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Fault diagnostics in LOGSET forest machines

Development of improved fault diagnostics in the TOC control system of LOGSET harvesters and forwarders

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Thesis abstract

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Logset uses its own control system called TOC in its harvesters and forwarders. TOC includes fault diagnostics section in which states of signals sent from and received by modules can be observed. Currently the system is not giving enough information in order to enable efficient problem solving and too much time has to be spent on finding the faulty components and handling the error situations. Documents for more informative and clearer error messaging were produced in this project to ease maintenance tasks.

This project studied CAN bus technology, which handles the communication between different modules of the machine, machine maintenance, occurrence and types of different faults and their diagnostics in automation. TOC system is introduced in this project as well as improvement ideas and actions to be made in order to develop fault diagnostics further. In addition the methods used when investigating the problems with the current fault diagnostic system and the wanted developments are presented. The results of this project will help maintenance work by accelerating the locating of faulty components. The results will also make the control system more informative when the new error messages and TOC windows are implemented.

Given the nature of this work the appendices contain confidential information and have so been discarded from the public version.

Keywords: forest machine, circuit diagram, maintenance

SEINÄJOEN AMMATTIKORKEAKOULU

Opinnäytetyön tiivistelmä

Koulutusyksikkö: Tekniikan yksikkö

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Logsetin harvestereissa ja kuormatraktoreissa on omaa suunnittelua oleva TOC -niminen ohjausjärjestelmä. Ohjausjärjestelmässä on ominaisuus, jolla vikatilanteessa voidaan nähdä moduulilta lähtevän tai sinne tulevan signaalin tila. Kyseisen vikadiagnostiikka osion tarjoamat tiedot sekä nykyiset virheilmoitukset on todettu riittämättömiksi, ja aikaa vikojen selvittämiseen kuluuu liikaa. Työssä tuotettiin tarvittavat dokumentit, joilla virheilmoituksista saadaan kuvaavampia, informatiivisempia ja vikatilanteiden selvittäminen saadaan nopeammaksi.

Tässä työssä on tutustuttu pintapuolisesti CAN bus -väyläteknologiaan, jolla kommunikointi koneen eri ohjausmodulien välillä on toteutettu, sekä kunnossapitoon ja vikojen syntyyn ja niiden diagnosointiin automaatiotekniikassa.

Työssä esitellään TOC -järjestelmää sekä kehitysideat ja toimenpiteet, joilla vika diagnostiikkaa tullaan parantamaan. Työssä käydään myös läpi tutkimusmenetelmät, joiden avulla selvitettiin ja pohdittiin nykyisen vikadiagnostiikan puutteita sekä mitä uudistuksia toivotaan. Työn tuloksilla saadaan ohjausjärjestelmää kehitettyä informatiivisemmaksi ja vikojen paikallistaminen ja korjaaminen tulee nopeutumaan.

Työn luonteen takia sen liitteet sisältävät luottamuksellista tietoa ja ovat tästä syystä jätetty pois julkisesta versiosta.

Keywords: metsäkoneet, kytkentäkaaviot, huolto

ALKUSANAT

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Lisäksi haluan kiittää opiskelutovereitani, joita ilman mm. opiskeluvuoteni ulkomailla ei olisi ollut yhtä onnistunut. Omat kiitoksensa ansaitsee myös avopuolisoni, joka on tukenut minua opiskeluaikanani ja antoi minulle työrauhan opinnäytetyön tekemiselle.

Koivulahdessa 17.5.2013

Ville Rönkkö

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Tables and figures

Terms and abbreviations

TOC	Total operation control – The control system of Logset harvesters and forwarders
Fault diagnostics	Feature of a control system to detect errors in the functions of the machine
Error message	Notification for the driver on the TOC screen.
Circuit diagram	Drawing where electrical connections and wirings are represented graphically
CAN	Controller Area Network – automotive bus standard.
Downtime	Period of time when the machine is not available for operation
PWM	Pulse Width Modulation
USB	Universal Serial Bus
SPM	Smart Power Module
HCM	Hybrid Controller Module
MCL	Machine Control Logic
MIC	Multi Information Controller

1 INTRODUCTION

In this project Logset forest machines and the technology of their control system were studied. Also the basic principles of vehicle electronics and CAN bus technology and their role in the forest machines were examined as well as theory about machine maintenance. After the theory part follow the introduction to TOC system, practical implementation and the results.

This project was started on the basis of a need for better fault diagnostics. Current diagnostic window of TOC and the error messages it gives to the user are found inadequate. The feedback from the users, production and service people is that the error messages don't give enough information to locate the faulty components or connections making the repairs and fixes slow and difficult job. The goal of this project is to develop the fault diagnostics so that enough information is given directly in the error message and the TOC's diagnostic window so that fixing problems or ordering the needed spare parts would be easier and quicker.

2 BACKGROUND

2.1 Oy Logset Ab

Logset is a Finnish forest machine manufacturer. The company develops, manufactures and services all its machines by its own employees. Logset manufactures approximately 120 forest machines per year and all machines are built in Koivulahti, Finland. The company employs approximately 65 people in Finland.

2.1.1 Products

Logset harvester range consists of six models. Harvesters cover approximately one third of the sales. Logset also designs and manufactures its own harvester heads which consists of four models. Logset forwarder range consists of six models and forwarders cover approximately two thirds of the sales. Logset forest machines are used in forests of over 25 countries (figure 1) (Logset 2013).

Figure 1. Logset 5F forwarder and 8H harvester in a Latvian forest (Logset 2008).

2.1.2 TOC

Logset uses its own control system called TOC which is a Linux based computer software that is responsible for all functions regarding driving and crane operations in Logset harvesters and forwarders. TOC also shows all information traditionally seen on a dashboard (figure 2).

Figure 2. TOC display in Logset forwarder (Logset 2008).

2.2 Need for better fault diagnostics

Fault diagnostics is used to reduce downtime and to maximize the performance of the machine. The control system of Logset forest machines already has a fault diagnostics section but it has been found inadequate. Having inadequate automated diagnostic system leads to a situation where too many hours of work are put into finding the actual cause for the problem. When a machine is not able to function properly it will cost its owner a lot of money. Also spending a lot of time on just one problem is not ideal from the machine manufacturer’s point of view (Kytövaara 2013.)

Faults and errors delay the manufacturing of a machine as well. Even though a part of the cabling of the machine comes as ready wiring harnesses which have connector sockets at the end, some parts of the cabling and connections are done by hand at the factory. When mistakes happen and when they are discovered during testing, the mechanic has to start fixing the problem which naturally delays the manufacturing process. Having better fault diagnostics in TOC the problem solving would be faster in the production too. Possibly problems could be solved without even having to refer to circuit diagrams.

TOC includes also an alarm log window (figure 3). Alarm log is a database where a list of all diagnosed faults is stored and can later be examined. Alarm log still offers no additional information besides the number of occurrences of a single error and the date and time of the latest case.

Figure 3. TOC alarm log window (Logset 2011).

3 MACHINE MAINTENANCE

In industry and machine manufacturing maintenance is a vital component of the organization. The maintenance's part of a company's turnover is 5-20 % (Heinonkoski 2004, 12). In an effort to get the maintenance costs down companies sometimes decide to buy the maintenance from a specialized maintenance company rather than keeping an own maintenance department. Another way is to develop solutions that make maintenance easier and faster, for example software that automatically diagnoses faults and informs the user which actions to take.

According to the inquiry carried out in the year 2000 the total investment in industry was 3,2 billion euros. Most of that went to mechanical maintenance and one fifth went to electrical and automation maintenance (figure 4).

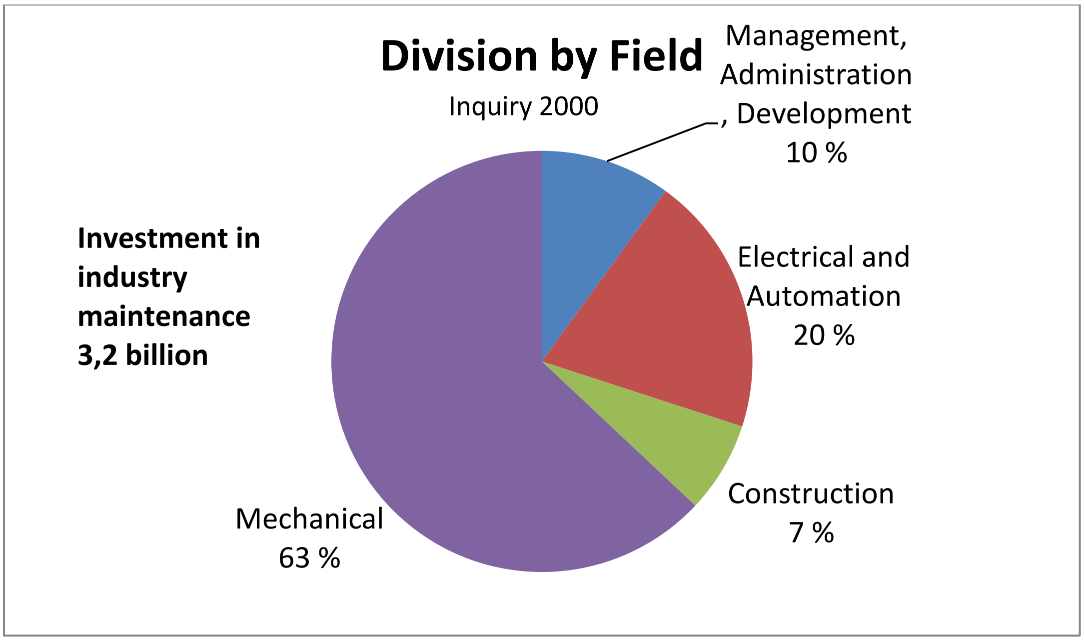

Figure 4. Division of maintenance by field (Heinonkoski 2004).

