Unipower HPL600

Tool Monitor System TMS

Features
* ❋ Detection of tool breaks
* ❋ Detection of tool bluntness
* ❋ Check on tool presence
* ❋ Check on material presence
* ❋ Supervision of up to 16 cuts
* ❋ Interface to PC for visualization
* ❋ Storing of statistics
* ❋ Export of data

1. Introduction

Unipower HPL600 is a base unit in a monitoring system used for detection of tool breaks and tool bluntness on tools used in different types of tool machinery. The complete system is called „Tool Monitor System" or TMS.

When using the HPL600 a 0-20mA analogue signal is needed. This could be obtained from a power measuring device but a load or torque sensor could also be used.

It is possible to connect the HPL600 to a PC through a RS232 interface. TMSMon (supplied with the HPL600) is used for visualization and setting parameters etc.

When supervision is based on power measurement the APM100 or APM380 are used. Both units are members of the Unipower Family. Typically the total power consumption of the spindle motor is measured. The idle power consumption of the spindle motor is subtracted and the shaft power P2 is found. P2 is proportional to the torque needed to perform the operation. So the basis of the tool supervision is an indirect measurement of this torque. The objective is usually to supervise drilling, milling and thread cutting operations. Lathe operations could also be supervised.

In addition to the analogue input the HPL600 integrates 6 digital inputs, 2 relay outputs and a RS232 serial interface port. The relay outputs are used for fault signalling and the digital inputs are used for control purposes by the CNC controlling the tool machine - in the following named CNC.

2. Installation

2.1 Typical installation
On pages 3 and 4 typical wiring diagrams for the HPL600 and APM380 or APM100 are shown. APM380 and APM100 are used to measure the spindle motor power consumption. APM100 is used when measuring on directly driven motors; APM380 is used when measuring after a frequency inverter. Technical data on the APM380 and APM100 are found in Appendix A and B.

2.2 Supply voltage
HPL600 is connected to 24VDC, ± 20% on connectors 1(+) and 2(-).

2.3 Analogue input
0-20mA from the measuring device is connected to connectors 3(+) and 4(-). Inputs are polarity and transient protected.

2.4 Digital inputs K1,K2.
The optocoupler isolated digital inputs K1, K2, are used for Reset and Start. They are activated by connection to 24VDC control voltage or by using a PLC output.-24VDC is connected to connector 7.

2.5 Connecting the relays.
The build-in relays are connected to the external control in accordance with the desired functionality. The relay outputs have a common terminal on connector 9. The common terminal is usually connected to 24 VDC. Connector 8 is used for Blunt signalling and connector 10 is used for Break/Missing signalling. Relay outputs are active in normal mode.

2.6 Digital inputs CS1-CS4
The optocoupler isolated digital inputs CS1-CS4 are used for Cut number selection (1 to 16). -24 VDC is connected to connector 15.

2.7 RS232 interface
When using serial communication through the RS232 interface TX is connected to connector 18, RX is connected to connector 17 and GND is connected to connector 16.
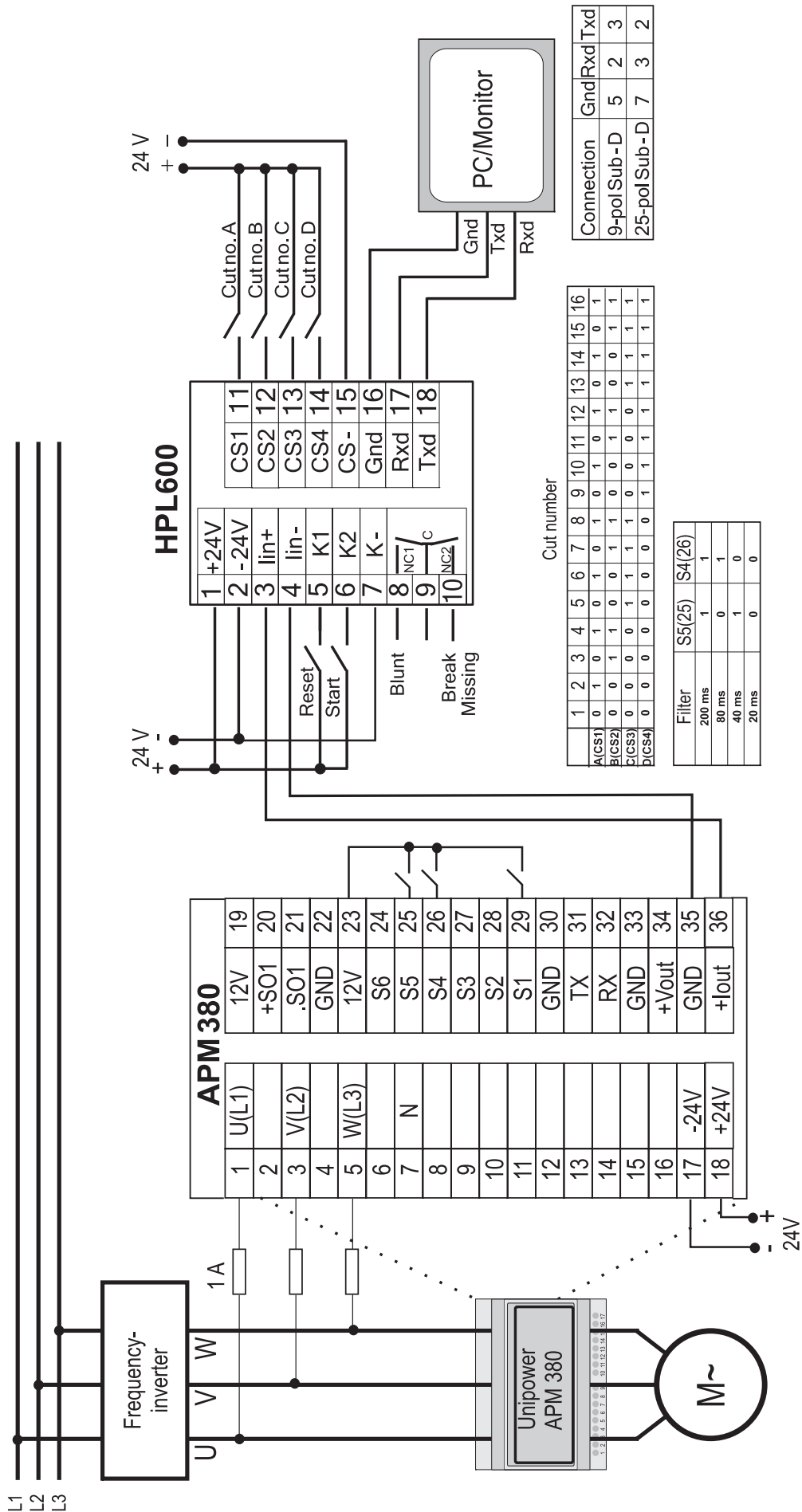
HPL600

