Extended diagnostics system for AS-interface networks

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Abstract: When troubleshooting a communications system (such as machines controlled by industrial networks) under or not the operation conditions, engineers or technicians try to use some standard format to come to a quicker solution. Industrial communications system do not always follow the tried and tested rules [1], which previously worked with hardwired inputs and outputs. There are some new methods [7, 9, 10], helps to reach the solution, but sometimes there is no possibility to recognize and eliminate problems under the operation conditions, without changing the main control unit for new one or temporary switching existing network segment to external control unit. The paper shows some samples of troubleshooting a communications system of a complex machine controlled by AS-i industrial network, which should to be done not under operation conditions. Also the basis of extended diagnostic system helping with detection of: earth fault, duplicate address and noise has been described.

Keywords: industrial networks, diagnostic, troubleshooting, AS-interface, Profibus DP

1. Introduction

The Actuator Sensor Interface (AS-i) protocol [2–6] was created in Germany in 1994 by a consortium of factory automation suppliers. Originally developed to be a low-cost method for addressing discrete sensors in factory automation applications, AS-i has since gained acceptance in process industries due to its high power capability, simplicity of installation and operation, and low cost adder for devices. Each AS-i segment can network up to 31 devices. This provides for 124 inputs and 124 outputs, giving a maximum capacity of 248 I/O per network on a v2.0 segment. The AS-i v2.1 specification doubles this to 62 devices per segment, providing 248 inputs and 186 outputs for a total network capacity of 434 I/O points. Both signal and power are carried on two wires. The newest supported version is v3.0 which consist of new group of field devices and provide new possibilities. Those new control units (AS-i masters or gateways) are ready to support very helpful maintenance functions such as detection of earth fault, duplicate address and historical view of noises. The oldest versions of networks (v2.0 and 2.1) doesn't support those important functions. During the research work based on the laboratory prepared AS-i network segment, implemented in Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Laboratory of Sensors and Industrial Networks the authors of the paper provide the concept of maintenance the AS-i network during the time when machine is not under the operation condition. This concept based on external control unit which has to be connected to the network segments during the diagnostic time. Thanks to this, those new functions can be reach.

2. The new master unit

New concept is based on external control unit with AS-i maser v3.0, which has to be connected to the network segments during the diagnostic time. Technically, the new master has been extended beyond the three typical layers as defined by the user organization for each AS-i – master (fig. 1). It goes without saying that these extensions neither violate the specification nor nullify parts of it [8].

On the lowest level, the **Bus interfaces**, all bus telegrams are generated as analog signals, incoming signals are detected and checked for possible errors. That's standard. A new feature on this layer is the additional surveillance of telegrams on the bus, which recognizes duplicate addresses, earth faults, EMC-disturbances, and strong common mode disturbances and relays them upwards.

The **Master Layer**, which works on top of the bus interface, primarily executes all the master functions

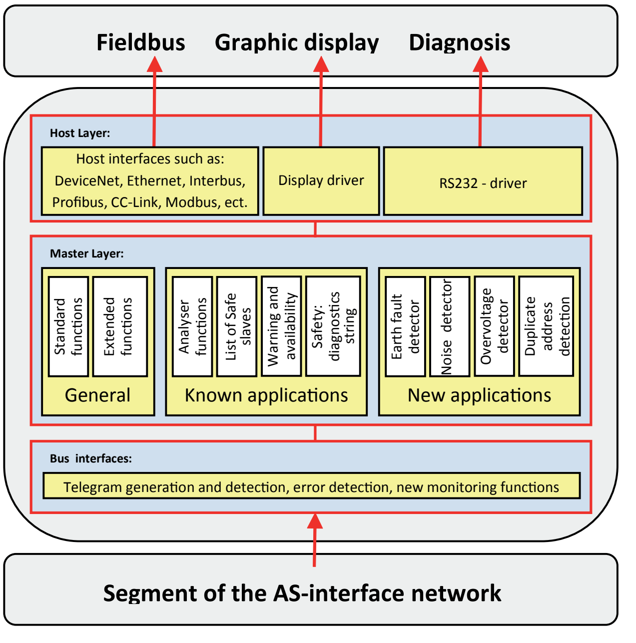

Fig. 1. Functions of the master: The functions of the AS-i standard and the already introduced, and the new application functions [8]