3.1 Description of a fault

An accurate description of the fault is needed when a machine is malfunctioning to help the service to detect faulty components or errors in the programming of the machine's control system. Because this project is about a control system, software related faults are looked with more detail in this section.

How accurate or how false the description is depends heavily on the professional experience of the person giving the description. The descriptions can be categorized in four classes:

1. Ideal description
    - The fault is professionally analyzed correctly
2. Almost correct description
    - All events are not acknowledged
3. Insufficient description
    - The fault is given but some of the needed information is missing
4. Flawed description
    - Contains irrelevant information

(Heinonkoski 2004, 61).

Integrating fault diagnostics in software provides unchanging information about the faults of the machine. In other words, the information is always the same in a given fault situation, in spite of the user. In contrast to situation where a user would give information, for example: “The machine stopped moving.” The control system provides more specific information and often the cause of the problem, for example: “Engine safety stop. Insufficient oil pressure.” In this case the control system has performed an emergency shutdown to prevent engine from damaging due to an insufficient lubrication and a person with adequate education would know to check if the oil pump is working properly.

The first thing of a good error message is an error number which serves as an identification for the fault. The error numbers are always the same regardless of the language in which the error messages are presented and control system used and, therefore, even if having a language barrier between the operator and technical support the problem can be determined by the number. The second part directs to a faulty component or a faulty connection. The third part gives an idea of what has caused the problem. So ideally the operators should be able to fix the problems by themselves or order correct spare parts without a long time consuming troubleshooting.

As automation in automotive and machine industry increases, the need for automated fault diagnostics and providing more information of the actions that are happening in the machine become increasingly vital for the user since it is otherwise impossible to know all the functions that are taking place.

3.2 Different types of faults

Short-circuit is a case where a power cable connects directly to a ground cable or to another power cable from a different source. Short circuit causes a great amount of current to go through the wire which generates heat significantly. If the cable is not protected by fuse short circuit may break electrical devices, burn the cable and even cause fires. Short circuits often happen as a result of mechanical abrasion of the insulation of the cable but may also happen inside electrical devices. In a forest machine electrical devices are in rough surroundings, as they are in an environment of great changes of temperature and moisture. This added to the shaking and vibrations of the machine, the durability of the devices is under a hard test.

Another common type of malfunction is a randomly breaking connection. This is usually caused by stress in cables, aging, oxidizing, bad soldering, wearing of the connectors or over current or over voltage leading to a damage in the connections (Heinonkoski 2004, 94). Breaking is a frustrating problem. The source of the breaking can be very hard to locate since it occurs often very randomly and the signal is often lost only for a short time. Breaking can result from a broken cable or a loose connection of a cable or a connector. Connectors are vulnerable to dirt, moisture and oxidizing.

3.3 Diagnostics in automation

For different types of electrical systems also diagnostics must be defined appropriately for different situations. Basically diagnostics compare two variables to each other in a defined way.

Diagnostics of On/Off -type faults. In digital signals the diagnostics monitor the state signals. The state of an input is compared to the state of an output and if defined circumstances are not met, an error message is given. Another way is to count pulses and the magnitude of those pulses. The third way is to monitor different events and compare their interrelation (Heinonkoski 2004, 134.).

Pulses can be monitored also by their length. On the right side the pulses are too long (figure 5). Mechanical jamming can often be seen this way, for instance. By using a timer to count cycle times an alarm can be programmed to be given when the cycle times get too long.

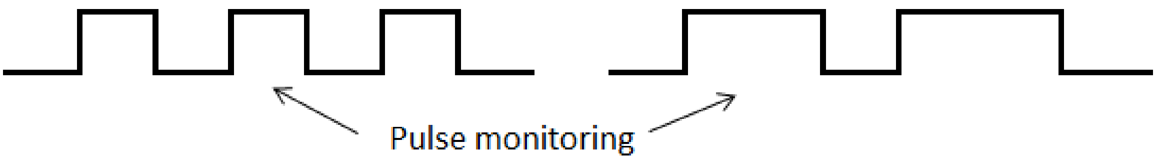

Figure 5. Pulse width monitoring.

Faults in analog devices. In a Logset forest machine the most used monitoring considering analog signals is a window comparator principle (Kytövaara 2013). This means that the magnitude of the signal is monitored and if defined limits are exceeded, an error is diagnosed. Analog signal faults can also be diagnosed by monitoring hysteresis and the crawling of the zero point (Heinonkoski 2004, 135). Since this is not typical in forest machines, these methods are not looked into in this project.

Analog signal usually carries current from 4mA to 20mA. Using current over voltage has certain benefits. Long distances cause voltage drop in the cable, proportional to the distance. In current loop that rarely causes troubles as long as the loop’s power source can compensate these losses. However, if transmitting sensors output as voltage, a use of high input-impedance devices and shielded wires is needed since high input-impedance devices are sensitive to noise. (Murata-Ps 2009.) Additionally, compared to 0mA to 20mA current loop, 4mA to 20mA current loop has the benefit of making the detection of broken cables possible if current drops to 0mA. Analog current loop is often calibrated to give certain values at given minimum and maximum value. Those values can be used as error limits in the monitoring system.

PWM -signal. Pulse width modulated signal is a digital signal but it can be used for controlling almost similarly as analog signal. PWM-signal's power is controlled by changing its pulse relation. In other words, the times how long the pulse is at state 1 and how long it is in state 0. Pulse width modulation offers basically similar control properties as analog signal but it is often a cheaper and less power consuming option (Barr, M. 2007.)

In figure 6 the signal on the left side is on 15% of period. In other words its duty cycle is 15%. The right hand side signal has the duty cycle of 85%.

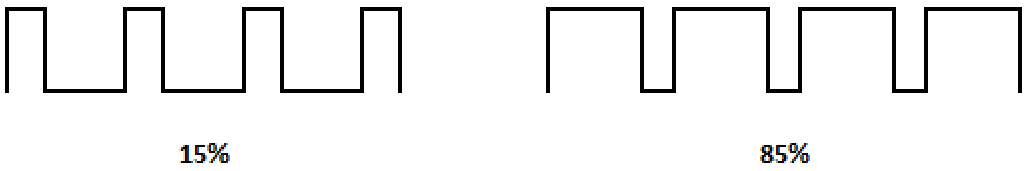

Figure 6. PWM signal

4 TOC SYSTEM

4.1 Features

TOC is the control system of the machine. It gathers almost all controls from switching lights to sending to and receiving from the forest product company. Very few mechanical buttons can be found in the cabin.

The main window (figure 7) offers the conventional information for example driving speed and fuel gauge. In addition it shows which lights are switched on and lots of other information about the functions that are switched on or off. It basically reminds a normal dashboard found in cars and other trucks and machines.

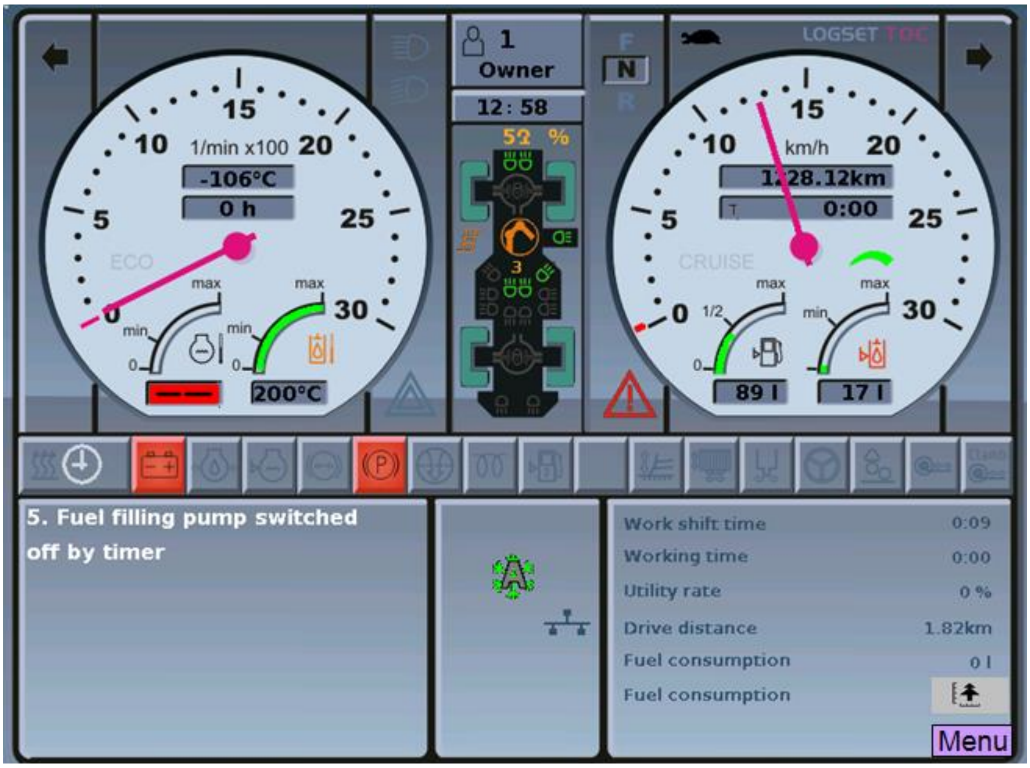

Figure 7. TOC main window (Logset 2011).

