What does the Process Automation understand under Diagnosis?

Olivier Wolff
Marketing Manager Industrial Ethernet
Endress+Hauser Process Solutions AG

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Abstract:

Having consistent diagnosis in Process Automation brings to customers great potential saving in the maintenance, repair and operations (MRO) phase. The German-based process industry end-user association NAMUR has published a recommendation, NE 107 ("Self-Monitoring and Diagnosis of Field Devices").
To follow these requirements, investigations and perspective on EtherNet/IP™ will be needed.
This paper will go through to these requirements.

Keywords:

Diagnosis, Process Automation, intelligent field devices, NAMUR NE107

Glossary:

PLC: Programmable Logic Controller, DCS: Distributed Control System, PA: Process Automation, FA: Factory Automation, ATEX: Atmosphères explosibles (explosive atmosphere), SIL: Safety Integrity Level

Introduction

Today, automation is everywhere in our lives. Automation is not one word to explain all, but is divided into several areas. This paper will focus on Process Automation (PA). To understand what Process Automation is, it will give an overview to classify and explain the differences between Factory Automation (FA), used by manufacturing industries, and Process Automation, used by process industries. When both industries come together in an automation application, we call them hybrid industries. Figure 1 shows the classification of the respective industry types.

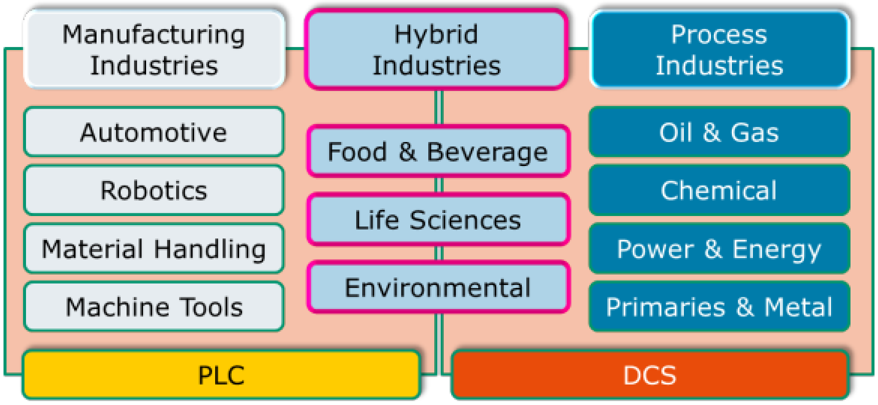

Figure 1: Classification of industries

The main focus of Factory Automation is the product being manufactured (see Figure 2). Acquisition costs should be as low as possible and high speed real time communication is needed. If there is a downtime or an issue in a machine, switching off to repair, replace or remove something is easy. It could also be a simple corrective maintenance strategy, which consists of detecting an anomaly and then restoring it to normal running conditions ("run to failure"). Since fast spare part delivery is mandatory and short runtimes of machines are common, detailed diagnosis of a device may not be necessary. Scalability of a machine and flexibility on the production floor are common requirements.

A key requirement in Process Automation is safety; functional as well as environmental (see Figure 2). A chemical plant close to a city is much more dangerous for the surroundings than an automobile-factory. There is no shut down button to rapidly switch off a process in the event of a danger or in order to replace a faulty field device. Long-term running for 10-20 year or more as well as high availability of the plant and its assets are common requirements. Typical chemical processes should be able to run up to 3 years without downtime. All these requirements need high investments that need to be protected and maintained in the best possible way. Intelligent field devices and field components offer added value to users. In addition to typical measurement tasks or signal converting and forwarding tasks, these devices are able to deliver information about their current status. Efficient life cycle management and predictive maintenance becomes possible with standardized diagnostic information provided to users.
Figure 2 summarizes the differences between Factory and Process Automation.

