SIEMENS

# Totally Integrated Automation

## PCS 7 PumpMon V1.0

Block Description

Version 2.1

# Description of PumpMon

**Object name** (type + number)
FB 1054

**Calling OBs**
The watchdog interrupt OB in which the block is installed (e.g. OB32). Also in OB 100 (see startup characteristics).

**Called blocks**
The block calls the following blocks:

| | |
|---|---|
| SFB35 | ALARM_8P |
| SFC6 | RD_SINFO |

**Function**
Power and process plants play a key role in the manufacture of virtually every product on the market today.
Pumps are among the most important machines used in these plants. Around 20% of the world's electrical energy consumption is used by pumps. If a pump fails, this can cause an entire plant to shut down and the resulting losses can quickly exceed the value of the pump many times over.
This is why the availability of pumps is an extremely important factor. Redundant systems and special monitoring systems are sometimes implemented to ensure the required availability, but they can be very expensive and complex.
The scope for saving energy, on the other hand, has yet to be fully leveraged.
The PumpMon block for monitoring PCS 7 centrifugal pumps was developed as a cost-efficient monitoring solution and to leverage potential for saving energy.

PumpMon is used to:

- warn against potential damage to pumps under unfavorable operating conditions
- provide early warning of developing damage to pumps
- optimize the pump design over the long term by means of statistical analyses of the operating data (load profile)

The block can be used for electrically driven centrifugal pumps with constant or variable speed.

PumpMon can inform operators of any violations of the nominal pump operating range and of deviations from the expected characteristic, and makes this data available for further processing via the block outputs. Of course, all the values can be processed further by means of the usual PCS 7 tools (calculations, trend recording, alarm history, and so on).

The block itself is designed purely for diagnostic purposes and, as such, does not intervene directly in the operation of the pump. This means that it can be deployed, or even retrofitted, without the risk of affecting the process. If required, active intervention (e.g. to reduce the speed of the pump in response to imminent cavitation) can be undertaken by evaluating the block outputs.

The following technical characteristic data is made available to the operator in the form of characteristics:

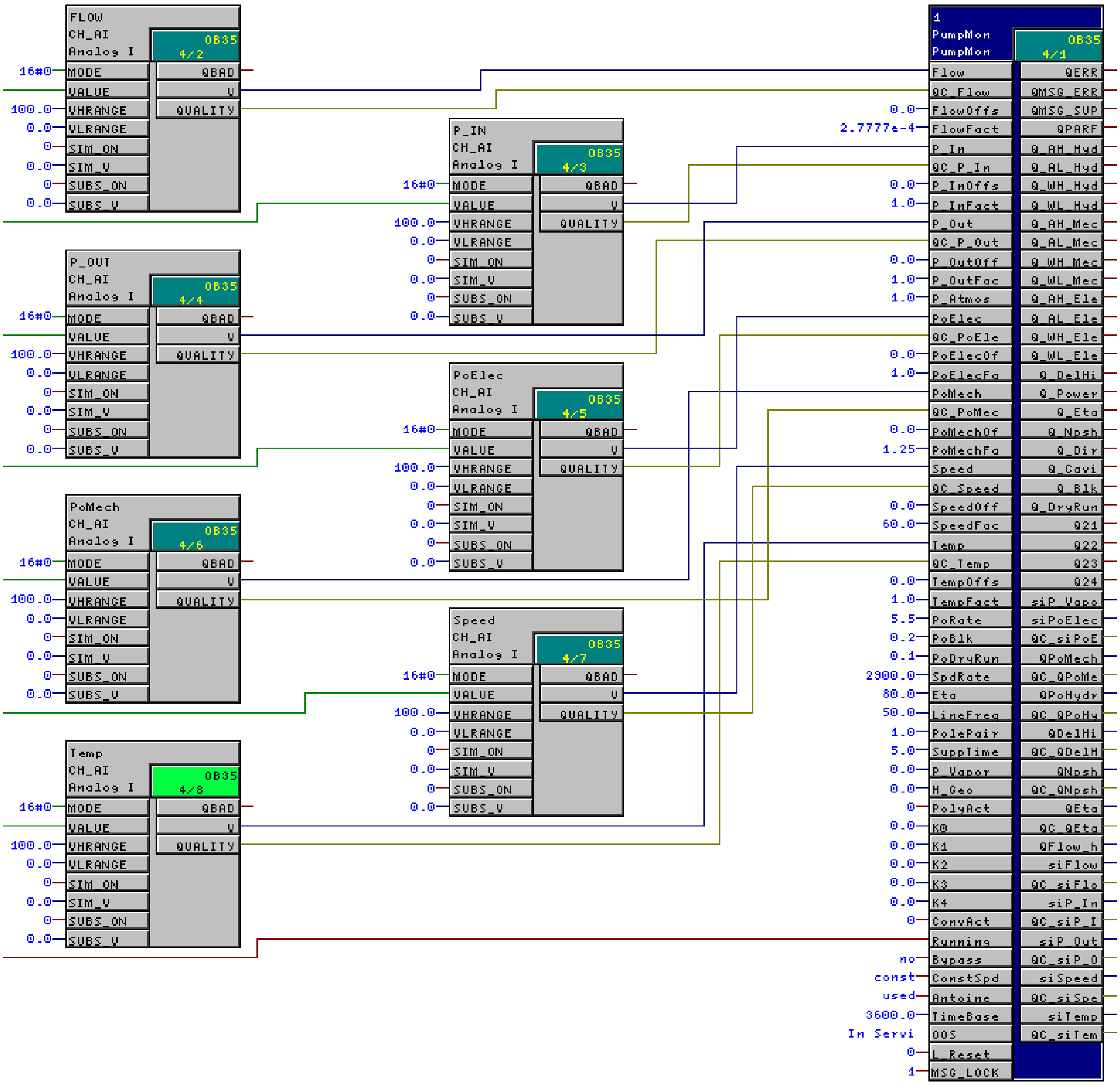
**H/Q characteristic:**
Delivery height as a function of the flow rate

