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A Practical Approach in Creating a Communication Channel for Industrial Environment

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***Abstract* - In many industrial applications, there is a need for communication channels to be available. Sometimes equipment needs to exchange messages with other equipment and sometimes the two machines are located very close to each other. Since in an industrial environment any wire or cable offers a possibility of a fault, many industries that operate in harsh environments have decided to switch to radio and wireless protocols. The paper will present an alternative designed for machines that use CAN protocol for internal communication and radio remote control and message exchange with other similar machines.**

Index Terms **- CAN-bus protocol, radio control, wireless communication.**

I. INTRODUCTION

Communication is broadly defined as the business of conveying information. Communication by means of symbol and gestures dates to the beginning of the human history. The term now has multiple meanings and it is used to define information exchange between devices using a network of some kind or other media while being regulated by standards and conventions that are collected and represent the technical specifications called communication protocol standards. Communication standards are used in industrial networks [2], [5].

What is an Industrial Network? By definition, an industrial network requires geographical distribution of the physical measurement I/O and sensors or functional distribution of applications. Most industrial networks transfer bits of information serially [3].

Serial data transfer has the advantage of requiring only a limited number of wires to exchange data between devices. With fewer wires, we can send information over greater distances. Because industrial networks work with several devices on the same line, it is easier to add a new device to existing systems.

To make all this work, our network must define a set of rules -- a communication protocol -- to determine how information flows on the network of devices, controllers, PCs, and so on. With improved communication protocols, it is now possible to reduce the time needed for the transfer, ensure better data protection, and guarantee time synchronization, and real-time deterministic response in some applications. Industrial networks also ensure that the system sends information reliably without errors and securely between nodes on the network [1].

CAN is the foundation for several popular field-level networks: DeviceNet, CANopen, SDS and others. When the developers of DeviceNet, CANopen, SDS and other CAN based networks sought a bulletproof technology for critical factory networking purposes, they opted for a ready - made solution from the automotive industry. Bosch developed CAN in the early 1980’s for eliminating large and expensive wiring harnesses in Mercedes automobiles [4].

CAN itself is a low-level message arbitration protocol implemented on inexpensive chips, which are available from multiple vendors and manufactured by the millions. In order to have a fully functional network protocol, an additional software layer is added.

Higher layer protocols like DeviceNet can be thought of as a sophisticated set of ‘macros’ for CAN messages, specifically suited for automation. SDS and CAN-open are automation networks also based on CAN. (The Society of Automotive Engineers created another popular standard, J1939. It is a CAN application layer used in trucks and buses.) [8].

CANopen networks are also used in forklifts, cranes, and other heavy equipment machinery. Other applications are public transportation (passenger and driver information systems) and ship control systems. However, the main application area is decentralized machine control [9].

II. OBJECTIVES

The objective is to setup and enable a full communication channel for an industrial assembly of two wood processing devices. The assembly is made out of wood trunks debarking equipment (referred as a flail) and a wood grinding equipment (referred as a grinder). Both work in tandem in order to transform wood trunks freshly cut into wood chips suitable for the paper industry (the requirement is less than 2% bark content).

The objective comes as a need to fulfil the task of having the two working together as one but to keep the possibility of separate control and command of individual equipment for the operator.

Three different types of communication need to be available. Each of the two has a communication protocol established between the diesel motor that powers the equipment and the controller. The flail and the grinder exchange messages and status via wireless CAN ad-hoc network. The third type of communication is between the each of the equipment and the radio remote (a separate remote for every equipment) that the operator can use to send commands to either the flail or the grinder when running in manual mode from a safe distance.

III. MATERIALS AND METHODS

The communication paths created consist of hardware installed and configured on both the flail and the grinder and software the routines created in IQAN Design for handling messages. The three types of communication channels are configured and work independent of other systems both software and hardware wise.

A. *Wireless CAN communications between grinder and flail*

In order to have this enabled on the two machines some assumptions, previous factory installed hardware, and software products are going to be used [7].