Industrial Tasks	
Process Automation	**Factory Automation**
Typical tasks : heating, cooling, mixing, separating, analyzing, calibrating	Moving, adjusting, mechanical processing, lubricating
Outdoor plants, high requirement for a wide range of temperatures and environmental conditions	Compact plants, skids, indoor, low requirement for a wide range of temperatures and environmental conditions
Continuous process control, analog values dominate	State recognition, binary signals dominate
Law regulation, Approval certificates for components	

Industrial Focus	
Process Automation	**Factory Automation**
Safety (ATEX, SIL,)	Product
Availability	Low acquisition costs
Long-term plant runtime (10 – 20 years)	Real-time operations (high-speed)
Runtime without downtime from1 to 3 years	High positioning accuracy (Drives)
Protection of investment	Scalability
Total Cost of Ownership	Flexibility (fast and easy convertible)
Data authenticity and confidentiality Remote Maintenance	Scheduled maintenance intervals.
Engineering and Asset Management Tools	Fast spare parts delivery

Figure 2: Different industrial tasks and focus

Diagnostic information

After explaining the different categories of automation, within these categories there is also a difference when it comes to diagnosis. In Factory Automation diagnosis provides the maintenance personnel only simple information like “everything works” - the typical green LED. In the event of a failure there could be a flashing red LED “failure”.

This kind of diagnostic information is far removed from what is commonly used in Process Automation. In Process Automation, there are various disciplines that need to be informed when it comes to diagnostic information (see Figure 3). While plant operators need to focus on the running process, maintenance technicians need to make sure everything is in place to ensure the “health” of the plant. This also includes field devices. To be able to understand each other, both sides need to have the same representation of diagnostic information..

Figure 3: Operator and maintenance console, both showing diagnostic information

A field device can provide several types of diagnostic information (sensor related, electronics related, configuration/service related). For instance, electronic related diagnostic information could be “ROM defect”. Diagnostic information linked to the process itself or to the environment can also be shown in the console, for example “corrosion warning” or “fluid inhomogeneous”.

Figure 4 shows an example of how diagnostic information is provided in a maintenance console. The technician can set a so-called “empty pipe detection” in a flowmeter. When a pipe is empty or partially filled in a process application, it could damage a pump or other equipment running in the process. Therefore it is necessary to detect this in advance.

Figure 4: Standardized overview for each field device.

Since a maintenance console can have several forms (centralized asset management software, decentralized web-server, etc.) diagnostic information has to be available in the same form in different places, see Figure 5. The same diagnostic information is available in the embedded webserver of an EtherNet/IP™ device.

Figure 5: Example of diagnostic information (maintenance console) in an EtherNet/IP™ mass flowmeter.

The menu “Health status” shows the diagnostic information “Partly filled”. A diagnostic number (assigned by the device maker) identifies the diagnostic information within the device. As described earlier, each piece of diagnostic information originates in the instrument (sensor specific, electronics plate, configuration) or the process/environment. In this example the diagnostic number is 862. It identifies the diagnostic information within the device. This is process-related diagnostic information because it is induced by the process itself. There is an associated text to describe the diagnostic information and its origin. A remedy and information for maintenance personnel is also provided. This lists possible solutions and as well as instructions on how to remedy the fault.

Diagnostic number and status signal are mapped into four categories within the device as shown in Figures 4 and 6. This is done in order to simplify understanding and allow quick action to be taken when diagnostic information appears. In our example the diagnostic called “Partly filled” is mapped to the “Out of Specification” category, which is why it is displayed with the “S” prefix (S862) in Figures 4 and 5 above.

These categories have been defined and standardized by an international association of process automation industry end users called NAMUR. The recommendation paper NE107 “Self-Monitoring and Diagnosis of Field Devices” resulted from their work.

NAMUR NE107: Requirements from Process Automation Users

NAMUR is an international association of process automation industry end users. It publishes recommendation documents to help end users by sharing best practices and to guide suppliers and industry foundations on future technology and product development. NAMUR represents approximately 15,000 process control experts, of whom approximately 300 are active in 33 working groups. Member companies include Novartis, BASF, Bayer, Evonik, Shell and Clariant.