Furthermore the main window has two information blocks in the lower part of the window. The right hand side block contains information such as current fuel consumption and the work shift time. All error messages are shown in the left block.

Operating environment and behavior of the machine can be personalized. TOC system can contain settings for ten drivers and each driver can store two sets of parameters. Identification of the driver is done by personal USB-stick that every driver carries. The USB-stick also replaces the traditional ignition key. Logging into the system can, however, be done with personal PIN-code if the USB-stick is for example lost or damaged.

Among all other setting and parameters TOC allows the driver to adjust driving parameters and the behavior of the crane. Speed, acceleration and deceleration of the crane movements can be set according to the driver's desires which make working comfortable and efficient. Some features are accessed vie mobile phone. For example external heater can be programmed to start with a text message and escorting lights can be turned on when arriving at the machine by a phone call (Kytövaara 2010.)

4.2 Menus

TOC menu structure is clear and easily approachable. Instead of using buttons and text or pop-up screens and menu bars, TOC menus contain lots of symbols as this has been found quicker to use. It also makes the window very clear and only relevant information is always shown on the screen. Microsoft Windows based control systems menus can be confusing and advancing in them often opens new windows on top of each other which makes the window very crowded and menus clumsy to use. This problem is familiar to people using Microsoft products.

Navigation through TOC menus and windows is done with the joystick and is fast and easy. Using as much symbols and little text makes the navigation very fast. The pie structure of the TOC menus (figure 8) also gives all menus a logical window numbers. This is a huge advantage since the numbers are always the same despite that the language changes so the driver can be easily guided to a certain window if assistance is needed.

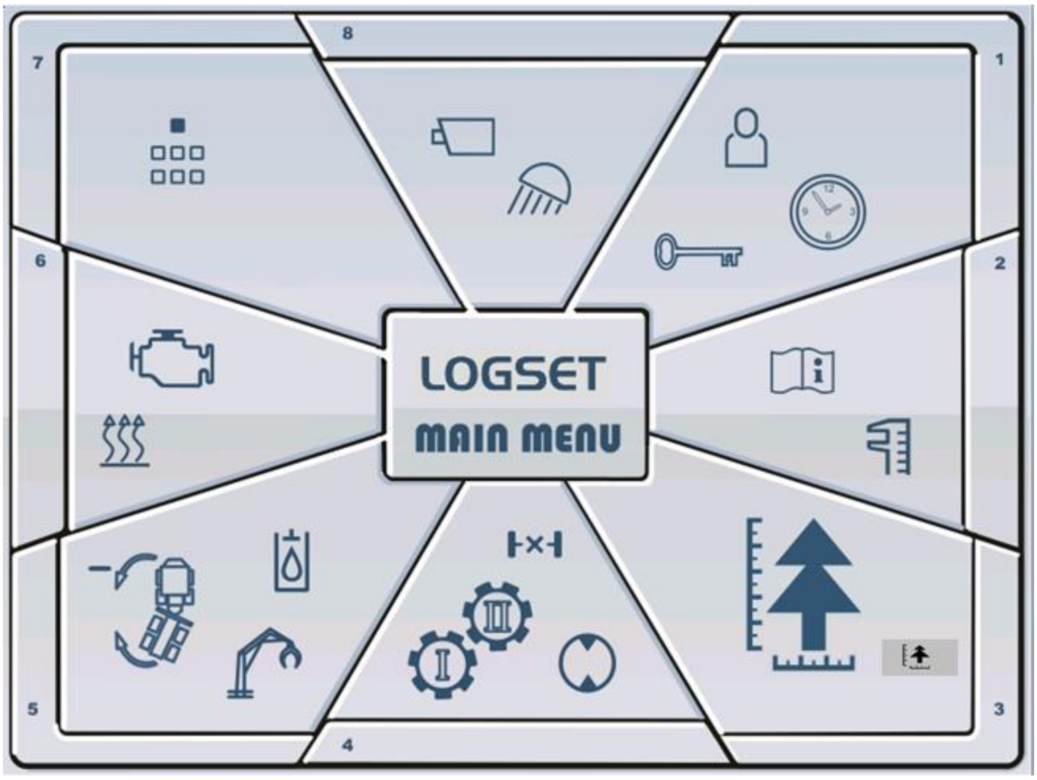

Figure 8. TOC menu pie structure (Logset 2011).

4.3 Communication

Communication between the operating modules of the machine is done via CAN bus. An introduction to CAN bus technology and the modules is given in this section.

4.3.1 CAN bus

Developed by Robert Bosch GmbH in the 1980’s the CAN bus is nowadays a standard technology in industry and automotive data transmission between sensors and actuators (Juhala, Lehtinen, Suominen & Tammi 2005, 129). Detailed information about CAN can be found for example in standard ISO 11898 and J1939 used by heavy-duty transportation stock (CAN in Automation [Ref. 7.4.2013]). J939 CAN bus is also used in forest machines.

A major benefit of using CAN bus technology is that it reduces the number needed of wires greatly. This is good because it helps to reduce costs and weight (Alanen

2000, 3.) In a forest machine this is a major benefit too because in forest machine cables are relatively vulnerable to elements, branches of fallen trees and other ground objects (Hangasmäki 2013). CAN bus is also advantageous for delivering information of one sensor to multiple control units of the machine. Adding new electrical devices is simple too thanks to CAN bus (Alanen 2000, 3).

All devices connected to CAN bus are called nodes. All nodes are given an ID and all nodes have an equivalent right to send messages. Other nodes then decide whether to collect the message or not by message’s ID (Sokka 2009, 9.) With modern components the number of nodes can be hundreds (Alanen 2000, 5).

A common practice is to use twisted pair cable as it is specified in the ISO-standard. The ISO-standard doesn’t specify the connector but CAN in Automation group has standardized 9-pin D-connector. Other than standardized solutions are also used both for cable and connector type though (Juhala, Lehtinen, Suominen & Tammi 2005, 134.)

In order to reduce signals echoing and making interference in the signal 120 Ohm resistors are placed in the ends of the line (figure 9).

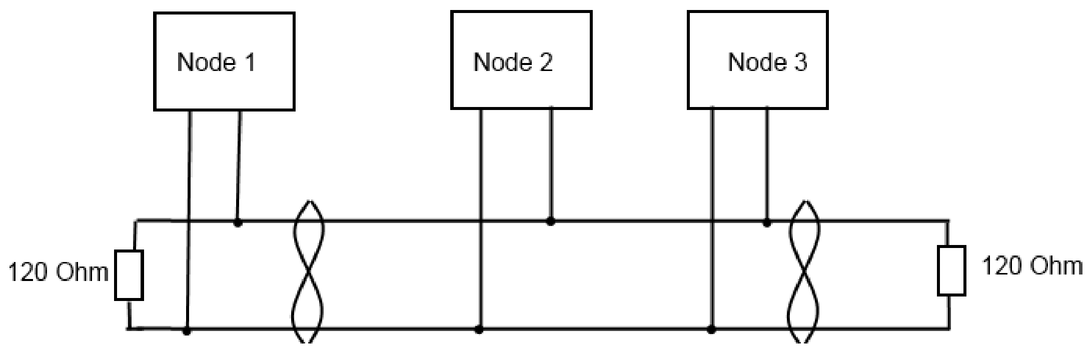

Figure 9. CAN bus physical principle

As mentioned before all nodes in CAN bus have the equivalent right to send messages to the bus. If multiple nodes send messages at the same time the order of the messages is defined by their priority. If a node needs certain information it can send a request to the bus and a corresponding node will then send the requested information to the bus. Since the messages are also received by all the needing nodes, same sensor can be exploited by multiple nodes (Juhala, Lehtinen, Suominen & Tammi 2005, 134.)

4.3.2 Modules

TOC system consists of number of different modules located in different parts (figure 10) and responsible of controlling different functions of the machine.

TOC modules and their main functions

- MCL 5000, safety and logical functionality of machine
- MIC 1000, display electronics, stores settings and parameters (older machines)
- MIC 1100S, display electronics, stores settings and parameters
- RD, display unit
- LC, crane control
- LT, transmission control
- LH, Harvester head module
- SPM-0, supply to MCL 5000 and cabin equipment
- SPM-1, engine preheater, air conditioning and other equipment
- SPM-2, crane work lights. Used only in harvesters.