The chipper is equipped with wireless CAN from the factory and the flail is not. The chipper will serve as Master wireless CAN and the flail will be a Slave Wireless CAN. Both software programs that control the machines have a routine created for wireless CAN communications [4]. Both hardware and software configuration work is performed on both grinder and flail for the function to be enabled. Hatox GmbH supplies the hardware modules presented in Fig 1 and used for wireless CAN communication [6].

Fig 1 Hatox modules

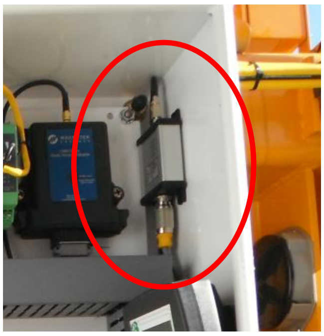

Fig 2 Hatox modules installed in panel

Fig 3 Wireless antenna on top of machine

As shown in the Fig 1 both modules allow for input and output direction of messaging. The baud rate used is 250KBaud and the data length is 8 byte. An 11-bit Id is used (master 0x5E0 for input and 0x5DF for output and slave 0x5DF for input and 0x5E0 for output). The complete system address contains fixed OEM address and adjustable address. Only adjustable address can be changed. This is the last four chars behind “Address:” on the transceiver (0 to 4095). The modules are physically installed in the electrical panel of each machine as seen in Fig

2. The module's antenna is extended outside the box for better coverage and is mounted on top of each machine as seen in Fig 3.

Once the hardware parts are installed, some adjustments will be performed in the controller routine by adding the code necessary for the wireless network.

A new routine called Wireless COMM. is added in the grinder and the flail controllers. This routine handles the wireless CAN communication and the exchange of status messages. A generic CAN bus module is created as Wireless CAN that is controlled directly by the controller and all the logic is done in the Wireless COMM. routine. In Fig 4 the hardware modules list includes a generic CAN module created to serve the purpose for wireless network. Fig 5 and Fig 6 picture the routine block diagram and code that run in the program and in Fig 7 a screen shot of the procedure control HMI screen is captured. On the screen there are safety messages popping out to warn the operator of the possible actions performed by both the machines once they start to exchange messages.

The chipper in the default factory state sends the following messages to the flail: emergency stop active, feed forward active, track mode enabled and chipper fault present.
The flail in the default factory state sends the following messages to the chipper: emergency stop active, feed forward active, flails running, and flail fault active.
The operator has the possibility to reset the connection or to cancel the pairing and even to see the status on the network.
In this state, there are still five available bits out of the eight bits sent in one message. The other five bits give the possibility for future development and can be programmed as requested to send additional messages.