**P/Q characteristic:**
Pump power data as a function of the flow rate and pump efficiency

**NPSH/Q characteristic:**
NPSH value as a function of the flow rate

**Configuration in the CFC**

The block monitors the effective electrical power of the motor, the flow rate, the inlet/outlet pressure of the pump, the temperature of the pumped medium, and a binary signal indicating whether or not the motor is running. These signals must be provided by upstream blocks.




The following input signals must be interconnected:

- ***Flow*** (flow rate of pumped medium)
- ***P_In*** (inlet pressure, intake pressure)
- ***P_Out*** (outlet pressure, delivery pressure)
- ***PoElec*** (effective electrical power)
- ***Temp*** (temperature of pumped medium)
- ***Running*** (binary signal indicating whether or not motor is running)

The following inputs must also be interconnected for variable-speed motors (***ConstSpd*** input = FALSE):

- ***Speed*** (speed)
- **PoMech** (mechanical power from converter when ***ConvAct*** = TRUE)

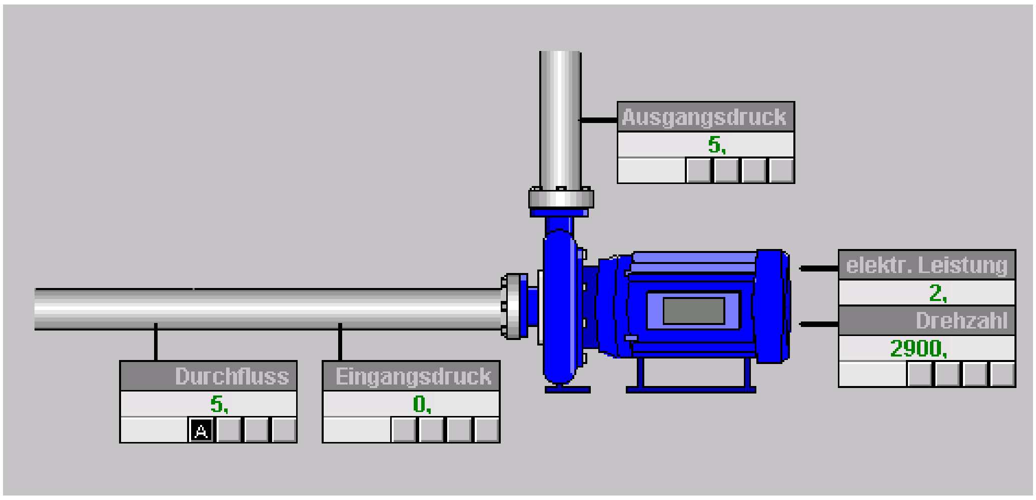
**Startup characteristics**
In OB100 and 102, the outputs are set to default values.

**Requirements**
Data for:

- Medium (density, vapor pressure (if relevant))
- Motor (rated power, rated speed, polynomial for dependency between mechanical pump input power as a function of electrical power (if relevant))
- Pump (diameter of intake and pressure sockets, characteristics for delivery height, mechanical power, efficiency, and NPSH value as a function of flow rate)

**Operating principle**
In the CFC, PumpMon block is supplied with current process values via the inputs ***Flow*** (flow rate), ***P_In*** (inlet pressure, pump intake pressure), ***P_Out*** (pump outlet pressure), ***PoElec*** (effective electrical power of motor), and ***Temp*** (temperature of pumped medium).
The ***Speed*** input is also required for variable-speed drives.

The binary input ***Running*** signals whether or not the motor is running. An interval can be parameterized via the ***SuppTime*** input. When the motor is switched on, all messages are blocked until this time has elapsed. The default value is 5 [sec]; when ***SuppTime*** = 0, this suppress time is not effective.




Preprocessing
The process values are normalized to SI units via the ***Offs** and ***Fact** inputs. The normalized values are output again at the output. The status signals of the process values (quality code) are not evaluated but are instead output again at the output.

| | | | | | |
|---|---|---|---|---|---|
| ***siFlow*** | ***= FlowOffs*** | ***+ FlowFact*** | **** Flow*** | | (normalize to $m^3/s$) |
| ***siP_In*** | ***= P_Atmos*** | ***+ P_InOffs*** | ***+ P_InFact*** | **** P_In*** | (normalize to bar) |
| ***siP_Out*** | ***= P_Atmos*** | ***+ P_OutOffs*** | ***+ P_OutFact*** | **** P_Out*** | (normalize to bar) |
| ***siPoElec*** | ***= PoElecOffs*** | ***+ PoElecFact*** | **** PoElec*** | | (normalize to kW) |
| ***siSpeed*** | ***= SpeedOffs*** | ***+ SpeedFact*** | **** Speed*** | | (normalize to rpm) |
| ***siTemp*** | ***= TempOffs*** | ***+ TempFact*** | **** Temp*** | | (normalize to °C) |