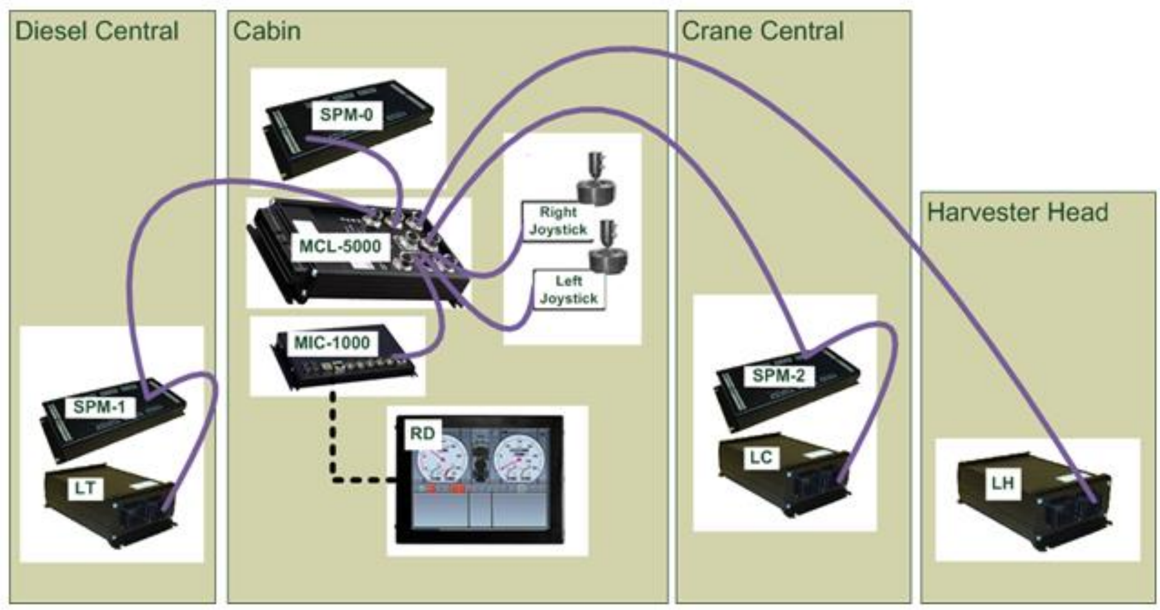

Figure 10. Harvester module layout (Kytövaara 2010).

LC, LT and LH are HCM2000 modules. They are interchangeable but store different parameters. SPM modules can be thought as CAN bus controlled intelligent relay card and MCL module is a programmable smart I/O module with CAN features.

4.4 Circuit diagrams

Circuit diagrams depict the electrical connections between electrical devices. What information is shown on one sheet varies. A comparison between two styles of circuit diagrams is done in this section.

4.4.1 Function based circuit diagram

The current circuit diagrams are drawn to present devices related to a same function. In other words one sheet may have for instance parts of three different modules (figure 11).

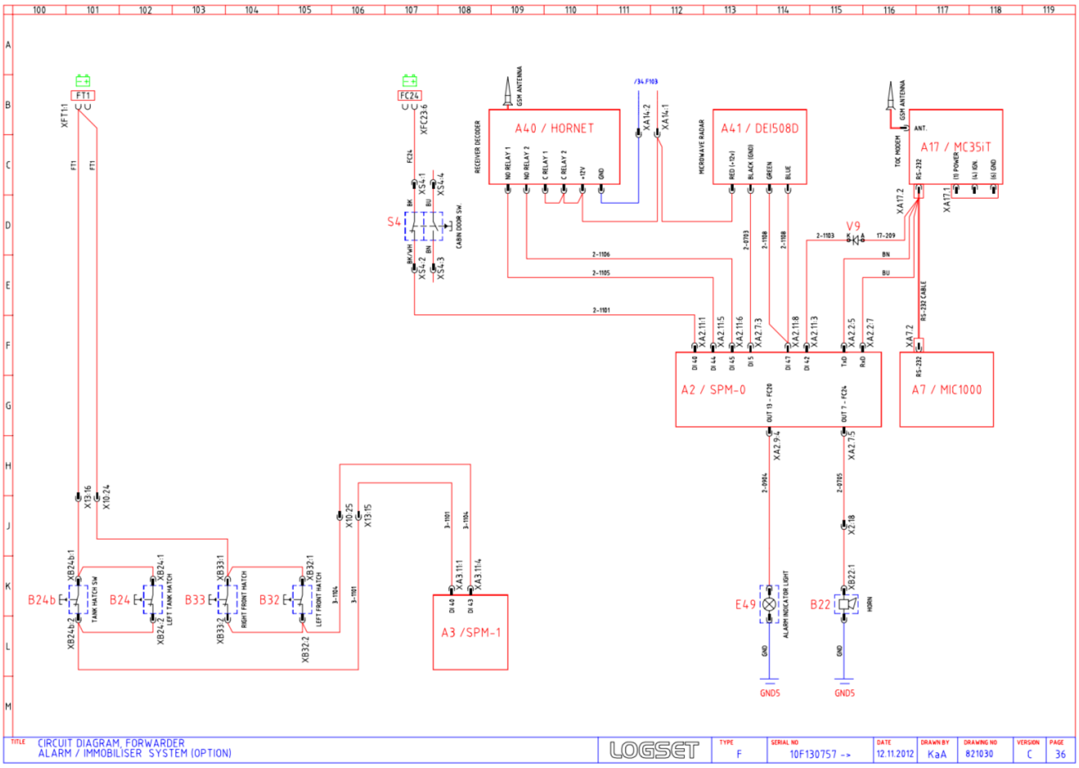

Figure 11. Circuit diagram, Forwarder alarm/immobilizer system (Ala-Välkkilä 2012).

Often when finding a faulty connection based on the error message the user starts looking for a certain module, because the error message tells that but not the function, finding the correct part of the module is slow.

In the bottom left corner of the diagram sheet is the name of the function that is displayed on the sheet (figure 12). In the current situation this is the information that has to be known to find a connector pin in a reasonable time.

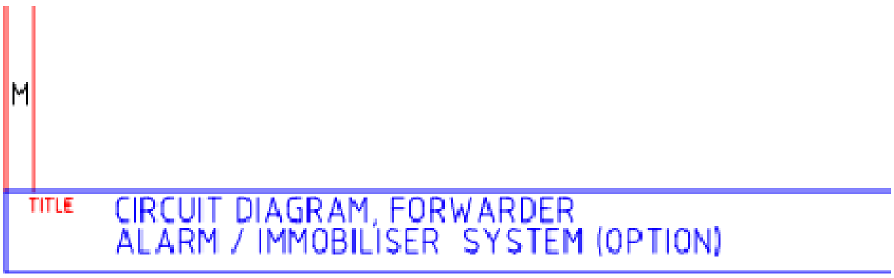

Figure 12. Circuit diagram sheet label (Ala-Välkkilä 2012).

TOC error messages only tell the module and the pin that is in error state but since the modules are split in different sheet according to the functions of the pins finding the pins is difficult. In circuit diagrams only the needed parts are drawn on the sheet. For instance drawing the whole SPM-1 module (figure 13.) on sheet when only two of the pins are used would take took much space on the paper and only make it look more complicated.

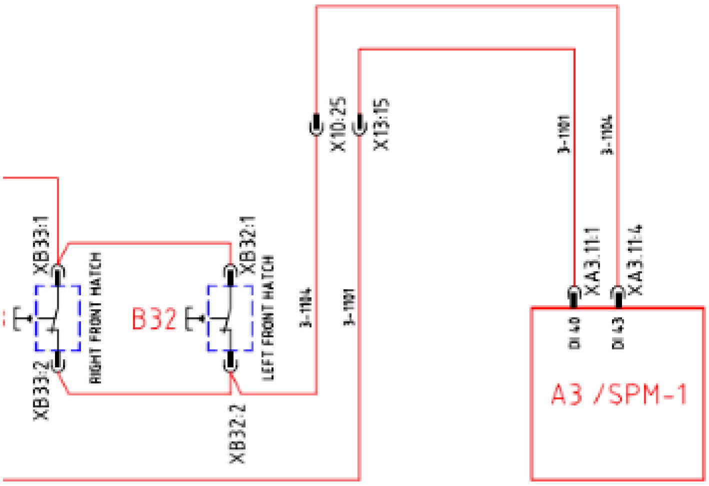

Figure 13. Part of SPM-1 module in circuit diagram (Ala-Välkkilä 2012).

A normal procedure is to draw only inputs on the top side of a block and outputs on the bottom side of the block (figure 14). Uniformity and rules like this make circuit diagrams easier to read and less confusing.