Rys. 1. Funkcje mastera sieci AS-interface: standardowe, nowe już przedstawione oraz całkowicie nowe [8]

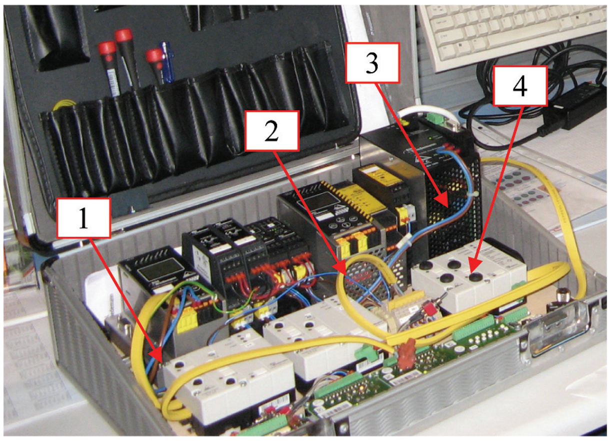

Fig. 2. External unit – build-in aluminium industrial case – ready for diagnosis in field

Rys. 2. Zewnętrzna jednostka zabudowana w aluminiowej walizce – przystosowana do diagnostyki w terenie

as set down by the general specification (C.S.2.11), as well as the already introduced application functions of Bihl+Wiedemann company: the "Analyser functions" (configuration, diagnosis, error statistics, error treatment, display of the list of periphery errors, treatment of slave malfunctions), the reading or conscious setting of actual periphery data without the host, the logging of warning and readiness messages, as well as the listing of safe slaves and the analysis of causes for a stop in Safety at Work applications. Here, the error statistics is based on the telegram control functions within the bus interface. A new application function is the treatment of the mentioned information for the surveillance of the bus physics. It edits all these data in such a way that they can be provided to the user according to his or her wish.

The highest level, the **Host Layer**, optionally now provides a diagnosis interface with an RS-232 socket, in addition to the interface to different hosts (gateways to higher bus systems) and to the graphical display. As all three possibilities access the master layer, identical information can not only (as was already possible up to now) be provided via the higher fieldbus and via the display on the unit, but it can now also be read via the RS-232 socket directly to a PC. Thus, comfortable options for displaying and documentation are available on-site via PC. During the diagnosis of the network having to work with different buses we can – in spite of differences in the buses – always use the same master functions and the same method of diagnosis.

2.1. Master switching procedure

The external control unit, shown on the figure 2, consist of AS-i maser v3.0 (1), AS-i power supply (3), AS-i tuner and terminator (4), AS-i Safety monitor with build-in master v3.0 (2) and some I/O modules useful on testes. During the diagnostic time the unit has to be connected to the network segment instead of existing AS-i master in v2.0 or v2.11. Because of the master switching procedure the machine mast to be not under the operation conditions and the power supply has to be switch off.

The external diagnostic unit is ready to supply the AS-i voltage, so if there will be such a need also the existing power supply unit has to be switched for a power supply from the external unit case. Also if the diagnosed network segment consist of safety I/O modules we are able to connect this segment to the master with safety integrated functions (2).

2.2. The new application functions

Thanks to new master connected to the network segment, we are able to support four new application functions: the duplicate address detector, earth fault detector, noise detector and overvoltage detector.

In recognizing duplicate addresses, the new master solves an old, irritating problem: Due to the system specification, it has usually been difficult in practice to reliably recognize the assignment of one address to two slaves. The master now identifies this case and issues a corresponding error message. Meanwhile, it sets the flag "configuration error", so that the higher PC will be informed and can react accordingly. The user does not have to fear a system deficiency anymore [1, 4, 8].

Our master also contains an earth fault detector, which so far has only been sold either as a stand-alone component of the net or as the supplement to a power supply. An accidental earth fault in the network causes the system to be more vulnerable against electro-magnetic disturbances; a double earth fault might trigger a stepping error in special circumstances. Therefore, an earth fault detector has been recommended for critical applications for a long time. It detects already the first earth fault and thus hedges the system. If the earth fault detector, as in the case of the our external device, is implemented in the master, it has the "direct line" to the controller, which can process its signal immediately. The default setting releases a diagnostic signal is in the higher fieldbus. According to the application-specific settings, an alarm, an immediate stop of the application, or a systematic shutdown of the application can be triggered. Alternatively, an instant transition to the offline phase can be forced directly on the master layer [1, 8].