11	CS1		
12	CS2		
13	CS3		
14	CS4		
15	CS -		
16	Gnd		
17	Rxd		
18	Txd		

1	+24V	
2	- 24V	
3	Iin+	
4	Iin-	
5	K1	
6	K2	
7	K-	
8	NC1	
9	C	
10	NC2	

PC/Monitor — Gnd, Txd, Rxd

Cut no. A, Cut no. B, Cut no. C, Cut no. D

24 V + / –

Reset, Start, Blunt, Break, Missing

Connection table

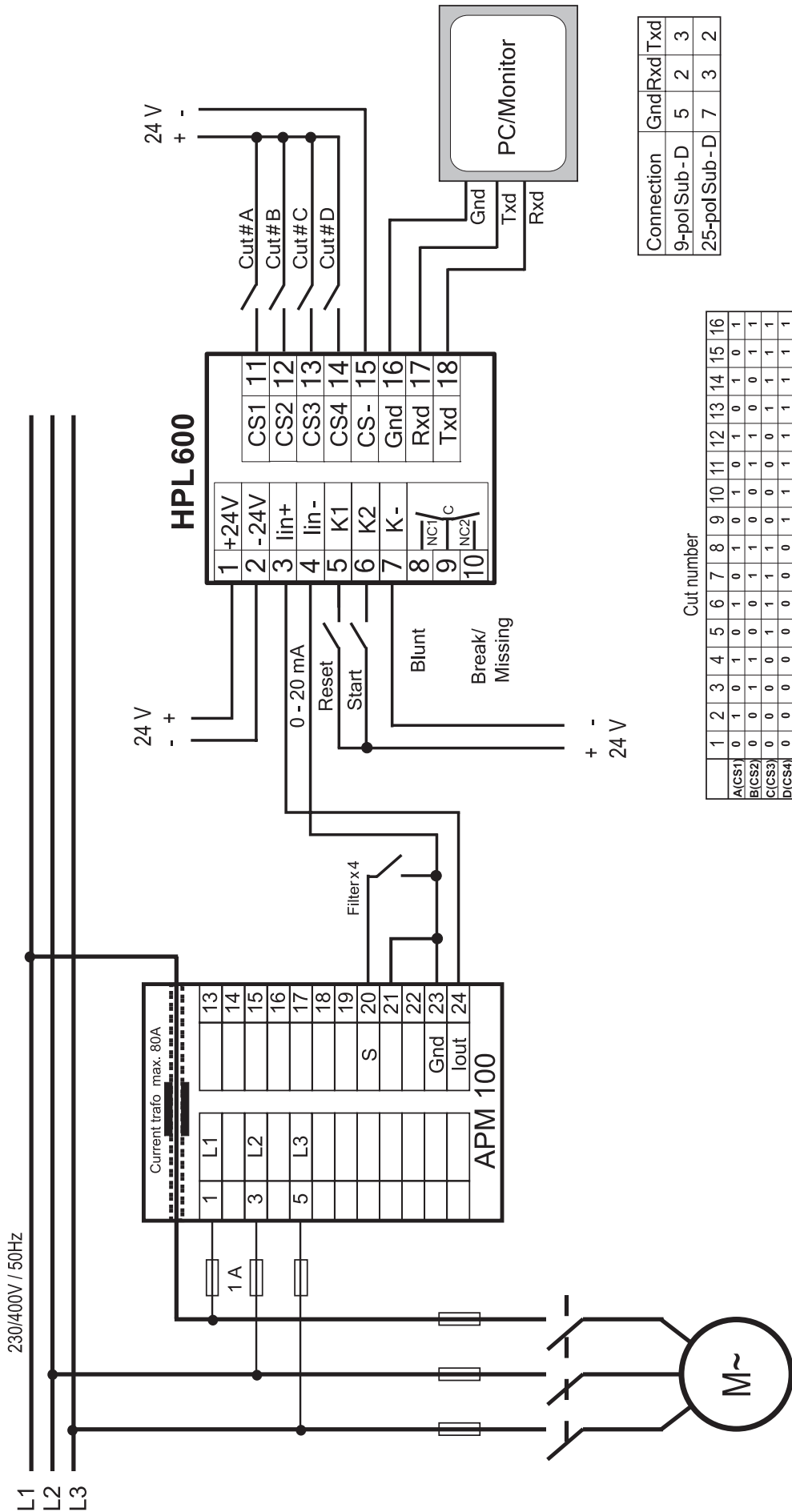| Connection	Gnd	Rxd	Txd
9-pol Sub-D	5	2	3
25-pol Sub-D	7	3	2

Cut number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A(CS1)	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B(CS2)	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
C(CS3)	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
D(CS4)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Filter

Filter	S5(25)	S4(26)
200 ms	1	1
80 ms	0	1
40 ms	1	0
20 ms	0	0

APM 380

19	12V		
20	+SO1		
21	.SO1		
22	GND		
23	12V		
24	S6		
25	S5		
26	S4		
27	S3		
28	S2		
29	S1		
30	GND		
31	TX		
32	RX		
33	GND		
34	+Vout		
35	GND		
36	+Iout		