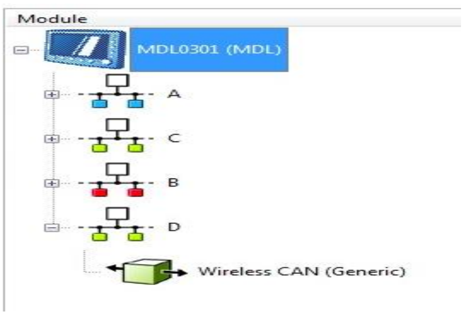

Fig 4 Wireless CAN module

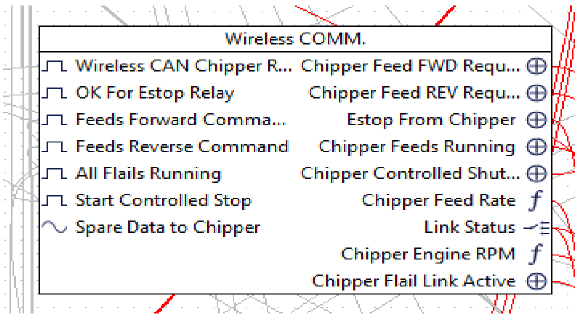

Fig 5 Wireless COMM. function block

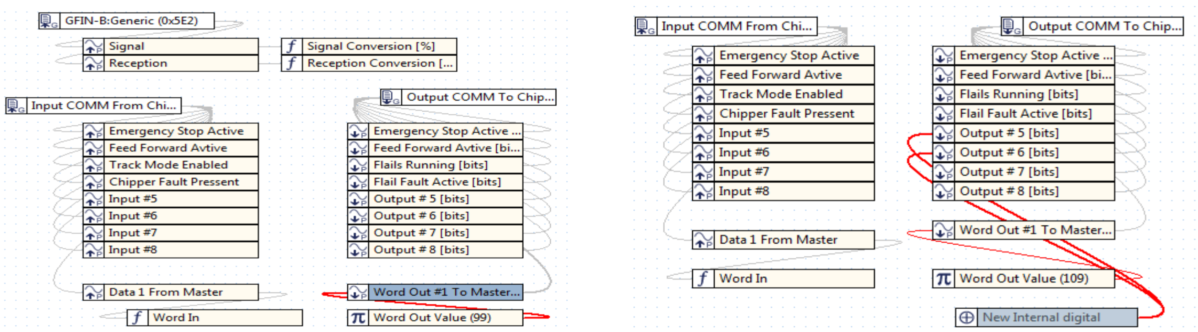

Fig 6 Wireless COMM. Routine code

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Fig 7 Wireless Link control screen

B. Radio communication for remote control both for grinder and flail

It is very convenient for any practical application in the field to provide to possibility of remote control. For this two additional devices are required to be added in the control system: a transmitter or the remote itself and a receiver.

Both the receiver and the transmitter are supplied by Enrange and are preconfigured with the messaging and once installed they are handled by the routine in the application. The receiver is a CAN-4 / 2.4 receiver that is designed for remote control of hydraulically “can-bus” controlled machinery. This receiver is designed to work with a standard J1939 communication CAN-bus system and it compatible with Parker’s IQAN modules.

The receiver comes in a small and rugged design built for outdoor environments. The CAN-4/2.4 has four digital outputs and CAN inputs and it is very safe about interference with 2.4 GHz FHSS RF channels.

The transmitter (Fig 8) is a custom part for each type of equipment. It has almost the same layout for the both and offers access to basic functionality.

The remote is intended for the machine operator to control the functionality from a safe distance due to the nature of the work performed. In addition, the transmitter provides the means to move the machine from one place to the other.

The remote transmitter (Fig 9) has an LCD screen (K in Figure 8) that displays information such as: time and day, engine rpm, engine temperature, oil pressure, fuel pressure, fuel consumption, feed power, feed rate, and clutch pressure.

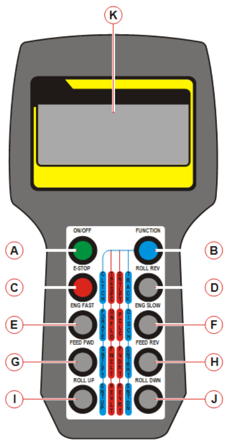

Fig 8 Enrange Transmitter

Fig 9 Enrange Receiver

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Volume 3, Issue 4, July 2014

As seen on the transmitter each button has one or multiple functions. In Table 1, the each function is detailed.

	Button	Button Function
A	ON/OFF	On/Off Switch 1. By holding this button for one second, the remote control is switched on. 2. It is switched off by pressing it again.
B	FUNCTION	Function Key By pressing this button together with another button, a choice for a specific function can be made
C	E-STOP	Emergency Switch
D	ROLL REV	Feed rollers in reverse. By pressing this button, the rotation direction of both feed rollers is reversed as long as the button is held, and the feed conveyor drive is switched off.
E	ENG FAST	Engine RPM Up. By pressing this button, the engine's RPM is increased and a purge cycle of the reverse fan is started.
F	ENG SLOW	Engine RPM Down. By pressing this button, the engine's RPM is decreased.
G	FEED FWD	Start / Stop Feed By pressing this button, the feed conveyor and both feed rollers are switched on/off in forward direction. Only possible when clutch is engaged and at maximum engine rpm.
H	FEED REV	Feed conveyor in reverse. By pressing this button, the rotation direction of the feed conveyor is reversed as long as the button is held, and the drive for both feed rollers is switched off.
I	ROLL UP	Top feed roller up. By pressing this button, the top feed roller is lifted as long as the button is held.
J	ROLL DWN	Top feed roller down. By pressing this button, the top feed roller is pressed down under pressure as long as the button is held.