Failure (**F**)	
Function **C**heck (**C**)	
Out of **S**pecification (**S**)	
Maintenance Request (**M**)	

Figure 6: NE107 Status Signals and Symbols

Of particular concern to NAMUR is the role of the operator and maintenance technician and their impact on plant reliability and uptime. Unplanned downtime is one of the primary enemies of the process industries. According to ARC Advisory Group (www.arcweb.com), unplanned downtime accounts for the equivalent of 20% of all production in the process industries. A single unplanned shutdown can wipe out your plant profit for the year. The same piece of ARC research states that 40% of unplanned downtime events can somehow be traced back to the human operator in the loop. We need not always blame the human in the loop, however, since that person may be working on faulty information or may not have the right information presented to them at the right time.

NAMUR NE 107 categorizes internal device diagnostics into four standard status signals — failure, function check, out of specification and maintenance required, (also known as "FCSM", see Figure 6). Each of these categories can also contain greater detail. In the case of failure, for example, can the failure be traced to the device or the process? Is maintenance required immediately, or is the requirement more for long-term maintenance?

The ultimate result of this is a series of new field diagnostic alarms that correspond to the four primary diagnostic categories outlined by NAMUR in its document. Several standardized, and therefore manufacturer-independent parameters, are available to configure the NAMUR category, the priorities and the filter mechanisms for the alarms. With NAMUR NE 107 diagnostics built in, you can turn off diagnostics you do not need or configure how the diagnostics are reported. This supports the configurability mandate of NE 107**.**

Digital communication protocols and NE107 implementation

Digital communication protocols focused on Process Automation such as FOUNDATION fieldbus, PROFIBUS PA or HART have already implemented this NAMUR recommendation in their respective specifications (“FF-912”, “PA Profile 3.02” and “HART 7”), in order to provide the required diagnostic information to Process Automation users.

This paper will use the implementation of FOUNDATION fieldbus with “FF912” as an example to show the details and benefits of implementing NE107 for Process Automation users. As mentioned earlier, from a device manufacturer’s view point, there are four type of diagnostic information in a field device. Sensor, Electronic and Configuration/Service diagnostic information are related to the instrument (field device). Process/Environment diagnostic information is related to the surroundings of the field device. Figure 7 shows the classification of the diagnostic information. Each piece of diagnostic information within each category does not have the same importance and therefore has to be classified based on its severity. This determines the prioritization of diagnostic information within the field device. Once this classification is done by the manufacturer, it becomes possible for the user to assign the diagnosis information to the status signals of NAMUR NE107 (Failure, function check, out of specification, or maintenance requested).

Sensor/Actuator element failures
Tube temperatur sensor defect
Exciter coils defective
Carrier tube temperature sensor defective
Electronic failures
Critical Failure Fault
EEPROM Failure
Totalizer Checksum Fault
Configuration/servicing failures
Board Incompatibility
Software Update in progress
Communication I/O Failure Fault
Simulation active
Configuration error
Process induced failures
Oscillation Amplitude Limit
Excitation Current Limit
Fluid Inhomogeneous
Noise Limit
Sensor Asymmetry Exceeded Fault
Corrosion
Erosion
Coating -Build Up
Air Entrainment
Slug Flow
Cavitation
Empty Pipe

Figure 7: Diagnostic information can be grouped in a field device

As there are four categories of diagnostic information and four grades of severity of the diagnostics within the field device, there are sixteen mapping possibilities. Field devices manufacturers have to define which diagnostic information (e.g. the 23 items in Figure7) should be in which of the 4 categories (in gray in Figure 7) and at what priority level within that category. Users should have the possibility to assign, these grades of diagnostic severity to the NE107 status signal. For instance, the status signal “failure” (red circle X from Figure 6) could be composed of all the highest prioritized diagnostic information of each gray category of Figure 7. In order to keep diagnostic information mapping with NE107 meaningful, manufacturers should issue recommendations in order to guide customers in their maintenance strategies.