1	U(L1)	
2		
3	V(L2)	
4		
5	W(L3)	
6		
7	N	
8		
9		
10		
11		
12		
13		
14		
15		
16		
17	-24V	
18	+24V	

24V + / –

Frequency-inverter

U V W

1 A

L1 L2 L3

Unipower APM 380

M~

HPL 600

APM 100

PC/Monitor

Connection	Gnd	Rxd	Txd
9-pol Sub-D	5	2	3
25-pol Sub-D	7	3	2

HPL 600 terminals:

1	+24V	
2	-24V	
3	Iin+	
4	Iin-	
5	K1	
6	K2	
7	K-	
8	NC1	
9	C	
10	NC2	
11	CS1	
12	CS2	
13	CS3	
14	CS4	
15	CS-	
16	Gnd	
17	Rxd	
18	Txd	

Cut#A, Cut#B, Cut#C, Cut#D

24 V + -

24 V - +

0 - 20 mA

Reset

Start

Blunt

Break/ Missing

+ - 24 V

Filter x4

230/400V / 50Hz

L1 L2 L3

Current trafo max. 80A

1 A

M ~

APM 100 terminals: L1 (1), L2 (3), L3 (5), 13, 14, 15, 16, 17, 18, 19, 20 S, 21, 22, 23 Gnd, 24 Iout

Cut number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A(CS1)	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
B(CS2)	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
C(CS3)	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
D(CS4)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Gnd, Txd, Rxd

3. Unipower HPL600

3.1 Display

The HPL600 integrates a 4 digit numerical display and 8 LEDs used to indicate any preselected function. In addition 5 LEDs are used as status indicators. 'Start' indicates when a start signal has been received from the CNC. 'Active' indicates when the HPL600 is supervising a process. 'Break', 'Blunt' and 'Missing' indicate alarm conditions.

The Numerical display has several other functions. Besides showing power the display is also used when showing and programming parameters. A complete list of parameters are shown on page 11.

3.2 Programming

The HPL600 is programmed by using 3 keys located on the face plate - 'Mode', 'Up arrow' and 'Down arrow'. 'Mode' is used to select any programmable parameter. When a parameter has been selected the value of the parameter is increased by pressing the 'Up arrow' and decreased by pressing the 'Down arrow'. A 'Reset' key is also found on the face plate. 'Reset' is mainly used for resetting alarms.

When programming the HPL600 the unit has to be unlocked. This is done by pressing 'Mode' until 'Locked' is lit. The text 'On' is shown in the display. Press either one of the arrow keys and the message 'Off' is shown in the display indicating that the unit is unlocked. If no key has been pressed for 5 minutes the unit is automatically locked.

Limit values and corresponding reaction timers 'Tr' are directly accessible. Supervision parameters are changeable under 'Parameter' as indicated on page 11. In the text to follow parameters are shown in bold face. Programmed values are stored in EEProm.

3.3 Digitizing

The 0-20mA analogue input signal is amplified and fed into a 10 bit A/D converter integrated in the microprocessor. Conversion is done every 10 ms. The HPL600 is capable of calculating an average value and the number of conversions used for this average is set under **Parameter 13**. Setting a higher value makes it possible to monitor noisy signals.

3.4 Zoom function

The HPL600 integrates a zoom function which is used when monitoring on power signals that are small compared to the idle power consumption of the spindle motor.

An example: A tool machine is capable of using a number of different tools. The spindle motor is powerful enough to use a 20 mm drill for one operation. In another operation a 3 mm drill is used. This operation requires much
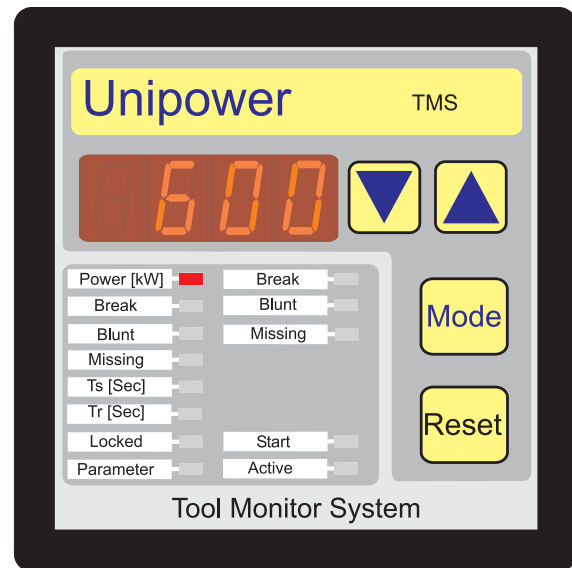
less power but the idle power consumption is higher due to a higher rotational speed. In fig. 1 a typical power consumption curve is shown. The idle power consumption is approx 50%. The increase in power consumption is approx. 10% during operation. Zoom is enabled and P1(min) is set to 40% and P1(max) is set to 70%. This changes the original span of 30% to 100%.
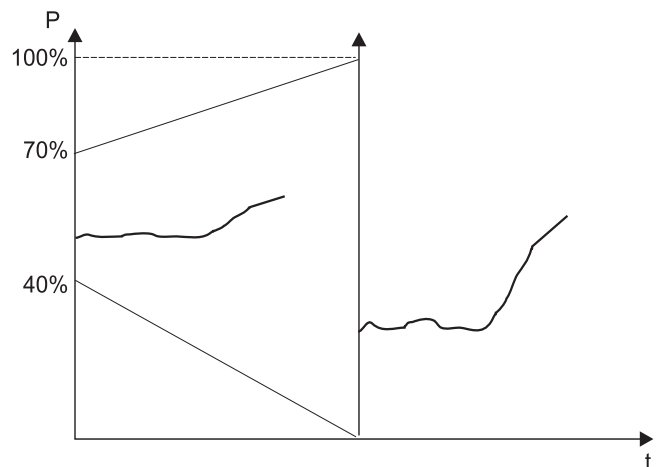

Fig 1. Zoom function

3.5 kW measurement transducer

This instruction is based on the use of kW measurement when monitoring the spindle motor power consumption. Using Unipower APM380 or APM100 is recommended. The APM100 is set to the maximum power consumption of the tool machine. The APM380 is set to the mains voltage and the current range is set to the maximum current used by the spindel.

A signal from the spindle drive may also be used as kW-signal.