Table I Detailed function for each push button on the transmitter

In order to have the receiver and the transmitter working and serving the purpose of allowing machine operation from a safe distance a routine called Enrange Remote is created in the application (Fig 10). In the routine the function bloc logic will handle all messaging and functions (Fig 11).

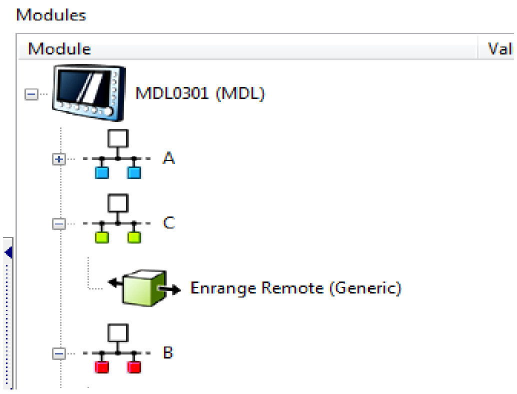

Fig 10 Enrange Remote module

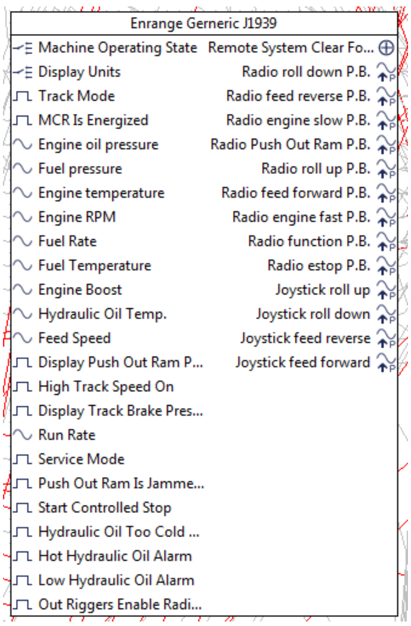

Fig 11 Enrange Remote function bloc

ISSN: 2319-5967
ISO 9001:2008 Certified
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The main functionality of a remote control in any system is to allow full operation and enable as many features as possible to be accessed by the operator from a safe distance. As a safety feature, it is impossible to start the machines from the remote control. Once the machine is put into operation manually from the controller the machine will run in Local mode but still with all the function in Auto, which means that the operator cannot operate any hydraulics from the machine or the engine (Fig 13). The functionality is provided by the logic in the controller. Once the machine is up to speed, temperature and pressure the operator can switch from Local Mode to Radio Mode. This is done by pressing one of the function buttons on the controlled (in our case F4 as seed in Fig 12) called "Local / Radio Toggle". When the equipment is in Radio Mode, the operator can start operating the machine from a safe distance using the remote. The start-up is performed with no material. Once start-up is complete, the operator can start loading wood into the flail or the chipper. The remote feature is designed the allow one operator to operate a loader while also having control of the processing equipment.