When the temperature value is normalized, note that the generally-applicable factors and offsets for temperature conversion need to be adjusted. The following applies:
***TempFact*** = 1 / default factor
***TempOffs*** = - default offset / default factor

| Input variable | default factor | *TempFact* | default offset | *TempOffs* |
|---|---|---|---|---|
| °F | 1.8 | 0.555556 | 32.0 | -17.777779 |
| K | 1.0 | 1.0 | 273.15 | -273.15 |

***P_Atmos*** is the air pressure that must be added to the measured pressures ***P_In*** and ***P_Out*** as an offset if the measured values only determine the overpressure.

Calculating the mechanical power
Three different variants are used in PumpMon:
1. Calculation for standardized motors (default setting).
   In this case, the operator only has to specify the efficiency and rated power of the motor.
2. Calculation for other motors, e.g. canned motor pumps (parameterization: ***PolyAct*** = TRUE, ***ConvAct*** = FALSE).
   A unique motor characteristic must exist here; the mechanical power is then calculated from the electrical power by means of a polynomial of the 4th order:
   $$QPoMech = CorrMech * (K0 + K1 * siPoElec + K2 * siPoElec^2 + K3 * siPoElec^3 + K4 * siPoElec^4)$$
   In this case, the ***Eta*** parameter is not taken into account. The coefficients ***K0*** to ***K4*** must be supplied by the manufacturer of the motor/pump.
3. The mechanical power is taken from a converter (parameterization: ***PolyAct*** = FALSE, ***ConvAct*** = TRUE)
   If a converter outputs both the electrical and the mechanical power, this value is read by PumpMon via the ***PoMech*** input and, if necessary, normalized with the ***PoMechOffs*** and ***PoMechFact*** parameters.

Slip correction
Variable-speed motors exhibit slip loss, which affects the measured speed and the mechanical power.
Slip correction can only be carried out for variable-speed motors as no speed is measured in other cases. For this reason, the setting is reset for constant-speed motors.

Calculating the delivery height
The delivery height is calculated from the pressure difference and density of the medium in the pump.
The calculated delivery height is limited to the value range 0...***MaxDelHi***. If this is exceeded, the quality code ***QC_QDelHi*** is set to 16#82; if undershot, the quality code is set to 16#81.

Calculating the hydraulic power
The hydraulic power is calculated from the normalized flow rate, the delivery height, and the density of the medium.
The calculated power is limited to the value range 0...***MaxPower***. If this is exceeded, the quality code ***QC_QPoHydr*** is set to 16#82; if undershot, the quality code is set to 16#81.

Calculating the NPSH value
NPSH stands for **N**et **P**ositive **S**uction **H**ead. The NPSH value is, along with the flow rate and delivery height, one of the key characteristic values of a pump. To ensure that the pump operates smoothly, the following must apply:
NPSH (plant) > NPSH (pump), otherwise cavitation will result.

The current NPSH value of the plant (NPSHa) is calculated from, among other things, the vapor pressure, which can be calculated in accordance with an Antoine equation (***Antoine*** input = TRUE).

Vapor pressure = factor * $10^{(A - B/(siTemp + C))}$

The default values for water in the 1 … 100°C range are:
***AntA*** = 8.07131
***AntB*** = 1730.63
***AntC*** = 233.426
***AntFact*** = 0.0013332 as a conversion factor from [mmHg] (Torr) to [bar]

For other media The parameters must be adapted accordingly. If the integrated vapor pressure calculation in accordance with Antoine is not used (***Antoine*** input = FALSE), the input value ***P_Vapor*** [bar] is used.
The calculated NPSH value is limited to the value range 0...***MaxNpsh***. If this is exceeded, the quality code ***QC_QNpsh*** is set to 16#82; if undershot, the quality code is set to 16#81.

<u>Calculating the efficiency Eta</u>
The efficiency is calculated from the ratio of the hydraulic power to the mechanical power.
The calculated efficiency ***Eta*** is limited to the value range 0...***MaxEta***. If this is exceeded, the quality code ***QC_QEta*** is set to 16#82; if undershot, the quality code is set to 16#81.

<u>Characteristic curves</u>
Four characteristics (delivery height, power, NPSH value, and efficiency) are stored in the block.
The characteristics each have 15 nodes, whereby the following applies:

| | | | | |
|---|---|---|---|---|
| x scale: | 0 <= ***Flow1*** | <= ***Flow2*** | <= ... <= ***Flow15*** | <= ***MaxFlow*** |
| y scale (delivery height): | 0 <= ***DelHi1*** | <= ***DelHi2*** | <= ... <= ***DelHi15*** | <= ***MaxDelHi*** |
| y scale (power): | 0 <= ***Power1*** | <= ***Power2*** | <= ... <= ***Power15*** | <= ***MaxPower*** |
| y scale (efficiency): | 0 <= ***Eta1*** | <= ***Eta2*** | <= ... <= ***Eta15*** | <= ***MaxEta*** |
| | | | | |
| x scale (NPSH): | 0 <= ***FlowNp1*** | <= ***FlowNp2*** | <= ... <= ***FlowNp15*** | <= ***MaxFlowNp*** |
| y scale (NPSH): | 0 <= ***Npsh1*** | <= ***Npsh2*** | <= ... <= ***Npsh15*** | <= ***MaxNpsh*** |

The x scale values do not have to be equidistant, but the time basis to which the values relate must be specified (e.g. ***TimeBase*** = 1 with scaling in $m^3/s$, but ***TimeBase*** = 3600 with scaling in $m^3/h$).
The NPSH characteristic has separate x values for the flow rate (***FlowNp1***, ..., ***FlowNp15***) because the characteristic cannot be determined by means of the teach function.