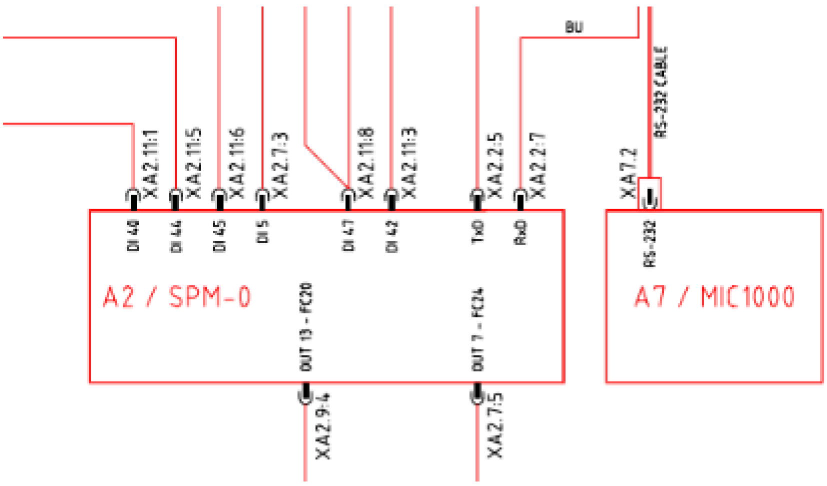

Figure 14. Part of SPM-0 and MIC 1000 modules in circuit diagram (Ala-Välkkilä 2012).

4.4.2 Module based circuit diagram

In comparison to previously seen diagram a module based circuit diagram makes finding pins faster gathering all of them on one sheet (figure 15.)

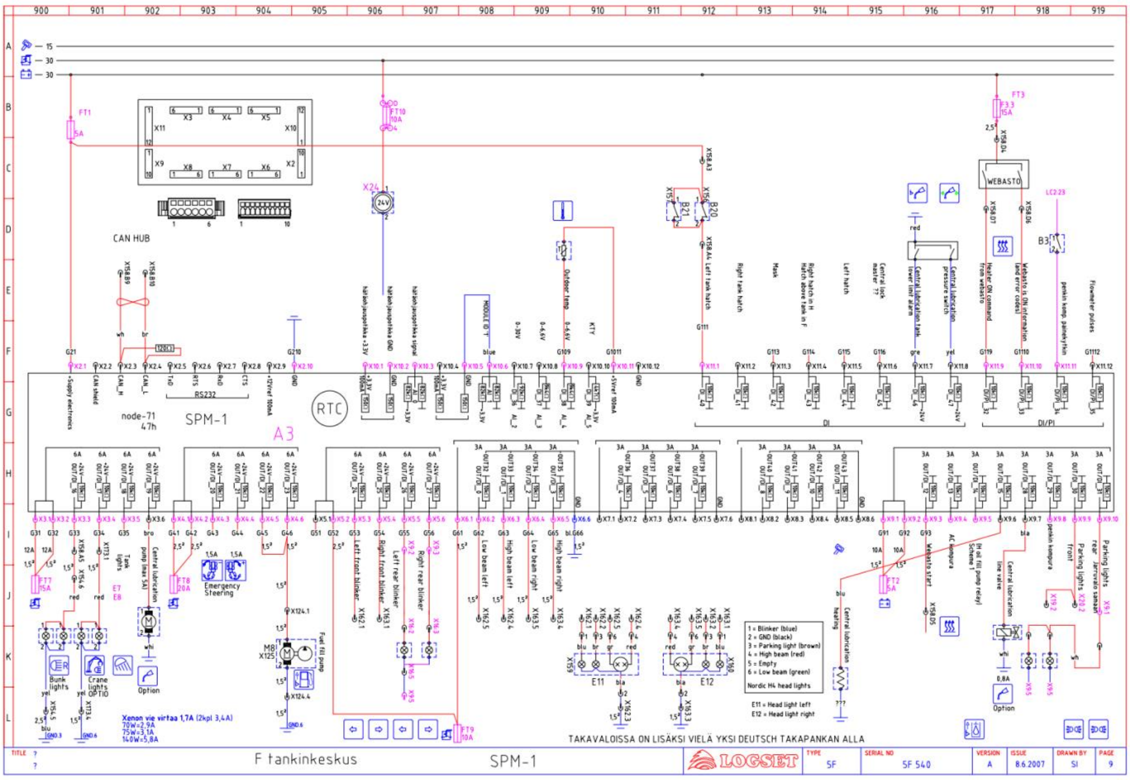

Figure 15. Wiring diagram of SPM module (Ilomäki 2007).

From this diagram all pins and functions connected to the pins can be found quickly. The function can be appointed with a symbol and a text. Common procedure is also cross-references to the corresponding circuit diagram sheets.

Simple electrical connections can be seen directly here. More detailed connections related to a certain pin may be observed from a different sheet where all connections considering the corresponding function are displayed but finding that particular sheet is now much easier since the function can be found here.

5 IMPLEMENTATION

5.1 Research

The ideas on improving the fault diagnostics and the problems of the current error messages and TOC diagnostic windows were mainly gathered from discussions with people in technical support, production and maintenance. Also a personal experimenting with a simulator and going through the circuit diagrams gave a good impression of the situation.

As part of the research an inquiry was carried out in the company organization. The people to be included in the survey were discussed with the superior. The number of those people was wanted not to be too high since it might lead to a too big scale of different opinions. By keeping the sampling small and within the people who were considered to have the best point of view in the matter, good ideas could be gathered from the answers and a good overview of the main problems and the most wanted improvements could be concluded. The inquiry was posted to 10 people and an answer was received from 4 of them. The inquiry consisted of open questions.

5.1.1 Inquiry summary

The first question was about the error messages. The answers were consistent with the feedback that was received earlier during the project. The new messages are wanted to give more information that directs straight to the faulty function or devise. Another thing that is desired regards the error messages of the engine. The engine has its manufacturer’s own diagnostics system and TOC is designed to only inform if some of the engine’s error messages are activated. TOC does not tell what the error is or where the user can access the information. The user can access engine’s alarm log via TOC though. The users often call technical support to ask where that alarm log is rather than trying to find it by themselves or checking the owner’s manual. The research shows that the improved fault diagnostics should at least give a suggestion for the user to check the corresponding TOC window to see more information. Uniting the engine manufacturer’s error messages directly into TOC error messages is considered to be unlikely (Kytövaara 2013). The model of a new message with the description of the function connected to the corresponding connector pin was found good. Also in the case of analog signals the message is desired to tell if the signal is too high or low rather than just pointing out an error.

The second question regarded TOC diagnostics windows which show all the module connector pins. A conclusion could be drawn that a better visual expression of the pins and the states of the pins has to be designed. In addition more information about the signals should be added, namely the expected and measured voltages and currents.

The third question was an open question about the desired improvements in general. The main line was concluded to be that the fault diagnostics should be more guiding and give suggestions of the actions needed to be taken in the given fault situations for example: “check fuse X”. TOC diagnostic windows should also be treated to give more information. Clarifying text messages, more understandable pictures and cross references to the circuit diagrams would be beneficial.

5.1.2 Experimental faults

To find out what kind kinds of behavior different kinds of faults create in different signals a thorough experimenting was done. Three different faults were created and the effects on the signals were monitored with computer software through a CAN bus signal. First experiments were done with a PWM-signal used for frame steering and after that the signal was converted into an on/off-signal and the same faults were created.

The following situations were experimented both for PWM-signal and on/off-signal:

- Faultless signal
- Cable disconnected / Wire cut
- Shortcut to ground

– Shortcut to positive lead

In the following pictures the different colored lines represent following signals:

– Black: control
– Green: input
– Blue: output
– Red: error
– Pink: current

In the beginning the behavior of the signals are inspected when the system is working properly (figure 16). The input and output signals are at state 1 and current runs in the circuit.

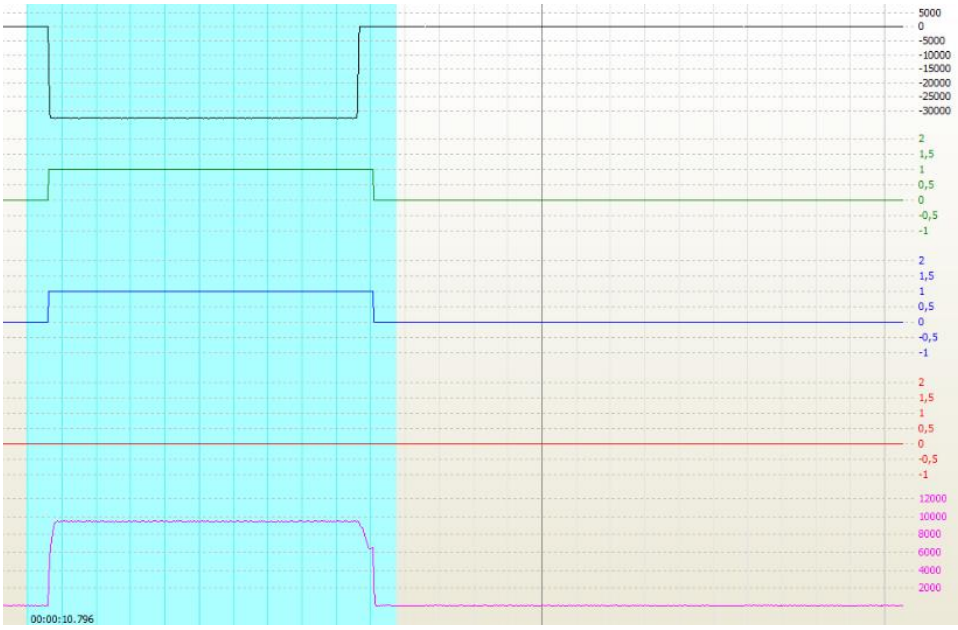

Figure 16. Proportional output. Signal faultless.