Fig 12 Machine in Radio Mode

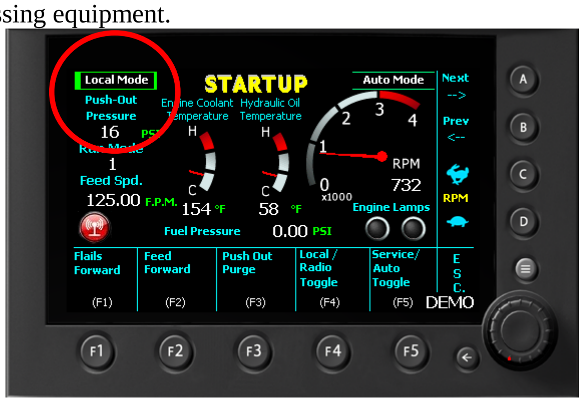

Fig 13 Machine in Local Mode

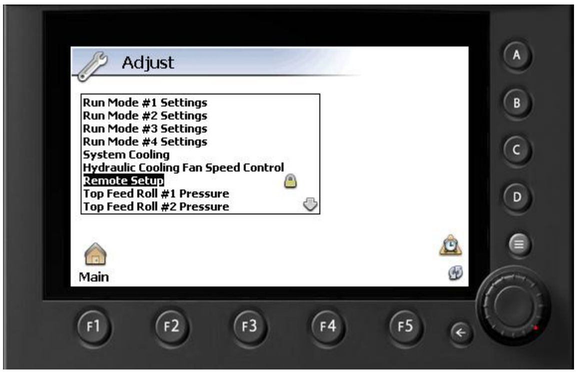

Fig 14 Remote setup option

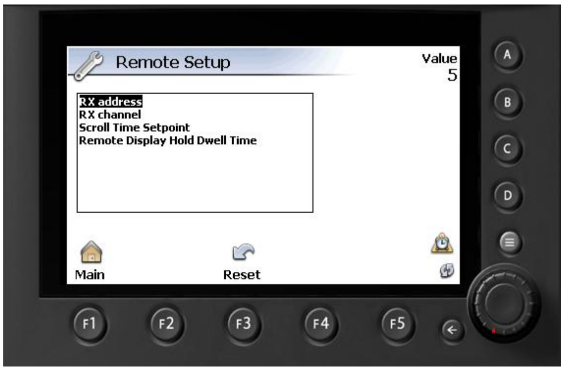

Fig 15 Remote setup menu

C. Messaging on J1939 protocol with the engine

As seen in Fig 11 there are inputs to the Enrage function bloc for the status of the machine. The Enrange remote is pre -programmed to display the desired text when the controller has sent the associated number to it. This is done using messaging on J1939 protocol. On the remote screen, information about the engine is displayed. A sheet with display values and associated messaged was created to serve this purpose. Because of this, there are two display groups (one for SAE & one for metric).

Each display group has eight identical values and associated text numbers sent to the remote, the display group one for Society of Automotive Engineers (SEA) or the display group two for metric.

The points in both groups are the same but display in SAE E.U. for group 1 and metric E.U. for group 2. The text number is based on the sheet created and the appropriate number must be sent at the same time as the value, to display the associated text to identify what the current value is.

This text number will change for SAE (group 1) vs metric (group 2) to display the correct engineering units. The Display Units button (SAE - metric) on the "Setup" display screen will determine if group 1 or group 2 text #s &

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Volume 3, Issue 4, July 2014

values is selected.

The display groups texts associated number) and values are: [Time (1)], [Engine RPM (4)], [Engine temp (5) SAE (6) metric], [Engine oil pressure (7) SAE (8) metric], [Fuel Rate (10) SAE (11) metric], [Fuel pressure (12) SAE (13) metric], [Engine boost (17) SAE (18) metric], [Fuel temperature (14) SAE (15) metric].

These displayed values are cycled through automatically, changing every 2 seconds continuously unless one of the "display hold" conditions in the logic is initiated by the control system. If one of these "display hold" conditions is initiated by logic then the display will show that conditions value and text (by text #) for 10 seconds and then return to scrolling the 8 initial values (exception is Estop active will clear when Estop is reset).

There are five conditions in the machines logic to display on radio remote if initiated. A generic frame out for an output channel from IQAN to Enrange using J1939 can be observed in Fig 16.

There are a series of parameters that will need to be configured in order for the frame out to adapt to our communication. First the identifier (0x1FF0527 - output) is unique and will pair a receiver with only one transmitter. The data length will be set for 8 bytes. The transmission will be continuously with a transmit rate of 100ms. The following parameter starting from 1 can be configured to send / receive messages as desired.