The input value for the characteristics is the normalized flow rate. The flow rate is normalized with the ***TimeBase*** factor. The output values of the characteristics are determined by means of linear interpolation.
The characteristic is not extrapolated beyond the operating range. If the flow rate value is less than the first node, the first y value is output. If the flow rate value is greater than the 15th node, the 15th y value is output.

The binary signals ***Q_DelHi, Q_Power, Q_Eta***, and ***Q_Npsh*** are set when the deviations from the characteristics are outside the configurable tolerances (***Tolxxx***) over a configurable period (***T_xxx***). The duration of each limit value violation is determined in separate counters.

<u>Special feature of variable-speed motors</u>
The input ***ConstSpd*** = "variable" (FALSE) must be set for variable-speed motors. In addition, a value must be specified for the rated speed ***SpdRate*** and the current speed must be read via the ***Speed*** input.

Blockage and dry running

The electrical power varies (non-linearly) with the motor load (i.e. the flow rate).
During dry running, the intake-side valve is closed, the flow rate of the pumped medium is zero, and the electrical power value is reduced to a minimum value ***PoDryRun***.
When a blockage is present, the discharge-side valve is closed, the flow rate of the pumped medium is again zero, and the electrical power value is ***PoBlk***.
The value during a blockage is higher than during dry running because the pump still contains pumped media, which is being circulated.

**Note:** The limit values ***PoBlk*** and ***PoDryRun*** only apply to operation under rated conditions. With variable-speed drives, the effective limits depend on the current speed.

Gas conveyance, cavitation, and incorrect direction of rotation

Gas conveyance: This is diagnosed when the delivery height falls but the NPSH value remains unchanged. A reduction in the delivery height can have a number of causes: gas conveyance, forming of cavitation, pump damage, etc.
Cavitation: This is diagnosed when the delivery height and NPSH value have violated the permissible limit values.
Incorrect direction of rotation: This is diagnosed when a significant deviation of the delivery height (< 60%) and smaller deviation of the power (> 80%) is detected; the motor was connected incorrectly and rotates in the wrong direction.

Determining the running time of the pump in different load ranges

The flow rate range 0...***MaxFlow*** is divided into 10 equal sub-ranges. Each of these sub-ranges is assigned a counter for the load period:
***Load1*** = 0..10% of ***MaxFlow***
***Load2*** = 10..20% of ***MaxFlow***
***Load3*** = 20..30% of ***MaxFlow***
***Load4*** = 30..40% of ***MaxFlow***
***Load5*** = 40..50% of ***MaxFlow***
***Load6*** = 50..60% of ***MaxFlow***
***Load7*** = 60..70% of ***MaxFlow***
***Load8*** = 70..80% of ***MaxFlow***
***Load9*** = 80..90% of ***MaxFlow***
***Load10*** = 90..100% of ***MaxFlow***

An additional counter is used to determine downtime.
*Load0* equates to the duration of the downtime (not ***Running*** or ***PoElec*** = 0)

The ***LoadReset*** input is used to reset the counters and the overall counter ***LoadTime*** to zero and restart them. The counters are also reset when ***MaxFlow*** is changed.
The ***LoadTime*** counter is incremented with the sampling time and specifies the monitoring duration in [h]. The individual counters are incremented on the basis of the flow rate value. They specify the running time of the pump for the sub-ranges resp. downtime in %.

Determining the histogram for deviations of the NPSH value from the characteristic

The flow rate range 0...***MaxFlow*** is divided into 10 sub-ranges. Each of these sub-ranges is assigned a counter for the load period:

***DevNpsh1*** = deviation of ***AbwNsph*** < -1 m
***DevNpsh2*** = deviation of ***AbwNpsh*** < 0.5 m
***DevNpsh3*** = deviation of ***AbwNpsh*** < 0 m
***DevNpsh4*** = deviation of ***AbwNpsh*** < + 0.5 m
***DevNpsh5*** = deviation of ***AbwNpsh*** < + 1 m
***DevNpsh6*** = deviation of ***AbwNpsh*** < + 1.5 m

***DevNpsh7*** = deviation of ***AbwNpsh*** < + 2 m
***DevNpsh8*** = deviation of ***AbwNpsh*** < + 2.5 m
***DevNpsh9*** = deviation of ***AbwNpsh*** < + 3 m
***DevNpsh10*** = deviation of ***AbwNpsh*** > + 3 m

An additional counter is used to determine downtime.
***DevNpsh0*** equates to the duration of the downtime (not ***Running*** or ***PoElec*** = 0)

The ***LoadReset*** input is used to reset the counters and the overall counter ***LoadTime*** to zero and restart them. The counters are also reset when ***MaxFlow*** is changed.
The ***LoadTime*** counter is incremented with the sampling time and specifies the monitoring duration in [h]. The individual counters are incremented on the basis of the NPSH value. They specify the running time of the pump for the sub-ranges resp. downtime in %.