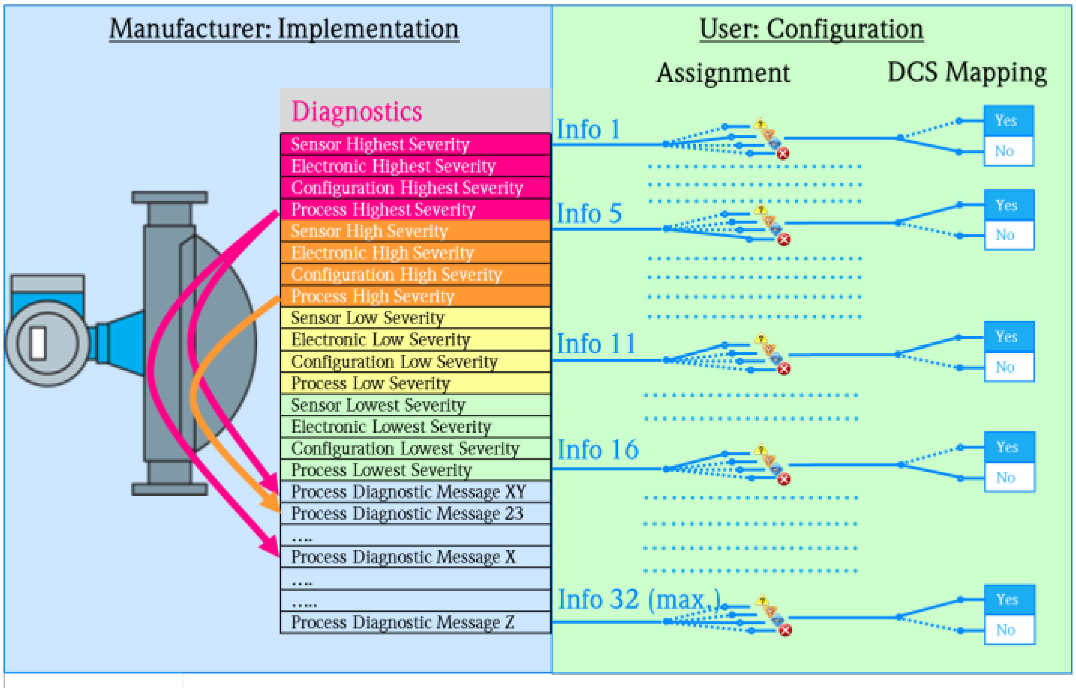

Figure 8: Assignment of diagnostic information prioritized categories to one of the four NAMUR NE107 Status Signals and Symbols as it is done within FOUNDATION fieldbus "FF912".

In addition to the assignment of each severity grade of a diagnostic information category (sixteen possibilities) to a NE107 status signal (four possibilities), it is possible within FOUNDATION fieldbus to have the user manually re-assign a single item of process related diagnostic information to a NE107 status signal. The user can configure if he wants to have this NE107 status signal also mapped to his operator console as an alarm, in addition to the maintenance console (Figure 8, DCS Mapping). Returning to the empty pipe example, it is possible to re-assign this diagnostic information item to one of the four NE107 status signals, independent of the other process related diagnostic information items.

A user could consider re-assigning every process related diagnostic information (see Figure7, the 12 items in "process induced failures" category) to an NE107 status signal depending on the field device (e.g. flowmeter, analysis transmitter) and the application (e.g. Clean in Place process in food industry). Therefore FF912 provides an area for single configurable diagnostic information (blue area, see Figure 8). Due to technical limitations of the protocol (4 Bytes available), however, the number of possible assignments is limited to sixteen. This means the process related diagnostic information which makes sense for the customer must be selected. For instance "corrosion" could be seen in one application as a failure status signal (F) that needs to stop the process, whereas in another application it is only considered as a maintenance request (M).