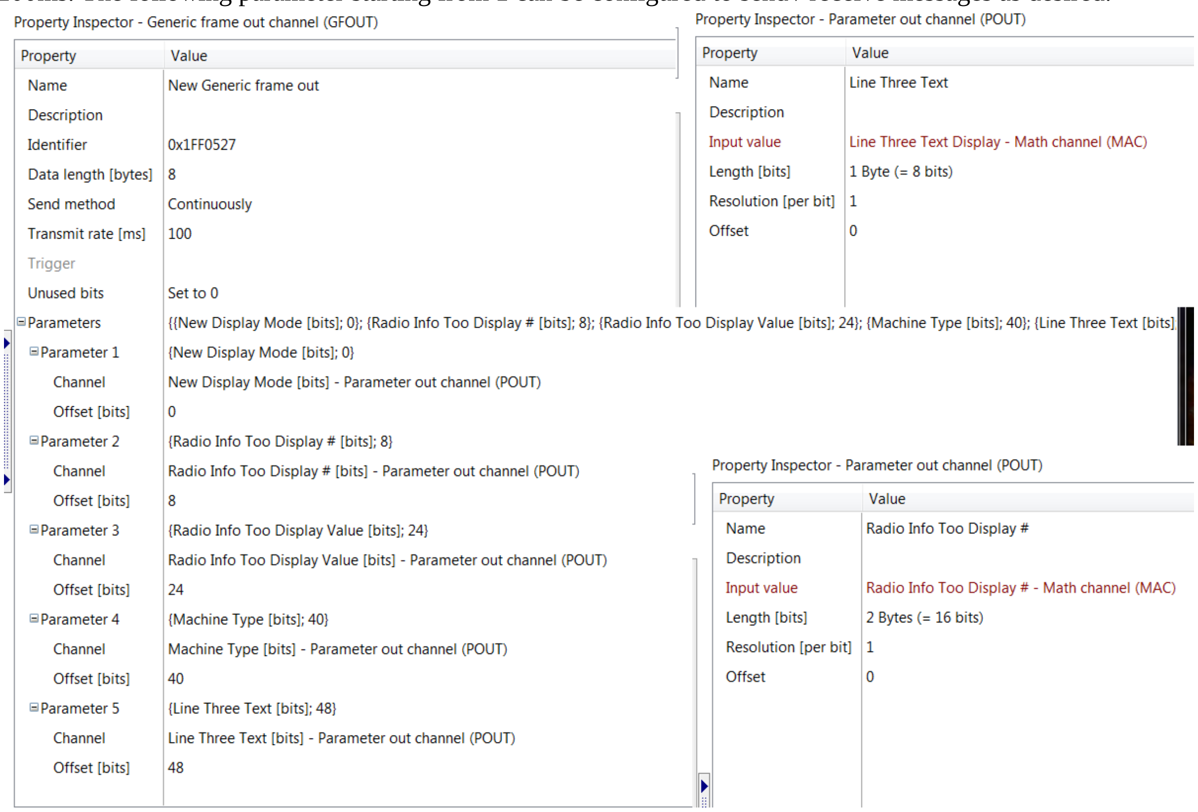

Fig 16 Generic frame out Channel from IQAN to Enrange using J1939

IV. RESULTS AND DISCUSSIONS

The most noticeable result of this approach is considered to be the of the communication channels for machines used in the wood processing industry. This solution is unique since the mix of technologies and protocols is new for the wood processing industry. Once the solution is set in place it can be used as is or with minor adjustments to any system that has a diesel engine as the main source of power and hydraulics attached to the controls.

The flexibility of the solution is provided by the individuality of the programming routines created. Each of the three can be use individually or in any combination of two. The most used is the routine for the radio controlled

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International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

remote. For this a list with Parameter Group Numbers (PGN's) was created in order to accommodate any other remote in the application. Each bit from the message will be assigned to a push button. The two most used are detailed in Table 2, Table 3 and Table 4.