The values are displayed in a histogram on the faceplate and indicate potential need for maintenance.

Teach function
The characteristics from the pump documentation should normally be used. If the documentation is not available or the current status of the pump is to be used as a reference, the individual pump operating points can also be approached manually and the value determined here for the flow rate, delivery height, power, and efficiency can be used as nodes for the characteristic values. The teach function can be used here as a tool for entering the nodes for the characteristics. The values calculated for the delivery height, power, and efficiency are used as nodes in the characteristics. The values can then be corrected manually if required.
Messages are suppressed while the teach function is active.

The position of the node is specified via ***PosTeach***. The ***PosTeach*** value range is 1..15. The teach function should only be used during operation under rated speed.
The NPSH characteristic cannot be determined via the teach function. The data on the pump data sheet must be used here.

Status signals
Two additional status signals are used to signal the status of the pump:
- ***Q_Run***: Motor running (= ***Running*** input)
- ***Q_StartUp***: Motor being ramped up (the motor is running, but the message suppress time is still active)

Bypass
With a bypass, an additional duct is used to convey pumped media from the discharge side back to the intake side of the pump. This is used to protect the pump and ensure that it is not damaged unintentionally.
A flow rate measurement will then normally be inaccurate because the flow rate through the bypass is not measured. In this case, a substitute value for the flow rate is determined on the basis of the mechanical power.
The flow rate value in the characteristic that equates to the mechanical power is used here. This calculation is only useful in the case of constant-speed pumps and when the power characteristic climbs continuously (no ambiguity).

When the flow rate is determined on the basis of the power characteristic, the power characteristic is no longer monitored.

**Time response**
The block must be called by means of a watchdog interrupt OB. The block sampling time is entered in the ***SAMPLE_T*** parameter (set automatically by the Wizard in the CFC during compilation).

**Quality code**
The **QC_Flow**, **QC_P_In**, **QC_P_Out**, **QC_PoElec**, **QC_PoMech**, **QC_Speed**, and **QC_Temp** parameters contain the quality codes for the input signals and must be interconnected with the QUALITY output on the associated driver blocks when the selected input signals are used. Depending on the signal type, the corresponding inputs are used to generate the following output-side quality codes: **QC_siPoElec**, **QC_QPoMech**, **QC_QPoHydr**, **QC_QDelHi**, **QC_QNpsh**, **QC_QEta**, **QC_siFlow**, **QC_siP_In**, **QC_siP_Out**, **QC_siSpeed**, and **QC_siTemp**.

The following quality code data is evaluated:
Quality code = 16#60: Simulation on driver block active (QSIM = TRUE)
Quality code = 16#80: Valid value
Quality code = <> 16#60 or <> 16#80 value is invalid (e.g. 16#81 = valid value range undershot or 16#82 = valid value range overshot)

**Messages**
PumpMon uses the Alarm_8P block to generate messages. Messages can be triggered in the following cases:

- Limit value violation of the electrical power ***siPoElec***, the mechanical power ***QPoMech***, or the hydraulic power ***QPoHydr*** (e.g. overload status when the upper limits for electrical power are overshot). Overload can be caused by increased viscosity of the pumped medium, blockage, or when the discharge-side valve is open too wide. Overload can result in significant cavitation and cause the motor to overheat.
- Deviation of the operating point from the configured characteristic (delivery height, power, NPSH, and Eta).
- The "Reduction in delivery height" message can indicate the following: gas conveyance, cavitation, drawn-in turbulence, or wear. The motor may also be rotating in the wrong direction (roughly half the delivery height with high power input).
- In the event of cavitation, gas conveyance, dry running, or blockage
- The flow rate can be monitored by means of MeasMon, which has to be installed separately.

<u>Message suppression</u>

- When the motor is switched on, signals and messages are suppressed until a configurable wait time (***SuppTime***) has elapsed. When ***SuppTime*** = 0, the suppression is not effective. The time range is between 0 and 10 [sec].
- Certain messages also have their own time delay ***T_xxx***. The message is triggered only if it is present for longer than this time delay. The time range is between 0 and 300 [sec].
- When the speed changes: If the speed changes by more than 10 rpm in consecutive block calls, the message suppression is also activated.
- No messages are generated in teach mode because the characteristics change.
- The limit value monitors each have an hysteresis that is set to the minimum value. The hysteresis of the electrical, mechanical, and hydraulic power can be changed via the faceplate. The other hystereses can only be changed on the block in the CFC.