The third new function is the noise detector. It continually checks the analogue signal on the bus line and detects disturbances (noise) in the pause time of the signal if they exceed a certain level. In that manner emerging problems can be covered in a state in which telegram repetitions do not yet occur. Critical situations can thus be analyzed more easily, such as disturbances that are cyclically linked to the course of a process, e.g. the activation of a motor.

The over voltage detector has a similar function; it recognizes severe common mode oscillations on the AS-i line, which sometimes disturb externally connected sensors. The design of AS-i as an earth free system may in fact sometimes lead to a highly fluctuating potential, which affects both conductors of a cable in the same manner. Due to the high common mode rejection, this will not trigger an error in the bus communication; however, a sensor (e.g. an inductive sensing device with low current consumption) may generate a short erroneous signal if it is not specifically protected. Although this happens very seldom and in extreme cases only (e.g. when fabricating PET-bottles) where other system will fail completely, this case cannot easy to be identified by other means. The transmission via AS-i remains technically correct, but the sensor signal is temporarily wrong. The overvoltage detector registers this danger which can then be similarly treated as EMC disturbances. In both cases the disturbances can be issued acutely or as a sum signal over the run time of the master [8].

All of those new functions are available also via the RS-232 communication port, so this external unit is prepare to become a part of more powerful diagnostic unit. Because of that possibility authors start-up the research investigation with IPC and touch panel supported by industrial network interfaces.

3. Sample implementation

3.1. Case description

Company "X" is one of the European market leaders in the field of paving stones. The production process, based on big concrete aggregates evokes the necessity of using industrial networks such as: Profibus and AS-interface. There are 7 SIEMENS S7-300 and S7-400 PLC's attending the system. All the PLCs are networked via Profibus. One aggregate has 9 AS-interface masters and each has the individual node number in the Profibus network (all of them are the Profibus gateways). One of the sub-networks responsible for palletizing the end product showed malfunction, and immediately stopped the machine. After two days of unsuccessful investigation Company "X" asked The University for help in service and maintenance of the network.

3.2. Before and during the service visit

Before the service visit, the maintenance engineer was asked to open the internet link to the SUFINED system, login as a new user, create a new states feature vector (SFV) and answer as many question as he could. On the grounds of this knowledge (description of the environment) the authors of the paper could prepare well for the service visit.

During the visit the gaps in the SFV were filled and the whole vector checked once again. In accordance with the proposed scenario of the network-machine oriented diagnostics, appropriate measurements, calculations and inference were carried out:

– At first, the reference measurement (with the use of the analyzer), in near-by the area of the control cabinet. The number of detected modules was precise, and also their types and assigned addresses in the AS-interface network. The transmission factor was calculated ($W_T = 5.98$ %) and the need of maintenance indicated.
– The reasoning process based on the inputted data was completed.
– The environment of the module with the highest W_T was checked.
– The mistakes and malfunctions were localized and eliminated.
– The final measurement for a final report carried out. The transmission factor was calculated ($W_T = 0.12$ %) and there was no indication of the need of maintenance.

3.3. Working with SUFINED system

During the service visit, the states feature vector (SFV) was created, basing on the knowledge about the machine, network, and measured parameters such as transmission factor W_T. Next, the reasoning process based on SFV was completed. As a result of the latter, the user was given the following information: 25 rules were accepted for the reasoning process, in which 4 rules rendered a perfect match in both reasons, rule 1 was half a match but the logical conjunction were "OR" type, so finally, 5 conclusions were derived.

It is important to mention that the creation of a new states features vector of the diagnosed system took about 15 min. The reasoning process was completed in 2 s, which can be omitted in the calculation time. Thus, such form of non destructive diagnostics is very fast (especially if compared with the two days which the customer wasted looking for the reason of the malfunction).

The conclusions from the reasoning process showed possible reasons of problems, such as excessive cables, and malfunction of the sensors connected to the module with the highest transmission factor W_T. Both conclusions were correct. In the control cabinet, excessive AS-interface flat cable was found, and one of the 4 sensors connected to the I/O module with the highest W_T had a broken head (still, power was supplied). The detected reasons of the malfunction are shown in fig. 3 and 4.

