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READING FIELD DEVICE DIAGNOSTICS WITH AN AUTOMATION APPLICATION

Technology and Communication
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Sähkö- ja automaatiotekniikka

TIIVISTELMÄ

Tekijä	Tim Lindfors
Opinnäytetyön nimi	Kenttälaittedien diagnostiikan lukeminen automaatio sovelluksella
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Ohjaajat	Markku Levanen Juha Ojanen (Valmet)

Opinnäytetyön tavoitteena oli luoda toiminnallinen automaatio sovellus UPM Biolaitokselle, joka lukisi HART laitteen diagnostiikkatietoja. Nykyinen HART diagnostiikkatietojen määrä oli rajoitettu viiteen, ja tavoitteena oli kasvattaa tietomäärää laitoksen kenttälaitteiden ennakoivana kunnossapidon tarpeisiin.

Tapaamisia asiakkaan kanssa järjestettiin jotta voitiin keskustella, mitä kenttälaitteita he haluaisivat lukea ja minkälaisesta diagnostiikkatiedosta he ovat kiinnostuneita. Asiakas toimitti kenttälaitteiden käyttöohjeet, joiden avulla ymmärrettiin perusteellisemmin, miten HART-diagnostiikkatiedot voidaan noutaa. Valmet oli luonut demoympäristön, jossa kaksi kenttälaitetta oli liitetty järjestelmään. Demo-ympäristö oli suuri etu testauksessa, koska se poisti mahdollisen vahingon riskin mahdollisten laitoshäiriöiden varalta, kun toiminnallista lohkokaaviota ladattiin tai testattiin. Valmetin tutkimus ja kehitysosasto tarjosi mallin toiminnallisesta lohkokaaviosta, joka muokattiin asiakkaan kenttälaitteisiin sopivaksi.

Käyttöohjeiden ymmärtäminen oli myös ratkaisevan tärkeää tehtävän suorittamiseksi, koska eri yritykset, jotka käyttävät HART viestintää kenttälaitteissaan, voivat lukea HART-signaaleja eri tavoin. Valmet DNA funktiolohkokaavion asianmukaisella muokkauksella on mahdollista laajentaa HART-diagnostiikkatietojen määrää kenttälaitteista.

Avainsanat HART, DCS, FBD, diagnostiikka

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ABSTRACT

Author	Tim Lindfors
Title	Reading Field Device Diagnostics with an Automation Application
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Name of Supervisors	Markku Levanen, Juha Ojanen (Valmet)

The aim of the thesis was to create a function block diagram for UPM Biofuels plant that would read HART diagnostic data. The current number of HART diagnostic data was limited to five and the aim was to increase the amount of data to improve the predictive maintenance of the plants field devices.

Meetings with the client were set to discuss what field devices they would like to read and what diagnostic data they were interested in. The client provided manuals for the field devices and from there it was able to understand more comprehensively how to retrieve the HART diagnostic data. Valmet had set up a demo environment where two field devices where connected. The demo environment was a great advantage for testing because it eliminated the risk of any possible accidental plant failures while downloading or testing the function block diagram. Valmet R&D department provided a template function block diagram that was modified to fit the clients field devices.

Understanding the manuals was also a crucial to accomplish the task because different companies that use HART communication in their field devices will read HART signals different ways. With proper modification of the Valmet DNA function block diagram, it is possible to extend the amount of HART diagnostic data from the field devices.

Keywords HART, DCS, FBD, Diagnostics

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1 INTRODUCTION

The thesis aims to develop a comprehensive functional block diagram (FBD) to retrieve diagnostic data effectively from Highways Addressable Remote Transducer (HART) field devices. These devices are integral to industrial processes, offering critical insights into the operational status and functionality of various field devices. The proposed FBD acts as an interface, facilitating the extraction of diagnostic data, enabling engineers and technicians to efficiently monitor and analyze field device performance.

1.1 Background of the Study

This thesis was completed at Valmet automation Oy in Imatra and the end customer for this thesis work was UPM Biofuels Lappeenranta. The customer requested that they need more information about certain field devices that are used in their process. At the moment the customer can read five diagnostic HART values and the aim of this thesis was to extend the field diagnostics to a higher number. The amount of diagnostic HART values will depend on the device that is being read and the customer needs.

1.2 Objective of the Thesis

The primary aim of the thesis was to architect an FBD capable of communicating with HART devices, triggering diagnostic data retrieval, and deciphering the received information. The aim was to ensure a reliable and optimized interface to collect and translate data effectively, leading to informed decision-making and maintenance strategies.

In the process, fundamental aspects of the HART protocol and its data structure are explored to create a functional framework that effectively interacts with customers field devices. Valmet DNA will be employed to develop and execute the FBD and the monitor window.

1.3 Structure of the Study

The main tool used in this project work was Valmet DNA Explorer where suitable modifications are made to the FBD. Also, Valmet automation had set-up a virtual plant of the biorefinery where testing could be made without disturbing daily process of the plant. The manuals of the field devises were studied to get an understanding of how to read and decipher the HART values that are sent from the selected field devices. Using these given tools and help from experienced Valmet personnel this project was completed.