PGN 65280 - Switch Inputs from Rlink			
Source Address: 76			
Transmission repetition rate: 100 milliseconds			
Data Length: 8 bytes			
PDU Format: 255			
PDU Specific: 00			
Default Priority: 6			
Parameter Group Number: 65280 (FF00 h)			
Bit Start Position/Bytes	Length	Description	Value
1	1 bit	SW3(A)	(0=off, 1=on)
2	1 bit	SW2(B)	(0=off, 1=on)
3	1 bit	SW6(C)	(0=off, 1=on)
4	1 bit	SW9(D)	(0=off, 1=on)
5	1 bit	SW12(E)	(0=off, 1=on)
6	1 bit	SW5(F)	(0=off, 1=on)
7	1 bit	SW8(G)	(0=off, 1=on)
8	1 bit	SW11(H)	(0=off, 1=on)
9	1 bit	SW14(I)	(0=off, 1=on)
11	1 bit	SW4(J)	(0=off, 1=on)
12	1 bit	SW7	(0=off, 1=on)
13	1 bit	SW9	(0=off, 1=on)
14	1 bit	SW13	(0=off, 1=on)
10, 15-65	Available for Future Use		

Table II PGH 65280 Configuration [8], [9]

PGN 65283 - Joystick Inputs, Battery info, RSSI from Rlink		
Source Address: 76		
Transmission repetition rate: 100 milliseconds		
Data Length: 8 bytes		
PDU Format: 255		
PDU Specific: 03		
Default Priority: 6		
Parameter Group Number: 65283 (FF03 h)		
Bit Start Position/Bytes	Length	Description
0	1 bit	Joystick SW 1
1	1 bit	Joystick SW 2
2	1 bit	Joystick SW 3
3	1 bit	Joystick SW 4
8-15	1 byte	Battery level (0=low, 10=full)
16	1 bit	Battery charge indicator (0=not charging, 1=charging)
17	1 bit	Handheld power source (0=battery, 1= plugged into adapter)
24-31	1 byte	RSSI (Received Signal Strength Indicator 0=min, 100=max)
32-39	1 byte	Mpsec (Messages per Second 0=min, 8=max)

Table III PGH 65283 Configuration [8], [9]

PGN 65281 – CAN Controller to Rlink Configuration
Source Address: 70
Transmission repetition rate: As needed
Data Length: 8 bytes
PDU Format: 255
PDU Specific: 01
Default Priority: 6
Parameter Group Number: 65281 (FF01 h)

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ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

Bit Start Position/Bytes	Length	Description	Value
1-10	10 bit	Address	
11-12	2 bit	reserved	
13-16	4 bit	Channel	
17-64	48 bit	reserved	

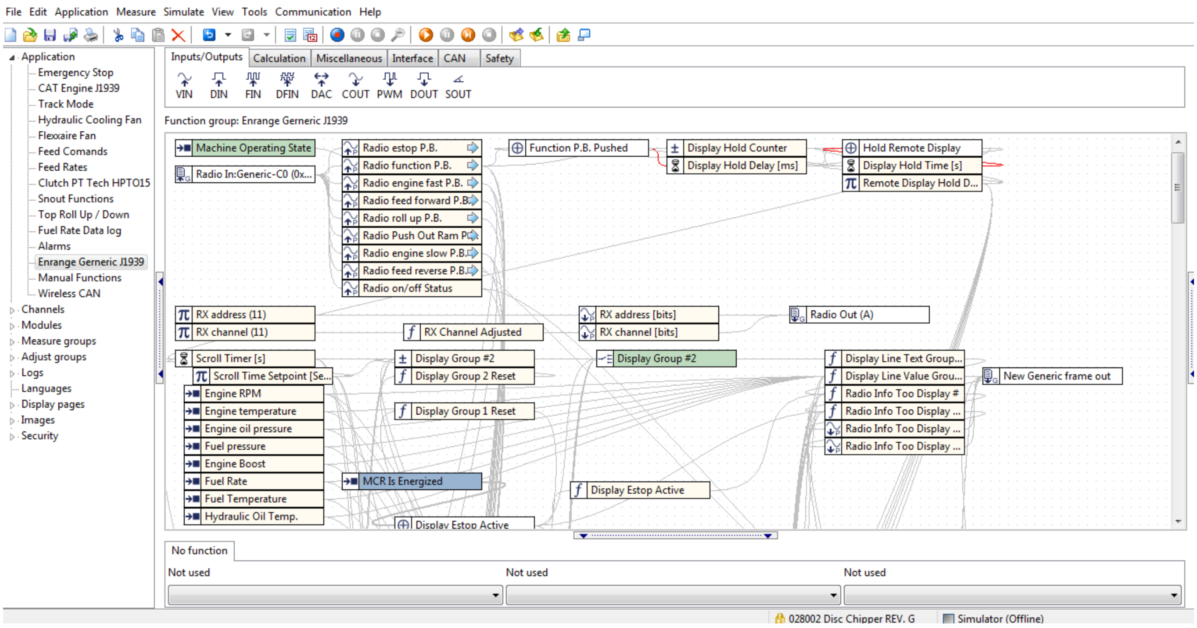
Table IV. PGH 65280 Configuration [8], [9]