The status of the network during the service is shown in fig. 5 – the reference measurement and the measurement taken after the removal of the flat and the measurement

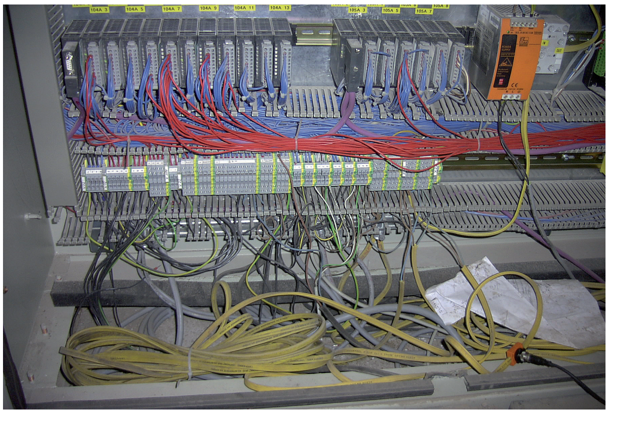

Fig. 3. Internal view of the control cabinet – excessive AS-interface flat cable

Rys. 3. Widok wnętrza szafy sterującej – nadmiarowe przewody magistrali sieci AS-interface

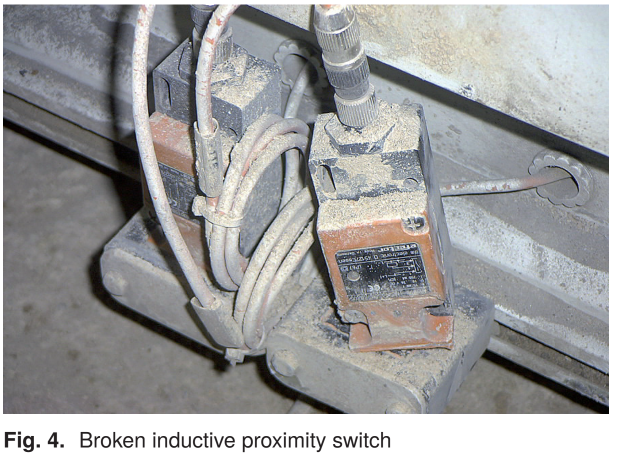

Fig. 4. Broken inductive proximity switch

Rys. 4. Uszkodzony czujnik indukcyjny

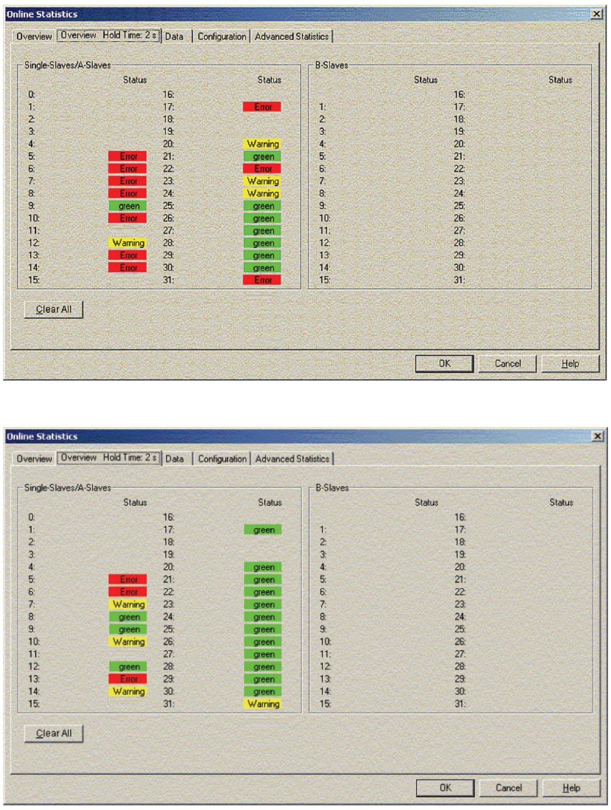

Fig. 5. Online status overview tabs of AS-i analyzer software. The reference measurement, and the measurement after the removal of the cable

Rys. 5. Okna programu diagnostycznego: pomiar referencyjny oraz po usunięciu przewodu nadmiarowego

taken after the exchange of the broken inductive proximity switch, and the final measurement.

After the replacement of the broken inductive proximity switch some of the data packages were still lost, and the transmission factor was equal to 0.21 %. There was no permanent error in the network, only some warnings. One of the conclusions from the reasoning process indicates a possible need of using special devices, such as: a terminator for the network that can offer assistance in case of excessive cable length. After the terminator has been used, the network worked perfectly, and the transmission factor is equal to 0.12 %. Finally, the malfunctions ware finally removed.

