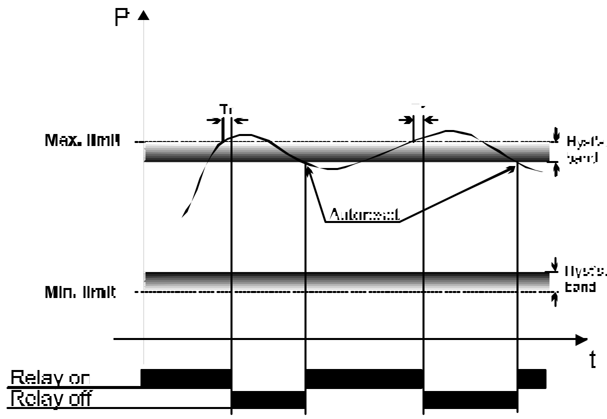
Alarms are reset either by the "Reset"-key on the front plate or via the digital input S1.

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 S1 is connected to Gnd thus activating the hysteresis function.

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 beware 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.

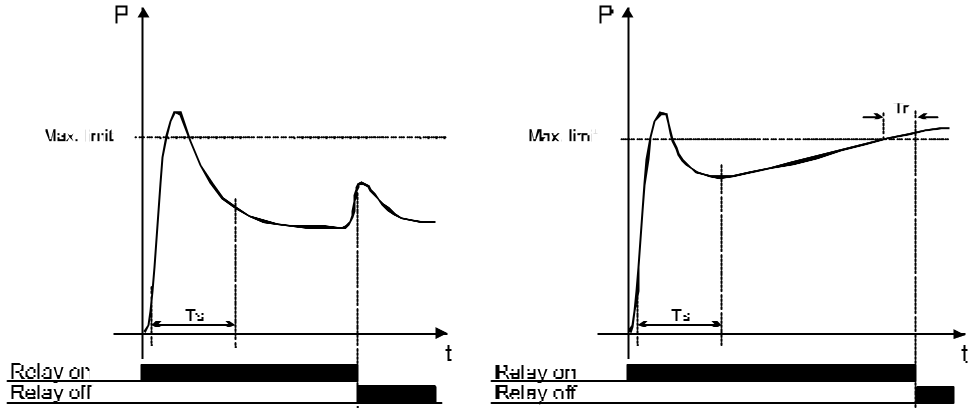
Besides the mentioned functions some special functions only exist in unique units in the Unipower-family:

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, whereas 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.

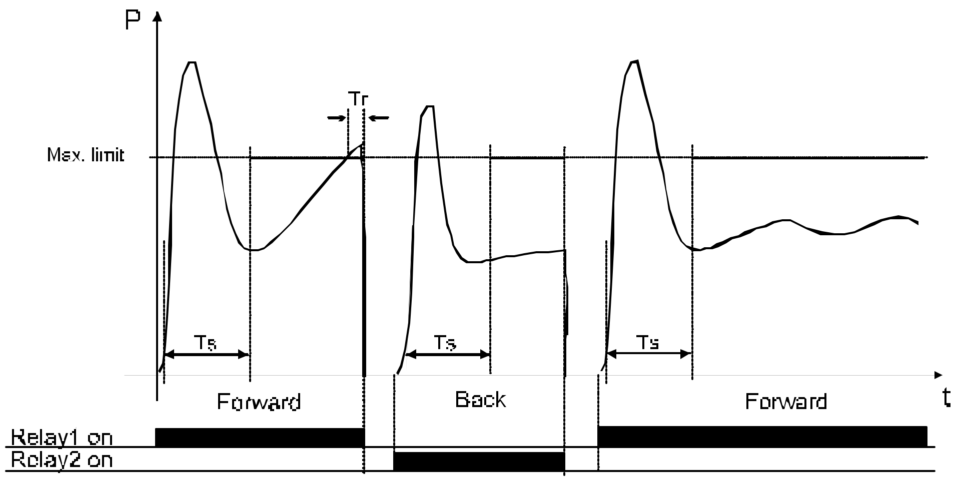


DU/dt supervision

If during the dP/dt-supervision voltage alterations (dU/dt) are not taken into account fault alarms may 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 blockage. The reversing time and number of reversing attempts are programmable.



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, U, I and cos φ and is usually used as a PLC-interface unit. The **HPL410-440** and the **HPL110** implement 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

It is typically not the motor but the machinery which requires supervision and control and it is within this framework that the Unipower family specialises. An almost infinite number of applications exist, which may be divided into supervision- and control tasks.

4.1 Supervision

a) **Overload:** Unipower modules replace friction clutches, shear pins, tacho controllers etc. in connection with equipment such as conveyors, screw feeders, elevators/hoists, pumps etc.

The Unipower solution for overloads provides exceptionally fast reaction times - down to 8msec - which are typically fast enough to minimize damage in the event of a jam-up. The actual trip point is programmable which makes adjustment much easier than with mechanical devices.

And resetting after a trip is as simple as a push of a button - much easier, quicker and more efficient than replacing shear pins, for example.

In many situations, the actual overload trip point required is not known until a machine is installed and in use. A good example of this is under-floor chip conveyors for transfer lines - drives are typically over-sized at the design stage making it common for chips to become fully packed in the conveyor before friction clutch or shear pin overloads trip. Unipower modules provide programmable overload limits which are easily adjusted once the system is installed and functional.

b) **Underload:** Monitoring for Underload is often as important as overload and can not be achieved with friction clutches and shear pins. Broken belt detection is a classic example - it is easy to detect if the motor is running but not so easy to tell if it is doing anything.