4. Systems specification

4.1 Generally

The purpose of the TMS is mainly to monitor for breaks and bluntness of tools used in tool machinery. Further more the TMS i capable of registrering whether a tool/material is present.

The systems specification is based on a system consisting of an HPL600 connected to an APM100 or APM380 hence the basis of the tool supervision is power consumption measurement of the spindle motor.

Prior to installation of the system please consider if supervision is possible via power measurement or if supervision should be established by other means e.g. torque sensoring.

In most applications power measurement is possible but in some cases this method is not applicable; 1. Lathe processes continuously changing revolution speed. 2. Drilling heads using more than 4 tools. 3. Small tools driven by very large spindle motors.

In the following paragraphs different measurement and supervision strategies are described in detail.

Fig 2. Tool break supervision
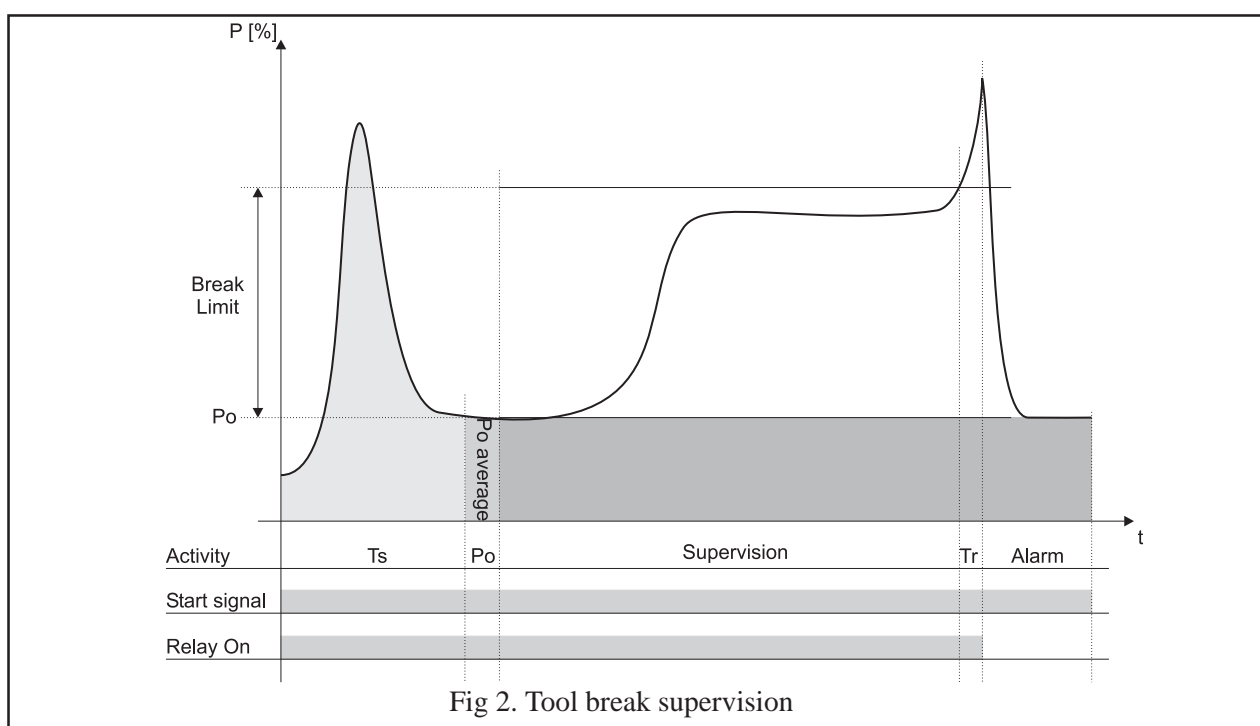
4.2 Indirect torque measurement, Po

Measurement transducer APM380 or APM100 mea-sure the total spindle motor power consumption P1. In order to calculate the spindle motor shaft power P2 it is necessary to measure the spindle motor idle power consumption Po before the tool engages the material. When Po is measured the value of Po is subtracted P1 giving P2. The value of P2 is used for calculations later on. Po is an average value of a number of samples. The number of samples is set under **Parameter 12**. A fluctuating signal requires a higher number of samples. In figure 2 Po is shown as the height of the dark rectangle. The graph above Po is the power consumption as a function of time t.

4.3 Start signal

The HPL600 requires a start signal on input K2 from the CNC. The signal must be applied before the tool engages the material and after a possible change of revolutions on the spindle motor. If the latter is not possible a start delay Ts should be used.

4.4 Start delay Ts

The start delay Ts is introduced in order to be able to delay the point where the HPL600 becomes active, compared to the point where the start signal from the tool machine CNC is generated. In figure 2 is shown an example where a start signal is generated at the same time as the motor starts. The power graph shown between start and expiration of Ts represents the initial power consumption of the motor. Po measurement is not allowed in this time span. This part of the power graph could also be generated by changing the number of revolutions of the motor. It must be emphasized that measurement of Po is done at a point where the power signal is steady and before the tool engages the material.

4.5 Alarm reset

An alarm is reset by pressing the 'Reset' button on the HPL600 or by activating input K1. **Alarms must be reset prior to a new start signal.**