The control signal in these experiments was taken from the knob used for frame steering. The knob can be turned left or right hence the values go from -32768 to +32767.

Next the cable was disconnected to represent a broken cable. Input signal is no more detected so the error signal goes to state 1. A periodical change in the input state was noticed (figure 17).

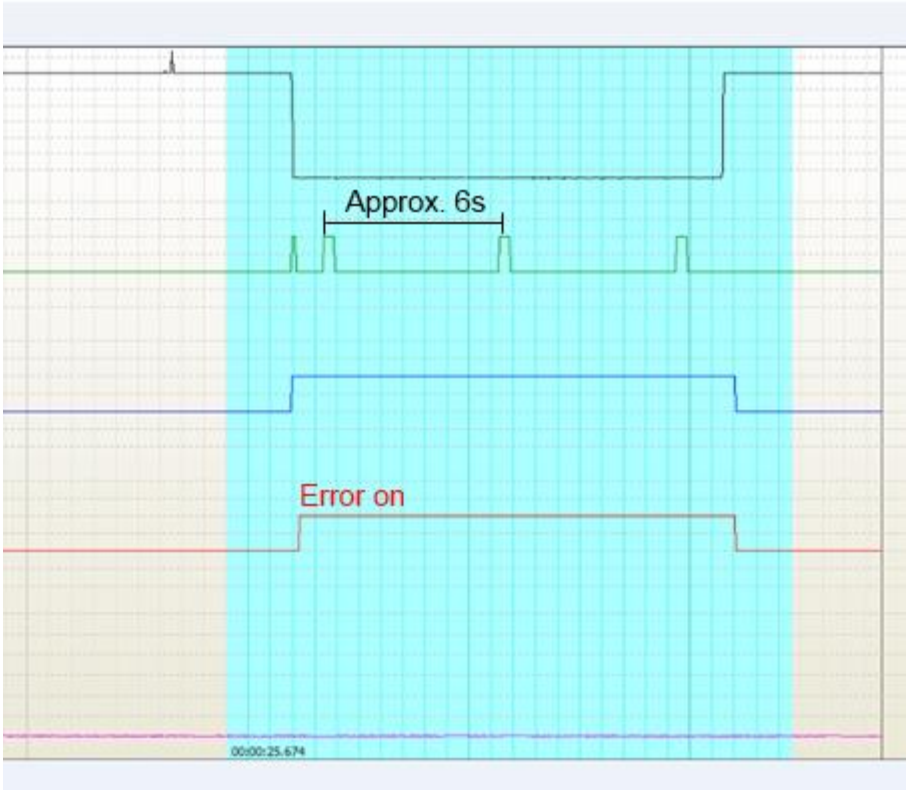

Figure 17. Proportional output. Wire cut.

This discovery led to a speculation if this characteristic could be taken advantage of and used to detect this error by using a timer and counter to check if pulses occur in the input signal. The measuring of the current was taken off as it was not needed.Next the cable was shortcut to ground using a short piece of cable. As input signal is not present here also error signal goes to state 1(figure 18).

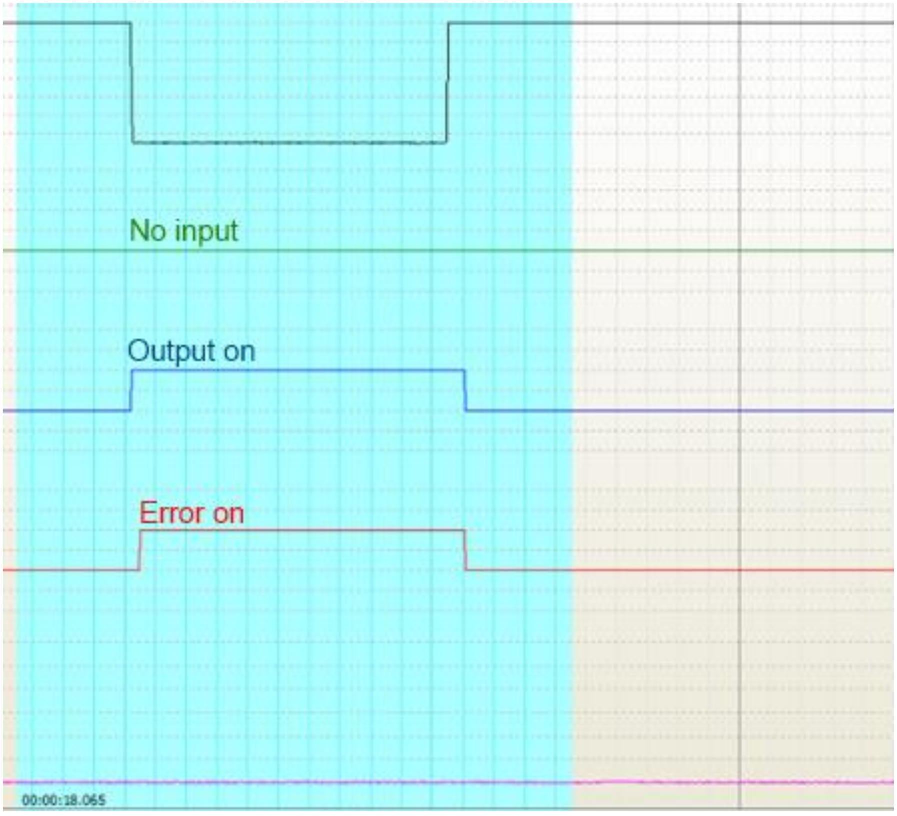

Figure 18. Proportional output. Shortcut to ground.

The third error situation happens when an unwanted current occurs in the pin from an unknown source activating the input signal. Since there is no output signal because the control knob is at 0 position the error goes to ON state (figure 19). This situation was created by using a short cable to connect 24V voltage from fuse box to the positive pin of the frame steering control.

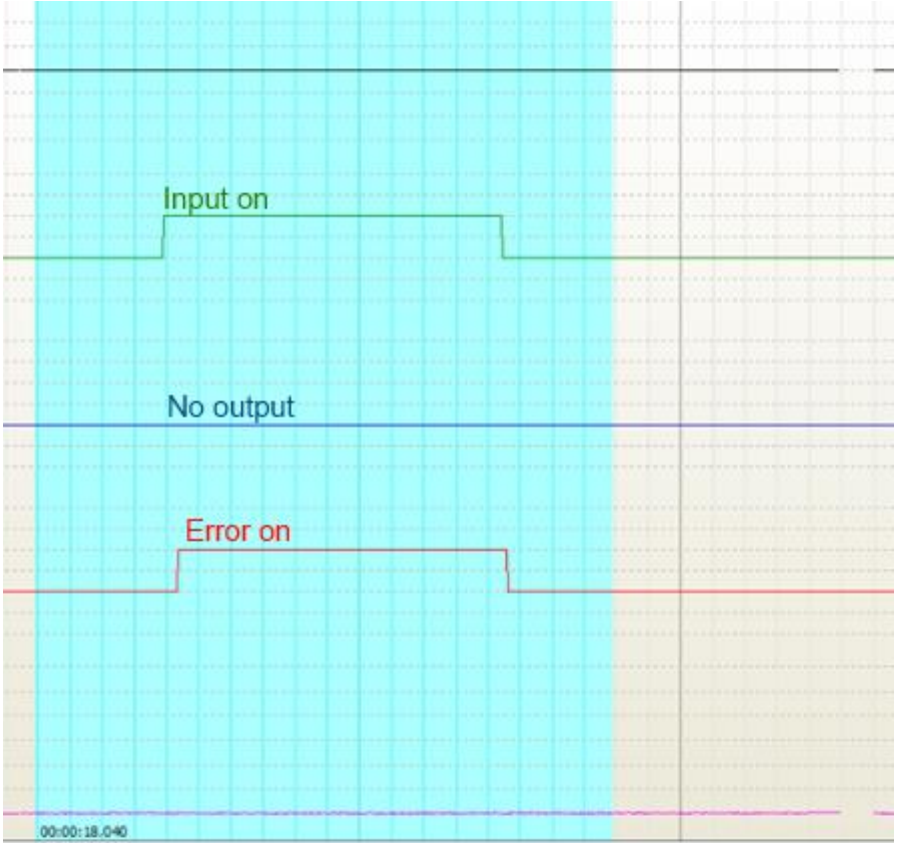

Figure 19. Proportional output. Shortcut to +24V.

The second phase of testing was done to the on/off -type signal. Unlike in PWM-signal wire cuts cannot be detected in an on/off -signal. The signal does not recognize load or its absence from the circuit (figure 20).