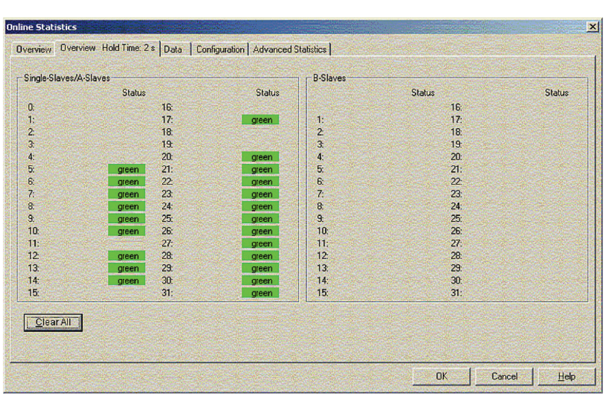

Fig. 6. Online status overview tabs of AS-i analyzer software – the measurement after the exchange of the broken inductive proximity switch – the final measurement

Rys. 6. Okno programu diagnostycznego: pomiar końcowy po wymianie uszkodzonego czujnika indukcyjnego

4. Conclusions

The general construction of the master, such as illustrated in fig. 1, persists. Bus-interface and master layer are the basis for the entire master family, which again comprises about a dozen different gateways. This core, which is always the same, is accessed from outside. The main functions of AS-i still have the – also temporal – absolute priority over all other functions. The master therefore remains interoperable with all other components that fulfill the general specification. This also means that all central features, such as the self-configuration of the master or the "auto addressing" of a substituted slave, remain operational. For the user who only wants to connect an executable system, AS-i remains as easy as before. All additional functions have a lower priority from the purely technical point of view. They influence neither the cycle time nor the communication to the host. This may completely change from the point of view of a user as soon as he wishes to have more information on an application or if it does not run immaculately from the start. Then all the application functions described in this article will have a high priority to the user, as they are suitable to issue a very complete diagnosis of the network and to identify errors quickly. In addition, the user receives this information on the spot.

The discussed concept of diagnostics and troubleshooting of industrial networks is a challenging task which may be successfully accomplished, only if faced with industrial reality. However the system already provide a good support for the diagnostics of machines supported by AS-i networks. In the next step we wish to implement all diagnostic algorithms into the touch panel IPC equipped in to three industrial networks masters (AS-i, Profibus, CANOpen). The research starts already and promise themselves well.

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Rozszerzony system diagnostyczny sieci AS-interface

Streszczenie: Współczesne realia rynku wymuszają wzrost konkurencyjności oferowanych systemów sterowania. Firmy w celu podniesienia wartości swojej marki w sposób ciągły obniżają koszty produkcji jednocześnie starając się o podniesienie jakości, estetyki oraz wytrzymałości produkowanych komponentów. Osiągnięcie tak postawionych celów wydaje się być niemożliwe bez wprowadzenia systemów automatyki odpowiedzialnych za prawidłowy przebieg procesu produkcyjnego. Systemy te stają się coraz bardziej złożone, a ich topologie coraz bardziej rozproszone. Wymiana informacji procesowych pomiędzy poszczególnymi modułami procesowymi wymaga zastosowania technologii komunikacyjnych sieci przemysłowych. Najczęściej stosowanymi standardami sieciowymi na rynku europejskim są sieci oparte o protokoły Profibus DP oraz AS-interface. Autorzy publikacji przedstawiają metodę skutecznej diagnostyki ukierunkowanej na prawidłowe działanie sieci przemysłowej (ze szczególnym uwzględnieniem zagadnienia transmisji danych). Przedstawiają nowe metody, które umożliwiają rozpoznanie i szybką eliminację przyczyn stanów awaryjnych w maszynach kompleksowo sterowanych urządzeniami sieci AS-interfejs.

Słowa kluczowe: Sieci przemysłowe, diagnostyka, usuwanie problemów, transmisja danych, AS-interface, Profibus DP

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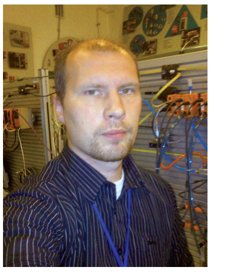

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