<u>Assignment of message text and message class to block parameters</u>

| Message block | Message number | Block parameter | Message text | Message class | Can be suppressed by |
|---|---|---|---|---|---|
| MSG_EVID1 | 1 | Q_DelHi | $$BlockComment$$ Delivery height (@8%d@m) | AH | MSG_LOCK, |

| | | | | | |
|---|---|---|---|---|---|
| | | | deviates from characteristic (possible reasons: too much gas, beginning cavitation or wear), siFlow =@4%f@m3/s | | SupDelHi |
| | 2 | Q_Power | $$BlockComment$$ Mechan. power (@6%d@kW) deviates from characteristic (siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupPower |
| | 3 | Q_Npsh | $$BlockComment$$ NPSH value (@9%d@m) is too low (siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupNpsh |
| | 4 | Q_Eta | $$BlockComment$$ Pump efficiency (@10%d@%) deviates from characteristic (siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupEta |
| | 5 | Q_Cavi | $$BlockComment$$ Cavitation! (Delivery height =@8%d@m, NPSH value =@9%d@m, siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupDelHi, SupNpsh |
| | 6 | Q_Dir | $$BlockComment$$ wrong direction of rotation (siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupDelHi, SupPower |
| | 7 | Q_Blk | $$BlockComment$$ Blockage! (siPoElec =@5%d@kW, QPoMech =@6%f@kW, QPoHydr =@7%d@kW, siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupBlk |
| | 8 | Q_DryRun | $$BlockComment$$ Dry Run! (siPoElec =@5%d@kW, QPoMech =@6%f@kW, QPoHydr =@7%d@kW, siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupDryRun |

For monitoring ***siPoElec***:

| Message block | Message number | Block parameter | Message text | Message class | Can be suppressed by |
|---|---|---|---|---|---|
| MSG_EVID2 | 1 | Q_AH_Elec | $$BlockComment$$ Electr. Power HH-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupAH_Elec |
| | 2 | Q_WH_Elec | $$BlockComment$$ Electr. Power H-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | WH | MSG_LOCK, SupWH_Elec |
| | 3 | Q_WL_Elec | $$BlockComment$$ Electr. Power L-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | WL | MSG_LOCK, SupWL_Elec |
| | 4 | Q_AL_Elec | $$BlockComment$$ Electr. Power LL-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | AL | MSG_LOCK, SupAL_Elec |

For monitoring ***QPoMech***:

| Message block | Message number | Block parameter | Message text | Message class | Can be suppressed by |
|---|---|---|---|---|---|
| MSG_EVID2 | 5 | Q_AH_Mech | $$BlockComment$$ Mechan.Power HH-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupAH_Mech |
| | 6 | Q_WH_Mech | $$BlockComment$$ Mechan.Power H-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | WH | MSG_LOCK, SupWH_Mech |
| | 7 | Q_WL_Mech | $$BlockComment$$ Mechan.Power L-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | WL | MSG_LOCK, SupWL_Mech |
| | 8 | Q_AL_Mech | $$BlockComment$$ Mechan.Power LL-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | AL | MSG_LOCK, SupAL_Mech |

For monitoring ***QPoHydr***:

| Message block | Message number | Block parameter | Message text | Message class | Can be suppressed by |
|---|---|---|---|---|---|
| MSG_EVID3 | 1 | Q_AH_Hydr | $$BlockComment$$ Hydr. Power HH-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | AH | MSG_LOCK, SupAH_Hydr |
| | 2 | Q_WH_Hydr | $$BlockComment$$ Hydr. Power H-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | WH | MSG_LOCK, SupWH_Hydr |

| | | | | | |
|---|---|---|---|---|---|
| | 3 | Q_WL_Hydr | $$BlockComment$$ Hydr. Power L-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | WL | MSG_LOCK, SupWL_Hydr |
| | 4 | Q_AL_Hydr | $$BlockComment$$ Hydr. Power LL-Alarm (siPoElec =@5%f@kW, QPoMech =@6%f@kW, QPoHydr =@7%f@kW, siFlow =@4%f@m3/s) | AL | MSG_LOCK, SupAL_Hydr |

The associated values are assigned as follows:

| Associated value | Block parameters | Description |
|---|---|---|
| 1 | ***BA_NA*** | Batch name |
| 2 | ***STEP_NO*** | Batch step number |
| 3 | ***BA_ID*** | Batch ID |
| 4 | ***siFlow*** | Flow rate |
| 5 | ***siPoElec*** | Active power |
| 6 | ***QPoMech*** | Mechanical power |
| 7 | ***QPoHydr*** | Hydraulic power |
| 8 | ***QDelHi*** | Delivery height |
| 9 | ***QNpsh*** | NPSH value |
| 10 | ***QEta*** | Efficiency |

***QMSG_SUP*** is set if the ***RUNUPCYC*** cycles have not yet elapsed since the system was restarted when ***MSG_STAT*** = 21 or when ***MSG_LOCK*** is set.
When the ***L_Reset*** input is set, PumpMon is reset to the default values internally.

**Error response**
Plausibility checks are only carried out for the input parameters ***SAMPLE_T***, ***SuppTime***, and ***TimeBase***.
If arithmetic errors occur in the program, ***ENO*** is set to 0 or ***QERR*** is set to 1.