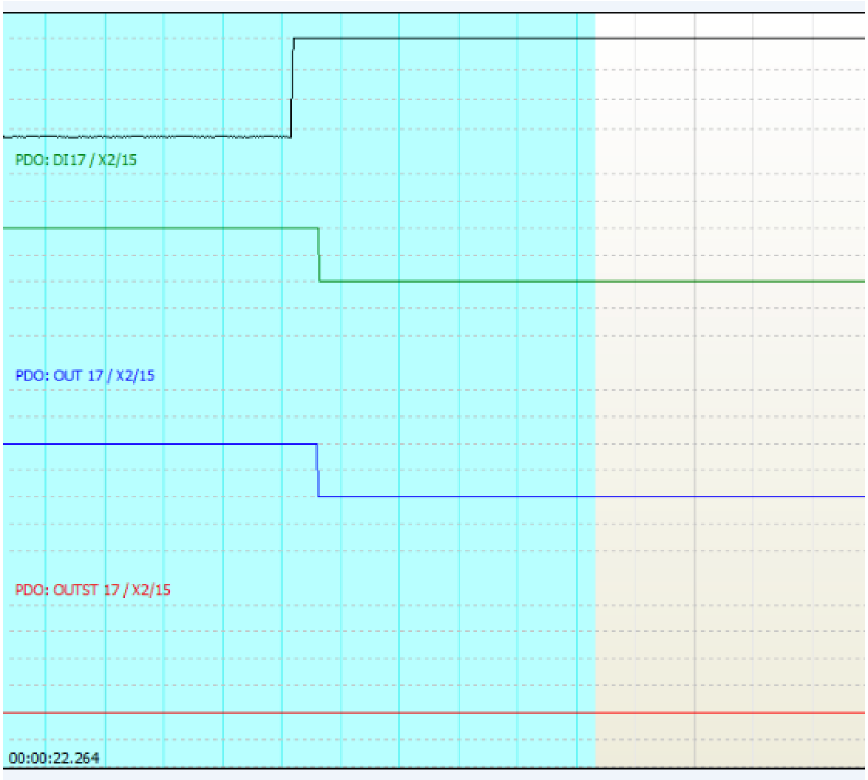

Figure 20. On/off -signal wire cut.

Detection of wire cuts could be achieved by using pull-up resistors. The idea of using them has been discarded though. Pull-up resistors generate current consumption and heat so the benefit gained from them has not been found to exceed the drawbacks.

A shortcut to ground was created again the same way as before. Similar results were also received as with the PWM-signal (figure 21).

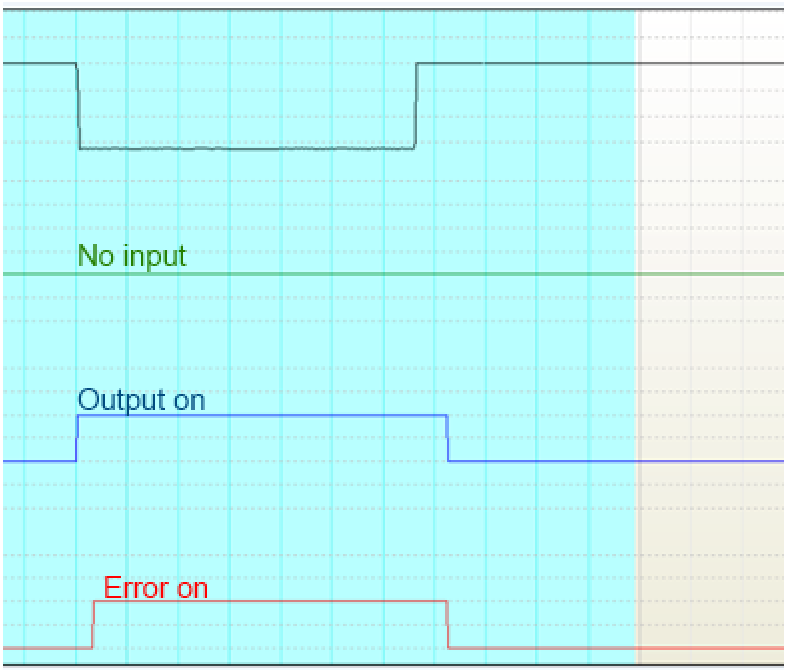

Figure 21. On/off -signal, shortcut to ground.

A shortcut to +24V voltage was also done similarly to the previous shortcut to +24V voltage -experiment. A little “shaking” can be seen in the input signal which is due to instability when connecting the cable between a fuse socket and the fuse (figure 22).

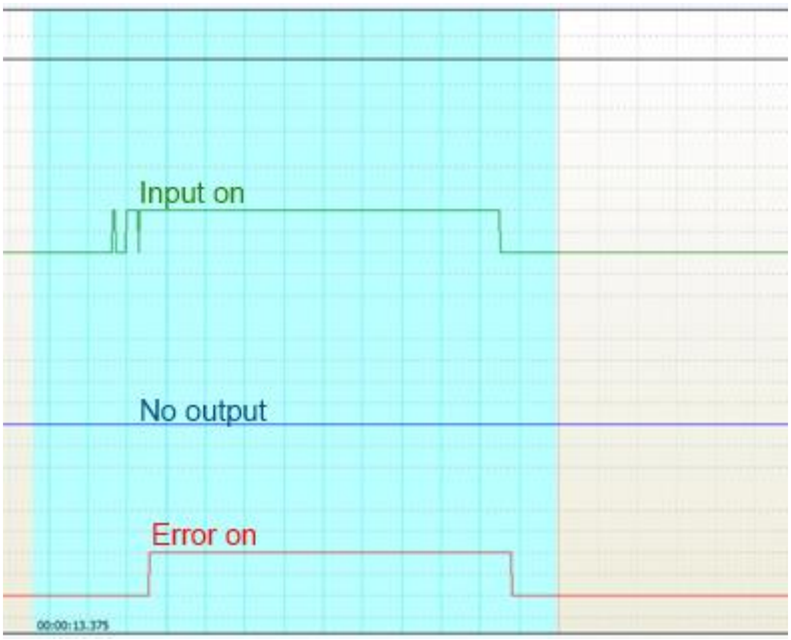

Figure 22. On/off -signal, shortcut to +24V.

Table 1. Truth table according to the experiments.

OUTPUT	INPUT	ERROR	PWM	On/Off
0	0	0	OK	OK
1	0	1	Shortcut GND	Shortcut GND
0	1	1	Shortcut +24V	Shortcut +24V
1	0/1	1	Wire cut	--
1	1	0	OK	OK

From the conclusions got from the experiments a truth table could be drawn (table 1). Defining new errors could begin using the table as the main principle.

5.2 Error messages

The current TOC error messages contain error code and a short description, for example “8: Error in LC input X1/9” where the first number is the error code, and after that there is a description. LC means crane module and X1/9 tells in which connector the error is. Another example of TOC error messages is “62: Lift boom potentiometer error” which is also not very helpful or precise. These messages do not help the operator to diagnose or fix the problem and are also insufficient even for an experienced service person. These messages do not tell if the measured value in the given connection is too high or too low, for instance. In a typical situation the faulty component has to be found from the circuit diagrams and if the only information is a pin number and the module name the search is going to be tricky. Usually the documents are in printed form or a pdf-file that cannot be searched for text. This makes finding the corresponding pin difficult and very slow. The circuit diagrams are drawn based on their function meaning that, for example, the connections of air conditioning are shown on one page and the connections of an anti-theft system on the other, even if they are powered by the same module. In the fault diagnostics point of view showing all connections of one module would be useful but that would make the drawings too complicated in many cases, since the modules may have over thirty pins. In the end. dividing the modules on different pages makes finding the error spot slow if the faulty function is not known.

The basic idea of improved error messages is to give so much information in the message that the circuit diagram would not necessarily be needed. The improved error messages tell the module name, then the pin named similarly to the ones in the circuit diagrams, the function of the pin and an individual component symbol.

The number of error messages is also increased significantly. Currently module outputs do not offer individual error messaging at all. They simply generate a message telling there is an error in a module output. Only the module name is given. In the improved version of TOC inputs and outputs will generate an error message telling that the signal is either too small or too large if possible.

There is also a section for error messages regarding the engine. Engines are manufactured by AGCO Power, former Sisu Diesel (AGCO POWER 2013) which uses its own diagnostic system. Therefore TOC is programmed to only notify the user that there is some error active regarding the engine. The notification is to be updated, however, to direct the user to the TOC window displaying the engine’s error messages.

5.3 TOC diagnostic windows

In the current diagnostic windows user can observe all connectors of all modules and test joysticks and buttons. Selecting the right module is easy as they are presented on the TOC window according to their real appearance (figure 23).

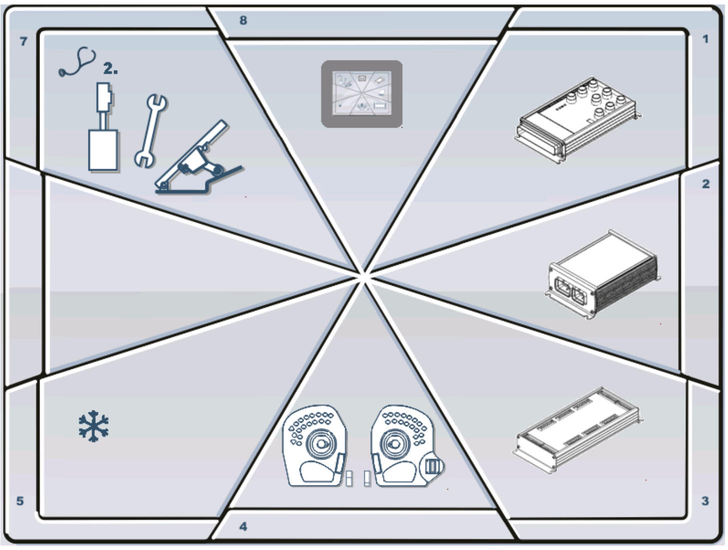

Figure 23. Diagnostics menu (Logset 2011).