In Process Automation it is very important to be able to classify diagnostic information.
A plant operator and a maintenance technician have to handle thousands of diagnostics, alarms and warnings within a day, therefore a good classification is mandatory to keep track of what to be done, when and where.

With the growing importance of EtherNet/IP ™ for Process Automation a concept for the implementation of the NAMUR NE107 is required. Looking at the implementation of NE107 in traditional process automation fieldbuses, there should be a mechanism to guide and help customers to optimize diagnostic information behavior.

Due to the power of the EtherNet/IP ™ protocol, a user should have the possibility to map each diagnostic information item from these categories (sensor, electronic, configuration, process related) to an NE107 status signal. However, to ease device configuration for the user, the device vendors should be able to limit which NE107 status signals can be mapped to certain diagnostic information.

NE107 possible implementation with EtherNet/IP™

This paper does not aim to make a final proposal on how to implement the NE107 recommendation into EtherNet/IP™ but to give a starting point and benchmark on what has been done already and identifying what more needs to be done.

The assembly object of EtherNet/IP™ has an attribute called input assembly. The device maker can define it in the way that makes the most sense. An input assembly of an EtherNet/IP™ flow device is represented in Figure 9.

Diagnostic No.	NE107 Status Signal	Channel	Data0, Data1, …Data N
2 Byte	**1 Byte**	**1 Byte**	**N Bytes**

Figure 9 EtherNet/IP™ input assembly proposal

- Diagnostic No. is related to the diagnostic information within the device. Diagnostic numbers are vendor specific. Possible range from 0 to 65535.
- NE107 Status Signal is related to one of four diagnostic classification categories; the assignment is fixed by the constructor, although it be should in the future configurable by the system integrator or end-user. Possible values (F,C,S,M: see Figure 6)
- Channel is used for field devices with multiple channels (for instance an analytical transmitter with several sensors, like pH, conductivity, oxygen). The value could be 0 or 1 indicating whether diagnostics are device related or channel related.
- Description of “Data Byte”(Figure 10)
    - Value means the Process Value (PV), such as the mass flow in a flowmeter.
    - Status indicates the data quality of the process value. Status can be labeled in three categories (GOOD, BAD and UNCERTAIN), (0x80, 0x0C, 0x40). Note: classification of information into NE107 categories and data quality status are two independent functions and will not be developed in this paper.
    - Padding Byte
    - Unit represents two bytes displaying the unit of the value (PV), for instance ounces/hour (0x086E, see CIP Spec, Vol 1 Appendix D, Vendor Specific range).

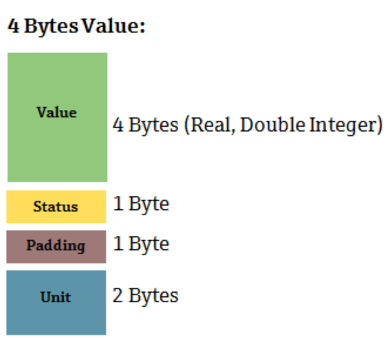

Figure 10 “Data Byte” structure proposal

EtherNet/IP™ and CIP™ offer the possibility to create new objects. A mechanism to manually assign a diagnostic number to a NE107 status signal is needed. The recommendation of this paper is to further investigate the creation of a new object called “diagnostic information”.

Conclusion

This paper discussed and presented the understanding and relevance of diagnosis in Process Automation. To increase acceptance of EtherNet/IP™ in Process Automation, diagnosis should be taken into account in ODVA CIP specifications. A standardized process of how to assign each diagnostic information category to a NAMUR NE107 status signal should be defined in order to give customers the highest flexibility in their maintenance strategies.

References:

Endress+Hauser: “Taking diagnostics to the next level”
NAMUR NE107 “Self-Monitoring and Diagnosis of Field Devices”.
FOUNDATION Fieldbus FF912