**Operating texts configured in the CFC on the block:**

| Parameter | S7_shortcut | S7_unit | S7_string_0 | S7_string_1 |
|---|---|---|---|---|
| PoRate | Rated Power | kW | | |
| SpdRate | Rated Speed | 1/min | | |
| Eta | Efficiency | % | | |
| SuppTime | Suppress Time | s | | |
| Density | Density | kg/m3 | | |
| P_Vapor | Vapor Pressure | bar | | |
| InSocket | Intake Socket | mm | | |
| PresSocket | Pressure Socket | mm | | |
| H_Geo | Height Geomet. | m | | |
| Accept | | | 0 | Accept |
| Antoine | | | Antoine=not used | Antoine=used |
| Bypass | | | Bypass=no | Bypass=yes |
| ConstSpd | | | Speed=variable | Speed=const |
| T_DelHi | Mon. Time DelHi | s | | |
| T_Power | Mon. Time Power | s | | |
| T_Eta | Mon. Time Eta | s | | |
| T_Npsh | Mon. Time NPSH | s | | |
| T_Blk | Mon. Time Blk | s | | |
| T_DryRun | Mon. Time DryRun | s | | |
| T_PoElec | Mon. Time PoElec | s | | |

| | | | | |
|---|---|---|---|---|
| T_PoMech | Mon. Time PoMech | s | | |
| T_PoHydr | Mon. Time PoHydr | s | | |
| HysDelHi | Hys. DelHi | % | | |
| HysPower | Hys. Power | % | | |
| HysEta | Hys. Eta | % | | |
| HysNpsh | Hys. NPSH | % | | |
| HysBlk | Hys. Blk | kW | | |
| HysDryRun | Hys. DryRun | kW | | |
| MinFlow | Min. Flow | m3/h | | |
| OptFlow | Opt. Flow | m3/h | | |
| MaxFlow | Max. Flow | m3/h | | |
| TimeBase | Time Base | h | | |
| | | | | |
| Flow1 | Flow 1 | m3/h | | |
| : | : | : | | |
| Flow15 | Flow 15 | m3/h | | |
| MaxDelHi | Max. Del. Height | m | | |
| DelHi1 | Del. Height 1 | m | | |
| : | : | : | | |
| DelHi15 | Del. Height 15 | m | | |
| MaxPower | Max. Power | kW | | |
| Power1 | Power 1 | kW | | |
| : | : | : | | |
| Power15 | Power 15 | kW | | |
| MaxEta | Max. Eta | % | | |
| Eta1 | Eta 1 | % | | |
| : | : | | | |
| Eta15 | Eta 15 | % | | |
| FlowNp1 | Flow NPSH 1 | m3/h | | |
| : | : | : | | |
| FlowNp15 | Flow NPSH 15 | m3/h | | |
| MaxNpsh | Max. NPSH | m | | |
| Npsh1 | NPSH-a 1 | m | | |
| : | : | : | | |
| Npsh15 | NPSH-a 15 | m | | |
| OOS | | | In Service | Out of Service |
| SupDelHi | | | Sup. DelHi=No | Sup. DelHi=Yes |
| SupPower | | | Sup. Power=No | Sup. Power=Yes |
| SupNpsh | | | Sup. Npsh=No | Sup. Npsh=Yes |
| SupEta | | | Sup. Eta=No | Sup. Eta=Yes |
| SupBlk | | | Sup. Blk=No | Sup. Blk=Yes |
| SupDryRun | | | Sup. DryRun=No | Sup. DryRun=Yes |
| SupAH_Elec | | | Sup. AH Elec=No | Sup. AH Elec=Yes |
| SupWH_Elec | | | Sup. WH Elec=No | Sup. WH Elec=Yes |
| SupWL_Elec | | | Sup. WL Elec=No | Sup. WL Elec=Yes |
| SupAL_Elec | | | Sup. AL Elec=No | Sup. AL Elec=Yes |
| MoHR_Elec | Bar High Limit | kW | | |
| MoLR_Elec | Bar Low Limit | kW | | |
| SupAH_Mech | | | Sup. AH Mech=No | Sup. AH Mech=Yes |
| SupWH_Mech | | | Sup. WH Mech=No | Sup. WH Mech=Yes |
| SupWL_Mech | | | Sup. WL Mech=No | Sup. WL Mech=Yes |
| SupAL_Mech | | | Sup. AL Mech=No | Sup. AL Mech=Yes |

| | | | | |
|---|---|---|---|---|
| MoHR_Mech | Bar High Limit | kW | | |
| MoLR_Mech | Bar Low Limit | kW | | |
| SupAH_Hydr | | | Sup. AH Hydr=No | Sup. AH Hydr=Yes |
| SupWH_Hydr | | | Sup. WH Hydr=No | Sup. WH Hydr=Yes |
| SupWL_Hydr | | | Sup. WL Hydr=No | Sup. WL Hydr=Yes |
| SupAL_Hydr | | | Sup. AL Hydr=No | Sup. AL Hydr=Yes |
| MoHR_Hydr | Bar High Limit | kW | | |
| MoLR_Hydr | Bar Low Limit | kW | | |
| U_AH_Elec | HH Alarm Elec. | kW | | |
| U_WH_Elec | H Alarm Elec. | kW | | |
| U_WL_Elec | L Alarm Elec. | kW | | |
| U_AL_Elec | LL Alarm Elec. | kW | | |
| HysElec | Hysteresis Elec. | kW | | |
| U_AH_Mech | HH Alarm Mech. | kW | | |
| U_WH_Mech | H Alarm Mech. | kW | | |
| U_WL_Mech | L Alarm Mech. | kW | | |
| U_AL_Mech | LL Alarm Mech. | kW | | |
| HysMech | Hysteresis Mech. | kW | | |
| U_AH_Hydr | HH Alarm Hydr. | kW | | |
| U_WH_Hydr | H Alarm Hydr. | kW | | |
| U_WL_Hydr | L Alarm Hydr. | kW | | |
| U_AL_Hydr | LL Alarm Hydr. | kW | | |
| HysHydr | Hysteresis Hydr. | kW | | |
| LoadReset | | | 0 | Reset |
| Teach | | | 0 | Teach Mode |
| PosTeach | Index | | | |
| | | | | |
| | | | | |