5. Break supervision

Fig.3 Break supervision using Ta
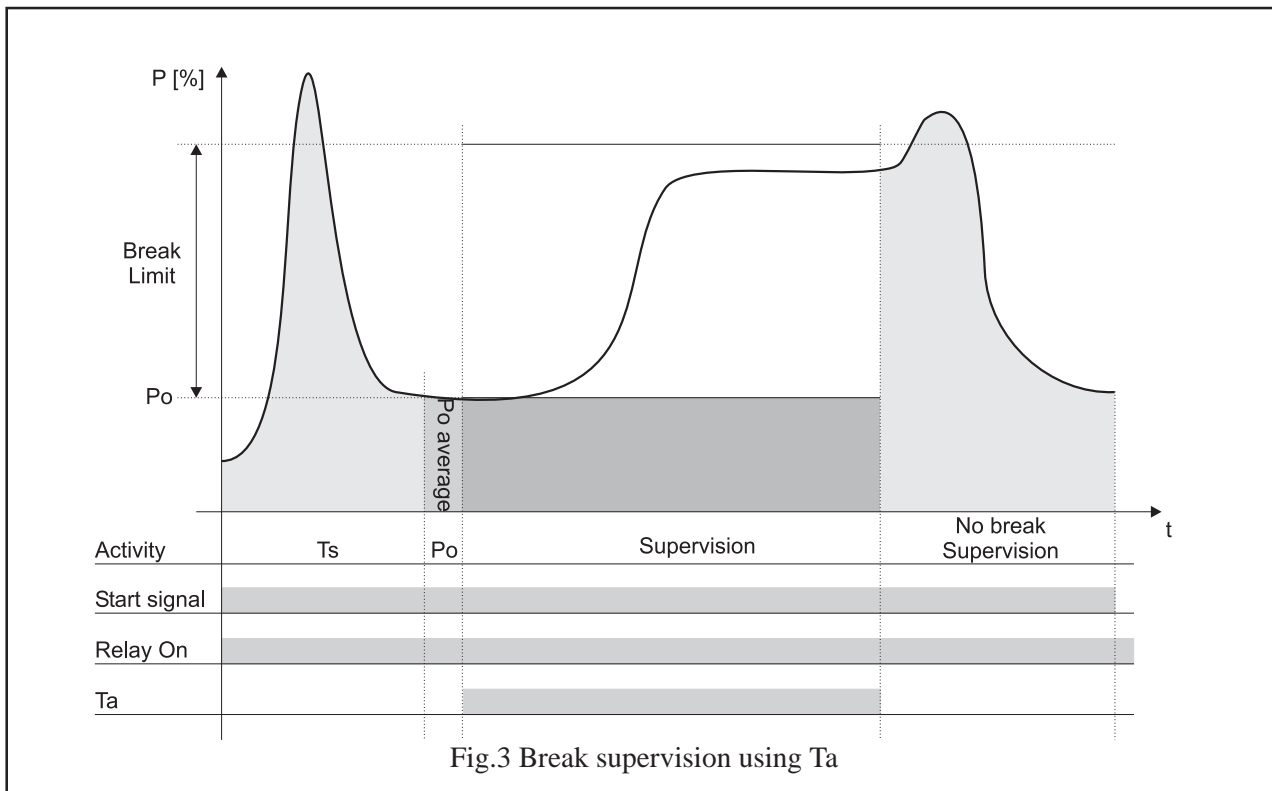
5.1 Break supervision
Figure 2 shows a machining cycle using break supervision. Following Start, Ts and Po measurement, a power graph originating from a drilling operation is shown. In the end of the power graph is shown a sudden increase in power consumption. The break limit is exceeded, a corresponding
timer **Tr** expires, switches the relay and the process is expected to stop. The power graph shown is typical to a tool break.

5.2 Break limit value and Tr.
Tr is defined as the duration of time for which the power consumption must be higher than the break limit before an alarm is generated. The limit is set between 0 and 100% of the measuring range or the zoom range if used.

5.3 Error message Er1
A possible error may occur: As described above the break limit is set as a percentage of the measurement range but the power consumption concerning the tooling is not known until Po is measured. If Po added to the break limit exceeds 100%, it is not possible to generate an alarm in which case an alarm is generated on both relays and the display will read 'Er1'. If a PC with TMSMon installed is connected, the power graph following Po will be presented in yellow and an error message 'Er1' is shown on the PC monitor.
It is possible to prevent an 'Er1' fault by changing the measurement range, the zoom range or by changing the break limit.

5.4 Break supervision using Ta
The HPL600 integrates a function, **Ta**, which makes it possible to perform a time limited supervision operation independant of the start signal. Ta is found under **Parameter 6** and is set to a desired time interval. By default **Ta** is 'Off' and consequently the supervision follows the start signal.
Ta is used when it is desired only to supervise the beginning of a machining cycle. For instance a drilling operation ended with deburring which hereby is not supervised. An example is shown in figure 3.
Another example could be supervision of a step drill operation using break supervision on the initial drilling operation and blunt supervision on the second drilling operation. In this case **Parameter 7** must be set to 'Off'.
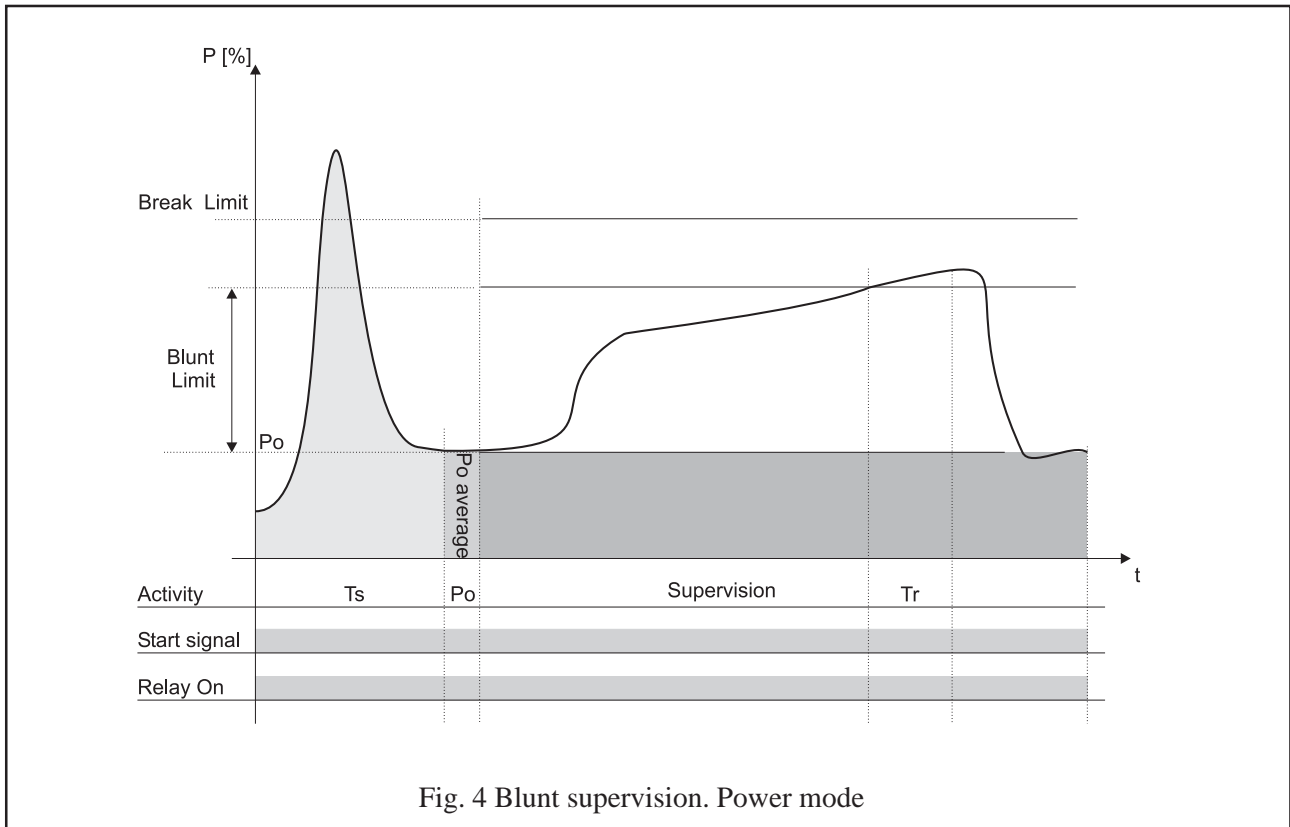
6. Blunt supervision