In the connector window variable information is given. Explanation of the color coding is shown at the lower part of the window below of the measured values of some pins (figure 24).

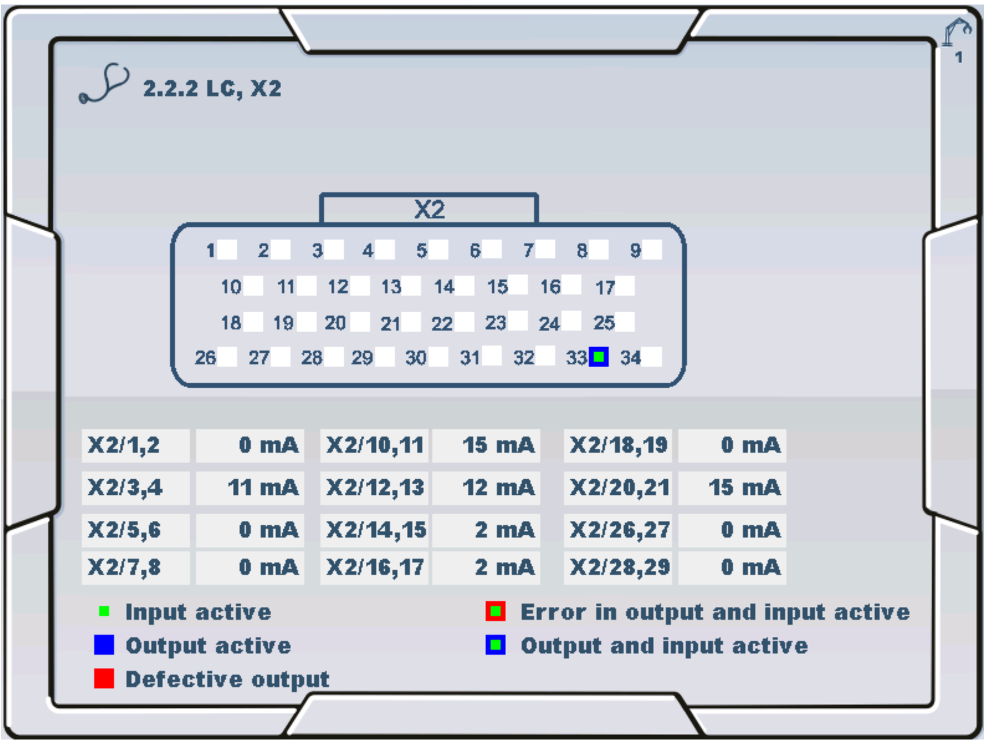

Figure 24. Connector window (Logset 2011).

The connector windows differ a little from each other and one of improvements to be done is to define clear instructions and a pattern to all windows to follow.

Modifications of the connector window (figure 25) in the new design

- Larger connector picture
- Larger pins
- Pin description added
- Interactive pins
- Background color of pin number in measuring table corrected
- New design of the pin state marker
- New legend

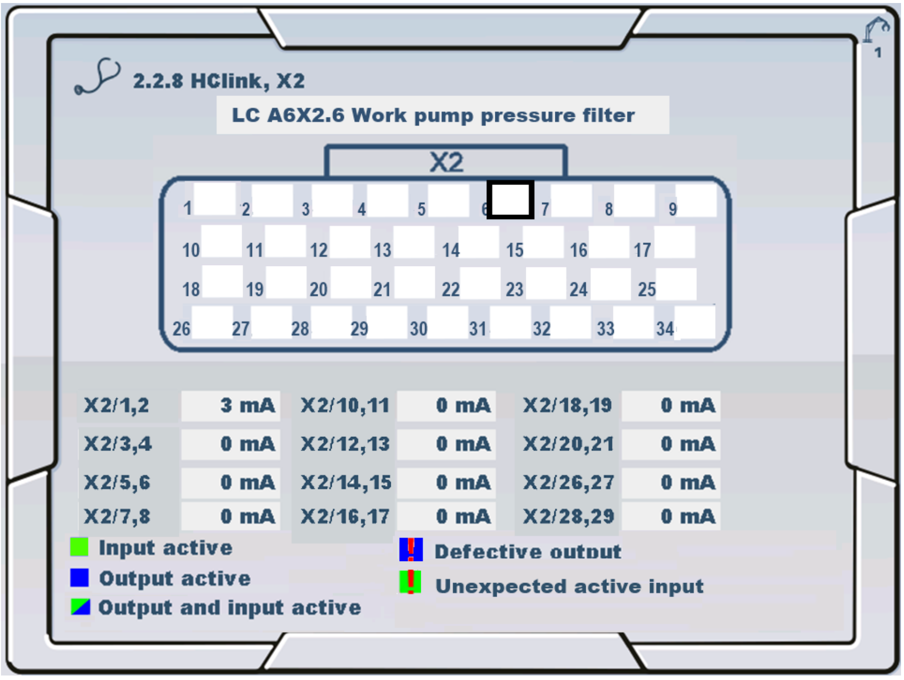

Figure 25. The new conncetor window

Another addition to the diagnostics windows section is the information screen that can be opened from every pin (figure 26). In that window a description of the fault can be seen and the device symbol which helps when ordering spare parts and locating the components from the circuit diagram. In the future this window is also expected to present even more information for example suggestion on fixing the problem, a picture or some other reference or method to access circuit diagrams.

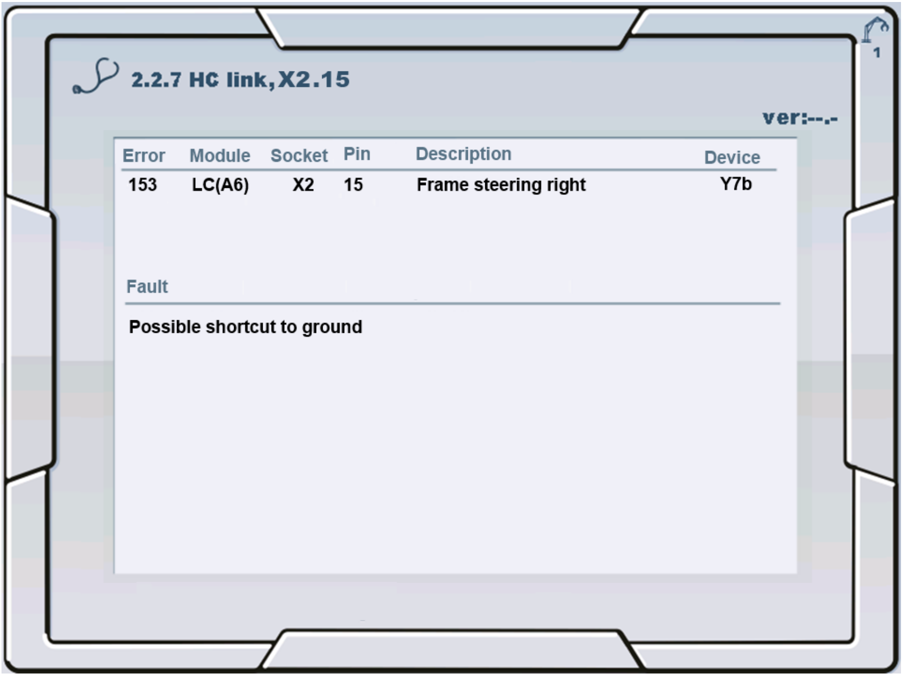

Figure 26. The new information window

6 RESULTS & REFLECTIONS

This project’s goal was to improve the fault diagnostics of TOC control system to make fixing problems easier and faster. An objective was also to make TOC diagnostic windows more consistent and easier to understand and interpret.

As a result of this work a documentation to increase the number of detectable errors significantly was produced. A new design and structure for diagnostic windows was also introduced. The listed new error messages are to be given to the partner in cooperation to be programmed into a system update. The work of implementing the results of this work into the TOC system is planned to be done during this summer. In the future the results of this work are expected to bring even more value and advantages as a new electrical wiring design program will be adapted to use and a new way of drawing the circuit diagrams will be established.

This project was very interesting and educating . The practical nature of this work and being able to do hands-on experimenting with the real forest machines made this project very pleasing and interesting to do, also knowing that the results will be seen in practice in the near future served as a good motivator. Finding literature about the electrical solutions in forest machines and suitable automation maintenance regarding machines proved to be more difficult than was expected and, since I had no previous experience with forest machines, this project allowed and forced me to learn about many new subjects which also made this project more challenging since the time schedule was very tight .

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APPENDICES