**Additional information about PumpMon**

**Relationship between available measurements and diagnosable problems**

| | Flow rate | Pressure across pump | Electr. effective power | Pressure upstream of pump | Temp. of medium | Density | Vapor pressure equation |
|---|---|---|---|---|---|---|---|
| **Blockage** | (x) (1) | | x (4) | | | | |
| **Dry running** | (x) (1) | | x (4) | | | | |
| **Gas conveyance** | (x) (2) | x | | | | x (6) | |
| **Cavitation** | x | | | x | x (5) | | (x) (7) |
| **Wear** | x | (x) (3) | x | | | | |
| **Overload** | | | x | | | | |
| **Low pump efficiency** | x | x | x | | | | |

Notes:
(1) Not strictly necessary, but useful for additional plausibility checks.
(2) For correction purposes when the diameters of the intake and discharge stubs are different.
(3) More apparent in the flow characteristic than in the power characteristic.
(4) Used to calculate the mechanical power (more significant than the electrical power).
(5) Insofar as this is not constant.
(6) Insofar as this is not constant; often available as associated value for flow rate measurement.
(7) Implemented in the block for water with a temperature of up to 100°C (Antoine equation); for other media, the respective Antoine coefficients or an external calculation has to be supplied .

**Diagnostics logic**
The block features the following diagnostic functions:

1. Generating process alarms to warn operating personnel in unfavorable operating conditions
   The following messages can be generated by the block supplied:
   - Limit value violation for the three power values (e.g. electrical overload).
   - Deviation of the operating point from the flow characteristic (i.e. reduction in delivery height: indication of gas conveyance, cavitation, blockage, or dry running).
   - Deviation of the operating point from the power characteristic.
   - Low pump efficiency: determined by means of the deviation of the current pump efficiency (ratio of hydraulic power to mechanical power) from the efficiency characteristic.
   - Cavitation: determined by means of the calculated NPSHa value; early warning when an NPSH reserve is undershot vis-à-vis the NPSHr curve by x meters (default: x = 0.5m).
   - Gas conveyance: determined by means of the reduction in delivery height (> x% deviation from the flow characteristic; default: x = 3%) when cavitation is not present.
   - Blockage: determined on the basis of a limit value for the electrical power being undershot. Can also be detected when the flow rate value (if available) is (almost) zero.
   - Dry running: determined on the basis of a (second, lower) limit value for the electrical power being undershot. Can also be detected when the flow rate value (if available) is (almost) zero.

- Incorrect direction of rotation: (i.e. the motor was connected incorrectly and rotates in the wrong direction): determined when the delivery height falls significantly (> 40%) but with only a slight deviation (< 20%) of the power characteristic.

Of course, all limits can be set and alarms suppressed as required.

2. Generating maintenance alarms to indicate advanced pump wear
This is not performed directly from the block but instead by a downstream AssetMon block (included in the standard scope of delivery of PCS 7). A range of different applications are possible here; a typical scenario would be as follows:

   Pump wear is indicated by a continuous reduction (over hours or days) in the delivery height (gas conveyance and cavitation can also have the same effect, but this should only be temporary). The "Deviation from flow characteristic" alarm could, therefore, be integrated chronologically by means of an operating hours counter (included in the standard scope of delivery of PCS 7) and a maintenance alarm ("Pump worn out?") triggered when a particular limit (e.g. three days) is reached.
   Current operational experience, however, is insufficient for gauging by how much a characteristic must deviate in order for the system to signal imminent pump failure; this is currently being investigated (2007 – 2010) in the BMBF project "ReMain" (see http://www.iml.fraunhofer.de/2227.html).

   Another useful diagnostic alarm could be generated when a particular number of operating hours for the pump in cavitation mode is reached. For this purpose, a second operating hours counter would have to be activated when NPSHa < NPSH characteristic. In this case, an alarm ("Pump damaged due to cavitation?") should be triggered after just a few hours in cavitation mode, although no generally-applicable guidelines have yet been defined for this.

3. Generating statistics (displaying the load profile of the pump) to check whether the pump design is correct
The diagram at the top of the "Histogram" view shows the distribution of the flow rate values. Ideally, this distribution should reach its maximum close to the optimum operating point of the pump (vertical green line). It is generally presumed, however, that many pumps in the process industry are intentionally overdimensioned, although this means that energy is lost when the flow rate is controlled by means of throttle valves (which is the usual case). This diagram can help to select a more suitable design when the pump is replaced.

   The diagram at the bottom of the "Histogram" view shows the relative distance of the pump operating point to the NPSH curve ("cavitation reserve"). Ideally, none of the values should fall below 0. If the histogram shows values less than zero, however, the data recorded in the control system can be used to analyze which (unexpected) general conditions lead to this. As more operational experience is gained, however, it may soon be possible to use the operating time in cavitation mode to calculate the remaining service life.