Unipower modules provide fast, effective and fully programmable supervision for underload situations including ranging from dry-running of pumps through blocked filters, fans that have lost their blades, missing parts in repetitive processes and broken drive trains.

c) **dP/dt:** In many overload monitoring situations, the actual base-line load might vary. In these cases, the ability to monitor the rate-of-change-of-power is useful since a jam condition is typically mechanical in origin and results in a sudden rise in motor load.

Typical examples include supervision of conveyors and elevators transporting granular material, e.g. grain elevators, and machinery with large, variable drag loads, e.g. high ratio gearboxes subject to severe temperature ranges. In these cases, the use of a dP/dt trip allows far more sensitive supervision than an overload trip on its own.

d) **Speed Compensated Overload:** In variable speed applications, the power at the motor will be proportional to both the speed and the torque. Since desired overload trip points will be torque related, speed compensation of the power trip point is required.

A number of applications exist for this Unipower function with the classic being multi-speed hoists. Using a speed input, the Unipower can correct for speed changes and keep the overload constant.

In many applications, combinations of the above supervision functions are used either as combined functions within a single Unipower or as combinations of Unipower modules.

Some specific Unipower supervision examples include:

Centrifugal pumps - using overload/underload to supervise for dry running, cavitation, jam, no-flow/dead-heading

Positive-displacement Pumps - again using overload/underload supervision with the overload function being very useful to supervise for over-pressure and eliminate by-pass valves in, for example, food processing.

Hoists - Unipower overload monitors provide a uniquely simple and effective overload supervision for hoists with Unipower models using one overload alarm for single speed hoists, dual overload for dual speed and speed compensated versions for variable speed hoists.

Conveyors - Many examples including overload and dP/dt and combinations of these functions are used for conveyors. Classic examples include chip conveyors in transfer line applications and grain elevators in the foods industry.

Broken-Belt - Underload detection is used for broken drive chain detection as well as situations where a process is missed, e.g. missing parts.

Process Start - It is often desirable to control a process based on the start point and this can be easily achieved using, for example, an HPL410. One application is Gap-Elimination on grinders where the infeed rate is changed once contact between the wheel and workpiece is detected. Another application is controlling infeed of an abrasive brush based on the first contact point between brush and workpiece.

4.2 Control

A number of relatively simple control tasks are implemented by the Unipower alone. More complex control schemes are typically managed by a PLC with the possibility of using one or more Unipower modules as sensor inputs.

As stand-alone controllers the Unipower modules are used as two- or four-point controllers with a suitable hysteresis band. Some examples include:

a) Control of <u>flow of material</u> - 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 continuous 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 70% (80% - 10%) is reached the relay activates the feeder again. There are a great number of equivalent applications.

b) Control of <u>mixing</u>.
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.

Examples include coal dust separation and ice-cream freezing.

c) Controlling <u>speed</u>.
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.

d) Control of <u>Tension</u>.
The fast reaction time of Unipower modules make them effective at detecting stop points. An example of this is in gripper control and strap tensioning - in both cases, Unipower

modules are used to detect the load on the gripper/strap motor and control the pressure exerted.

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

5 Other Unipower Models

Over time, requests for enhancements and changes to the standard Unipower HPL400 family have resulted in the development of a number of other Unipower -

5.1 HPL110

The most common functionality required in industry is the combined Overload/Underload monitor as represented by the HPL420. A stripped down version of this unit was developed as the HPL110 which includes Overload/Underload functionality linked to a single SPDT relay.

While this model lacks some of the advanced features of the HPL420, it provides an excellent basic supervision solution in many applications including pumps, fans, filters and broken belt detection. A panel mount version, HPL110A is also available

5.2 APM Family

A new family of Unipower modules based on pure analog technology with a new and enhanced measurement strategy. Lacking many of the features possible with digital implementation, these units are aimed at cost-sensitive applications where they will be set once and then rarely adjusted.

5.2.a APM110

Duplicates the basic High/Low trip limit functionality of the HPL420/110 units with internal measurement capability to 70kW.

5.2.b APM100

A load measurement transducer version of the APM110 with 4-20 mA and 0-10V analog output that can be scaled from 0.1 to 70kW Full Scale and includes kWH pulse output.

5.2.c APM300

A precision load measurement transducer for use with variable or fixed frequency systems. The unit uses three external current transformers and can be sized for any motor rating. Output is 4-20 mA and 0-10 V also with kWH pulse output.

5.3 PWM325

Variable frequency drives have become increasingly common and while the standard HPL measurement principle can measure power in front of a VFD, it is not capable of doing so behind the drive. A number of situations arise, however, where measurement between the drive and the motor is required either involving multiple motors driven by a single drive or where power storage by the drive creates errors.

For these applications, the PWM325 sensor was developed. This dedicated power sensor provides a 4-20mA analog output proportional to power and can operate between a drive and the motor at frequencies from 5 Hz to 5 kHz. The unit has internal C.T.s capable of full scale ranges of 25 or 50 A and can be used with external C.T.s above 50 A.

6 Conclusion

This concludes the discussion of the Unipower products.

Please bear in mind that the Unipower family is the result of constant and ongoing 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.