V. CONCLUSION AND FUTURE DEVELOPMENT

Industries such as paper manufacturing and processing can leverage machine advancements in portability to reduce fuel consumption and the overall cost of transportation. The portability is provided by remote control and by wireless communications. Tracks and wheels allow users to process material on site in remote locations, at landfills and even over rugged terrain. In many cases, this eliminates the need to transport bulky raw material to a production facility – thereby reducing fuel consumption and emissions while increasing profit. Additionally, they can grind chip or shred material to a size that makes the best sense for their product and maximize each truckload while conforming to legal weight limits. The commonality between wood processing industry branches is that they all rely on a steady supply of wood fiber. While this can result in competition, in terms of obtaining wood, these industries are all working to put the supply to the best possible use – and in many cases can be mutually beneficial to one another. In all of these applications, remote controlled machines are an important part of the most productive and cost-effective processing equipment. There is a need for further continuous improvement of the solution. Other alternative protocols are considered to be implemented and tested to optimize the results. There is also a need for ongoing code optimization and access to new technologies. Alternative ways and hardware is to be taken into consideration to lower the price factory price for the machines. The approach is considered advantageous by the end users and this path was followed to ensure the needed communication. Even with the mix of protocols (radio, wireless, CAN-bus and J1939) the programmed routines handle functionality very well with no glitches or delays. The controller in the background performs most of the actions automatically and the operator does not need advanced knowledge of control systems of any kind. When the communication protocols are set and enabled on the machine the operator will have little or no intervention. If needed or desired, any application can be converted from a mobile solution powered by a diesel engine to a stationary on powered by electricity. Of course, that the change will bring along besides software routine logic changes a lot of physical equipment changes. Wireless communication will still and while J1939 communication will be disabled, the radio remote control is rendered as useless. So once a mobile machine turns stationary the control is simplified and the cost for communication solution drops significantly.

APPENDIX

Appendix A. Sample code created in IQAN Design. Additional code can be provided upon request.



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Volume 3, Issue 4, July 2014

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[8] http://store.sae.org/j1939/contents

[9] ISO 11898-1:2003 Road vehicles -- Controller area network (CAN)

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Dacian Zainea (IEE member since 2013) was born in Medgidia, Constanta, Romania in 1986. He received the Bachelor's degree in automation and applied informatics in 2009, and a Master Scholar degree in advanced automated systems and information technology, in 2011, from the Faculty of Electrical Engineering and Computer Science of "Transilvania" University of Brasov, Brasov, Romania. In 2011, he was admitted to start his Ph.D. studies in electrical engineering at the Faculty of Electrical Engineering and Computer Science of "Transilvania" University of Brasov, Brasov, Romania. In 2011, he joined the Department of Automation and Information Technology and Department D09 – Process Control Systems, "Transilvania" University of Brasov, Romania where he was an Assistant Professor. His current research interests include automated system control, power electronics, electrical machines and drives.

Radu Mihai Campeanu (IEEE member since 2007) was born in Brasov, Brasov, Romania in 1948. He received the Bachelor's degree in electronics and telecommunication in 1971, and a Doctoral degree in Electronics technology, in 2000, from the Faculty of Electrical Engineering of "Transilvania" University of Brasov, Brasov, Romania. In 2007, he joined the Department of Automation and Information Technology and Department D09 – Process Control Systems, "Transilvania" University of Brasov, Romania where he is currently a Professor. His current research interests include power electronics, electrical machines and drives, linear electrical circuits, digital electronics.