6.1 Generally

Tool blunt supervision is the most important type of supervision in the TMS. Given a correct feed and number of revolutions compared to the condition of a tool, a tool which is not worn very rarely breaks during normal operation. Hence the importance of registering tool bluntness in time to avoid tool breaks. The HPL600 is capable of registering tool bluntness in two ways.

1. Supervision based on power and time (long Tr).
2. Supervision based on work (integration of power over time). Each method is selectable under **Parameter 8** or via PC (TMSMon).

The HPL600 also integrates a blunt alarm counter as well as the function **Ta** is applicable while using blunt supervision. Each function is described below.

Fig. 4 Blunt supervision. Power mode

6.2 Blunt supervision. Power mode

In principle this method is the same as when using break supervision. In figure 4 is shown a typical power graph of a drilling operation. Besides the break limit a blunt limit is
also shown. The blunt limit is exceeded in a time span Tr resulting in a blunt alarm. The blunt limit is set to a value below the break limit and Tr is typically measured in seconds. Setting a blunt limit can be done by reading out the peak value of a new tool either on the display of the HPL600 or on the PC monitor. The limit is set 10 or 20% higher.

6.3 Blunt alarm mode

In **parameter 9** it is possible to choose between two types of blunt alarm mode - 'End' or 'Immidiate'. By 'End' the alarm is generated after expiration of the start signal. By 'Immidiate' the alarm is generated as soon as the blunt alarm is detected. Usually the 'End' mode is selected. The

worn tool is propably able to complete the actual cut after which the tool should be changed.

6.4 Blunt alarm counter

At some working processes there may be uncertainty whether a blunt alarm is valid or not. This could be due to unstable feed, variation in material quality for example cast iron, unstable supply of cutting oil etc. In such cases it may be advantageous to enable a blunt alarm counter which is programmed to generate an alarm after a number of successive blunt alarms. The blunt alarm counter is programmed under **parameter 10** or via TMSMon. As an example the counter is set to 5. Consequently 5 successive blunt alarms must occur before an alarm is generated.

6.5 Supervision using Ta

The fundamental use of **Ta** is described in paragraph 5.4. The use of **Ta** on blunt mode monitoring is set under **Parameter 7**.
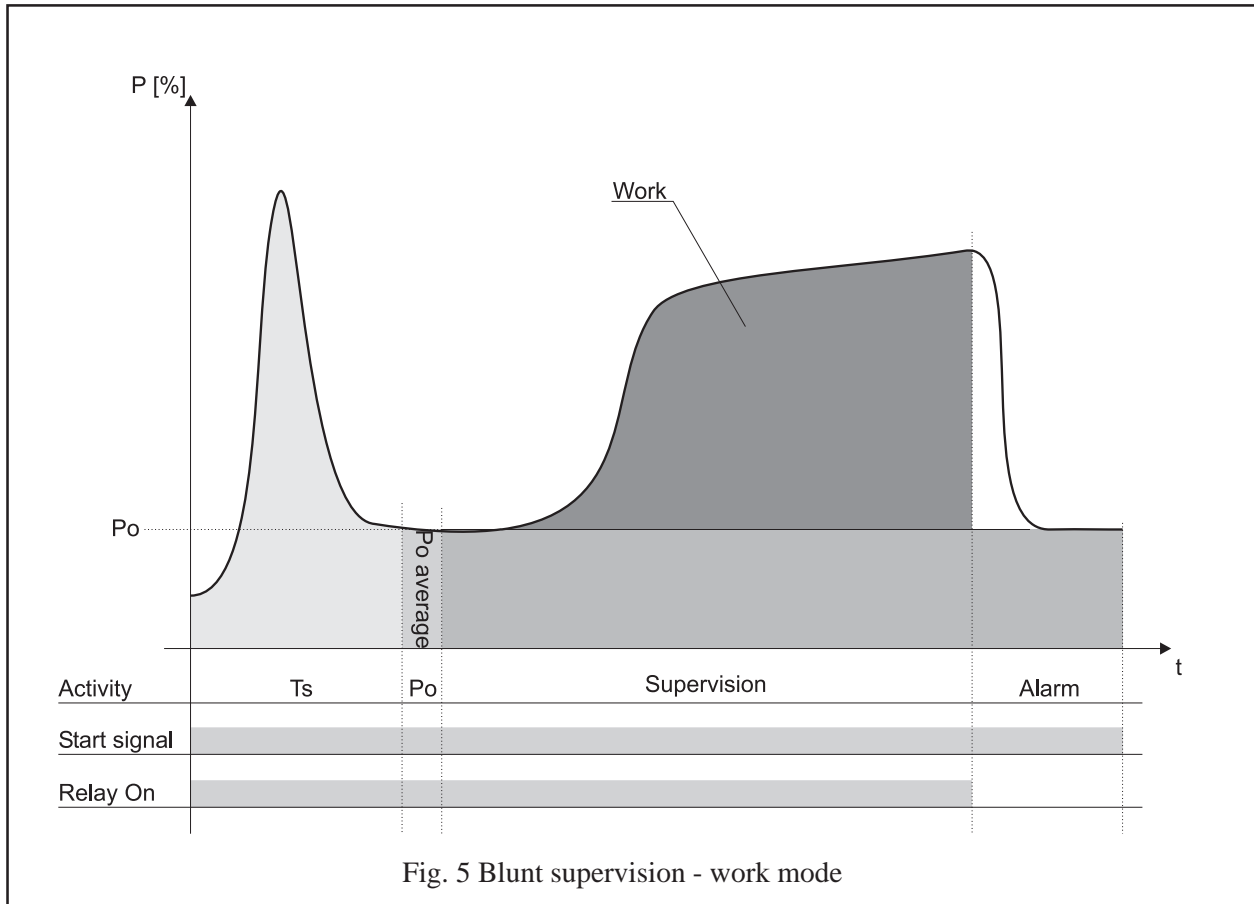
Fig. 5 Blunt supervision - work mode

6.6 Blunt supervision - work mode

When the HPL600 is set to measure work via **Parameter 8,** the following functionality for blunt mode monitoring is obtained:

In figure 5 a typical tooling process is shown. After having measured Po, the area below the power graph is measured by integrating all measurement samples. The area below the graph represents the amount of work needed to complete

the tooling process. If the value of the measured amount of work exceeds a preset limit, an alarm is generated. An example is shown in figure 5 where an alarm is generated immediately. The point of alarm which is set under **Parameter 9** is also used here. See paragraph 6.3.

The integrated work value is numerically capable of becoming very large and is of course also dependent on the duration and the power consumption of the tooling process. As all limit ranges in the HPL600 is given as a percentage between 0 and 100%, a work divisor is introduced. Its meaning is described below.

6.7 Work divisor

Under **Parameter 4** a number between 1 and 16 is selectable. The number is a power of 2, hence the divisor can assume values as 2, 4, 8, 16, 32,... etc. The number is used for division of the integrated work value, thus making it possible to keep the display value of the tooling process between 0 and 100%. Setting the value of the divisor in such a way that the display value is kept between 50% and 70% after ending the tooling process is recommended. This leaves room for setting limit values up to 100%.

Setting the value of the divisor could be done in the following manner: Let the tooling machine do normal machining cycles using a sharp tool (disable the relays via **Parameter 18** if necessary). If the display shows a small value after the tooling process has ended a smaller divisor value should be chosen. Conversely a higher divisor value is chosen if the display shows 100% after the tooling process has ended.

6.8 Supervision using Ta

Ta is applicable in the same manner as when using power mode supervision. The function is toggled under **Parameter 7**.

7. Missing supervision

Fig. 6 Missing supervision
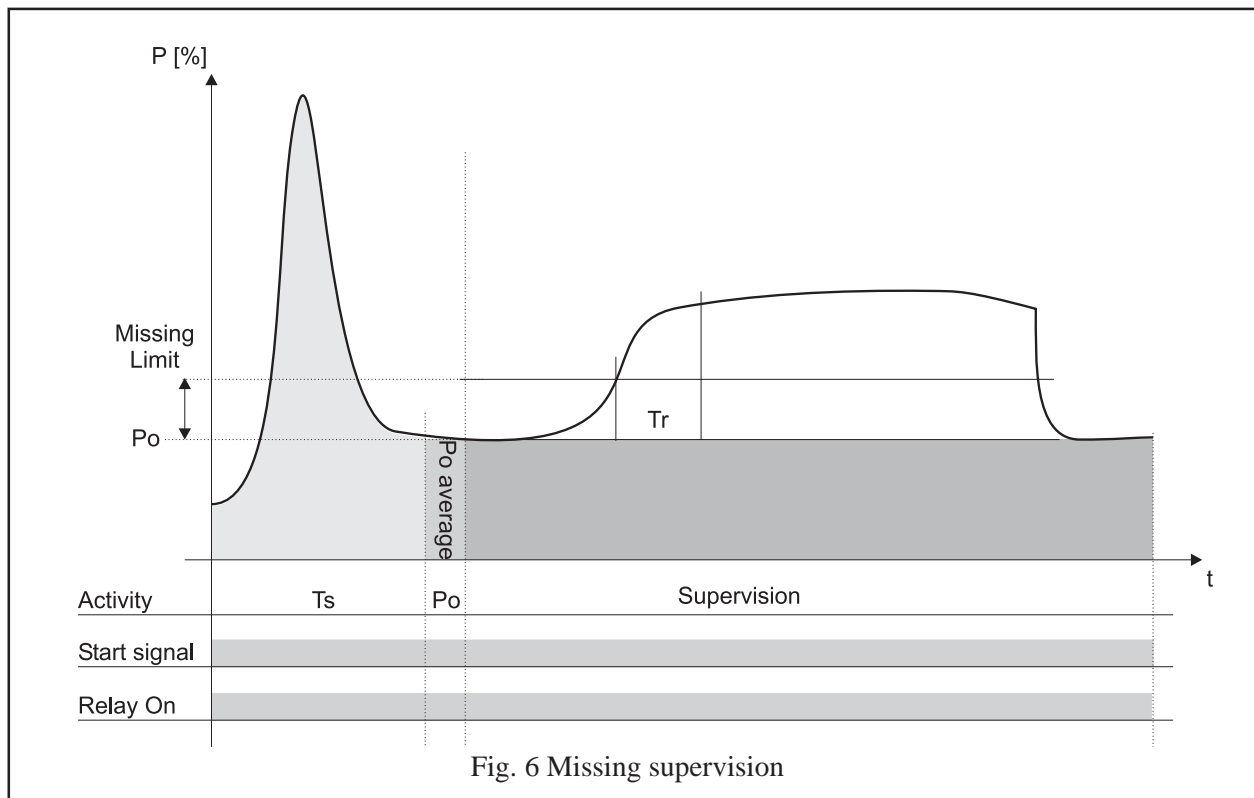
7.1 Missing limit and Tr

The concept 'Missing' is to be understood as detection of a tool missing or lacking of material. The missing limit is typically set to a value of 5 to 10% and Tr is typically set between 1 and 5 sec. The function is as follows: After expiration of **Ts** and measurement of Po an increase in power consumption is expected signalling that the tooling has begun. **Tr** is the amount of time in which the power consumption must be greater than the limit in order to approve the process. A missing alarm is generated after expiration of the start signal or by expiration of Ta, if active. A tooling process without a missing alarm is shown in figure 6.

7.2 Missing timer Tw.

Parameter 5 is used for chosing a timer **Tw**. If an increase in power consumption is not recorded during **Tr** seconds within **Tw** seconds, an alarm is generated.

7.3 Missing alarm counter

Under **parameter 11** is a programmable counter used for recording a number of successive missing alarms. As an example the counter is set to 5. Consequently 5 successive missing alarms must occur before an alarm is generated and the relay is toggled.

8. Cut number

8.1 Selecting a cut number

The HPL600 is capable of storing data from 16 cuts or operations. The active cut is selected by the CNC via inputs CS1-CS4. The inputs are read at the same time as the start signal and are valid until the next start signal is read.

When the keyboard on the unit is used for changing parameters, limits etc., the changes are always made on the active cut number. Changing data for other cut numbers is done by using the PC software TMSMon. The active cut number may be displayed by pressing the 'Up arrow' and 'Mode' keys simultaneously.

An outline on information of cut number codes are shown on pages 3 and 4.

Caution: If changes to parameters and limits are made via the HPL600 keyboard at the same time as a start signal and a set of new cut number codes are received, the changes may be stored under the new cut number and not the original active cut number as intended. Setting the tool machine on 'Stand by' while making changes is recommended. If possible please use a PC with TMSMon installed when making changes, hence the risk of errors as described above is eliminated.

9. Parameters

9.1 Setting Parameters

All parameters, their function and range are listed below. The name 'Global' indicates that the selected parameter is common to all cuts.

To change a parameter first unlock the HPL600. Then select 'Parameter' by pressing 'Mode' and select the parameter number by pressing one of the arrow keys. When the desired parameter number is displayed press 'Mode' again and the parameter is now changeable using of the arrow keys. When changes are made press 'Mode'. Pressing the 'Reset' key the HPL600 will show Power[kW] again.

Parameter	Function	Programming	Notes
Parameter 01	Firmware	----	
Parameter 02	P1 Max Zoom	10-100%	Cut Parameter
Parameter 03	P1 Min Zoom	0-90%	Cut Parameter
Parameter 04	Work divisor	1-16	Cut Parameter
Parameter 05	Tw	0,1-25,0 s and Off	Cut Parameter
Parameter 06	Ta	0,1-25,0 s and Off	Cut Parameter
Parameter 07	Ta on Blunt	0=No, 1=Yes	Cut Parameter
Parameter 08	Blunt Mode	0=Power, 1=Work	Cut Parameter
Parameter 09	Blunt alarm Mode	0=End, 1=Immediately	Cut Parameter
Parameter 10	Blunt counter	1-8,	Cut Parameter
Parameter 11	Missing counter	1-8,	Cut Parameter
Parameter 12	Po average	1-25 samples	Global Parameter
Parameter 13	Measurement average	1-25 samples	Global Parameter
Parameter 14	Cycles / screen	1-8	Cut Parameter
Parameter 15	Debounce	1-8 samples	Global Parameter
Parameter 16	kW Range	0.01-999 kW	No Function
Parameter 17	Unit ID	1-255	Global Parameter
Parameter 18 *)	Relais Active	ON, Off	Global Function

*) **Note:** This function is useful during setup of a machine. When the relays are inactive the Power[kW] LED is flashing.

10. Display information

10.1 Numerical display

The numerical display has several functions. It is primarily used for showing process values, but as described earlier it is also used when programming the unit. The display read out is dependent on which blunt mode supervision is selected. Below is an outline showing the changes when blunt supervision is changed from 'Power' to 'Work'. +Start signal indicates that the start signal is active. -Start signal indicates that the start signal is inactive. 'Peak' are peak values which are continously recorded during a process. SW means software version.

Blunt mode	+Start signal	-Start signal	↑ Arrow key	↓ Arrow key	↑ + ↓	↑ + Mode	↓ + Mode
Power	P2	Rel. Peak	Abs. Peak	Work	Po	Cut#	SW
Work	P2	Work	Abs. Peak	Rel. Peak	Po	Cut#	SW

10.2. Limits and timers

Directly selectable limits and timers and their corresponding ranges are listed below.

Start delay Ts: 0.0 -25,0 sec.

Break limit: 5-100%
Delay Tr: 0,0-2,5 sec.

Blunt limit: 1-100%   0% => Off
Delay Tr: 0.0-25,0 sec.

Missing limit: 1-100%   0% => Off
Missing timer Tr: 0.0-25,0 sec.

11. Teknical Specifications

Mechanical		**Electrical**	
Housing:	Noryl UL94V-0	Supply:	24V= +/- 20%
Mounting:	DIN 72X72 panel mounting	Power consumption:	3VA
IP class:	Front IP55. Terminals IP20	Analog input:	0-20 mA
Terminals:	Max 16A. Max 2,5 mm^2	Input resistance:	51Ω
	Max torque 4lb/in, 0,6 Nm	Control input:	12-30VDC
Temp.:	-15 to +50 ºC	Relay ratings:	250V/5Aac.
Weight:	200 g	Serial comm.	RS232C
Dimensions:	W 72 x H 72 x D 70 mm	Baud rate:	19.2 kBaud
Mount. hole:	68 x 68 mm	CE mark to:	EN61326-1, EN61010-1