1.4 Valmet

Valmet is a prominent global company specializing in providing technology, automation, and services for various industries, particularly in the field of pulp, paper, and energy. Headquartered in Finland, Valmet has a strong presence worldwide, with operations and customers in over seventy countries.

The company's core focus lies in delivering sustainable solutions for its customers, enabling them to produce high-quality products efficiently while minimizing environmental impact. Valmet's expertise extends across the entire life cycle of its customers' processes, from design and manufacturing to maintenance and optimization.

Valmet's diverse product and service offerings cover a wide range of industries, including pulp and paper, energy, and various process industries. The company is renowned for its advanced technologies in areas such as automation, industrial internet, and energy efficiency, contributing to enhanced operational performance for its clients.

With a commitment to sustainability, Valmet emphasizes the development of eco-friendly and energy-efficient solutions. The company actively engages in research and development activities to stay at the forefront of technological advancements, addressing the evolving needs of its global customer base.

Valmet's dedication to innovation, coupled with its customer-centric approach, has solidified its position as a key player in the global industrial technology market. As industries continue to evolve towards more sustainable practices, Valmet remains a trusted partner for businesses seeking cutting-edge solutions that balance economic efficiency with environmental responsibility.

List of Valmet automation used in different industries:

- Pulp
- Board and Paper
- Corrugated board
- Tissue
- Energy
- Marine
- Biofuels and biomaterials
- Chemical
- Food and beverage
- Gas processing
- Industrial gases
- LNG
- Mining, metals, and steel
- Nonwovens
- Pharmaceutical
- Power-to-X
- Refining
- Coating and laminating
- Water and wastewater

1.5 UPM Biofuels

UPM Biofuels is a leading company in the production of sustainable and advanced biofuels. Based in Finland, it is part of the UPM Group, a globally recognized forest industry company. UPM Biofuels focuses on creating renewable solutions to meet the growing demand for sustainable transportation fuels.

The company is known for its innovative approach to biofuel production, utilizing wood-based feedstocks from sustainably managed forests. One of its flagship products is UPM BioVerno, a renewable diesel made from crude tall oil, a residue of pulp production. This biofuel offers a significant reduction in greenhouse gas emissions compared to traditional fossil fuels.

UPM Biofuels places a strong emphasis on sustainability, aiming to contribute to a low-carbon future and mitigate climate change. The company's commitment to responsible sourcing and production processes aligns with global efforts to transition towards more environmentally friendly energy solutions. The company's dedication to innovation and sustainability positions it as a key player in the bioenergy sector, contributing to the transition to cleaner and more sustainable energy alternatives. (UPM, 2024)

Figure 1. UPM Biofuels Lappeenranta

2 VALMET DNA DISTRIBUTED CONTROL SYSTEM

Valmet Distributed Control System (DCS) serves as a central intelligence hub in industrial settings, overseeing and coordinating various processes across sectors, such as pulp and paper mills and energy plants. It adapts to different scales of industrial operations, providing an interface for operators with graphical elements, alarms, and features for interactions. Valmet DCS integrates with a range of field devices and sensors, capturing real-time data to ensure operational efficiency. Valmet DCS is engineered to sustain continuous processes, minimizing unexpected downtime. It incorporates backup controllers and communication paths for transitions in case of component failures. Equipped with emergency shutdown systems and safety features, Valmet DCS prioritizes operational safety. The system allows access to historical data, facilitating analysis, troubleshooting and compliance with regulations. Valmet DCS supports remote monitoring, enabling operators and engineers to oversee operations from a distance. These features collectively contribute to the efficiency, safety, and adaptability of industrial processes. (Valmet, 2023b)

2.1 Valmet DNA Network

In the operational setting, which includes the control room and offices, the Valmet DNA system comprises several servers that play crucial roles in monitoring, controlling, and maintaining the overall process.

The Operator Server (OPS) serves as the gateway for operators to access real-time information about the process and make necessary adjustments. Simultaneously, the Alarm Server (ALS) collects and manages data related to process alarms, forwarding this information to operators through the Operator Server.

The Info Server, also known as the History Server, accumulates historical data encompassing the process, operations, and alarms, providing a comprehensive overview of the system's past activities.

For effective process control, the Process Control Server establishes a connection between the Valmet DNA system and the controlled process. It manages fundamental controls through diverse field interfaces, ensuring interaction.

To facilitate integration with other systems, the Valmet DNA system incorporates Interface Servers, offering various interface stations.

In the design aspect, the Engineering Activity Server/Client (EAS/EAC) creates a collaborative design environment. It consists of a central design server (EAS) and one or more design workstations (EAC) connected through a network. (Heikkinen, 2022)

Ensuring the reliability and integrity of the system, the Backup Server (BU) becomes crucial. All application changes undergo verification and are then transmitted to target stations through this server. The disk memory of the Backup Server retains applications from every connected server. In case of disruptions, it autonomously restarts faulty stations by reloading the required applications. This architecture ensures the continuous and secure operation of the Valmet DNA system in various industrial settings. Figure 2 shows an example of Valmet DNA network.

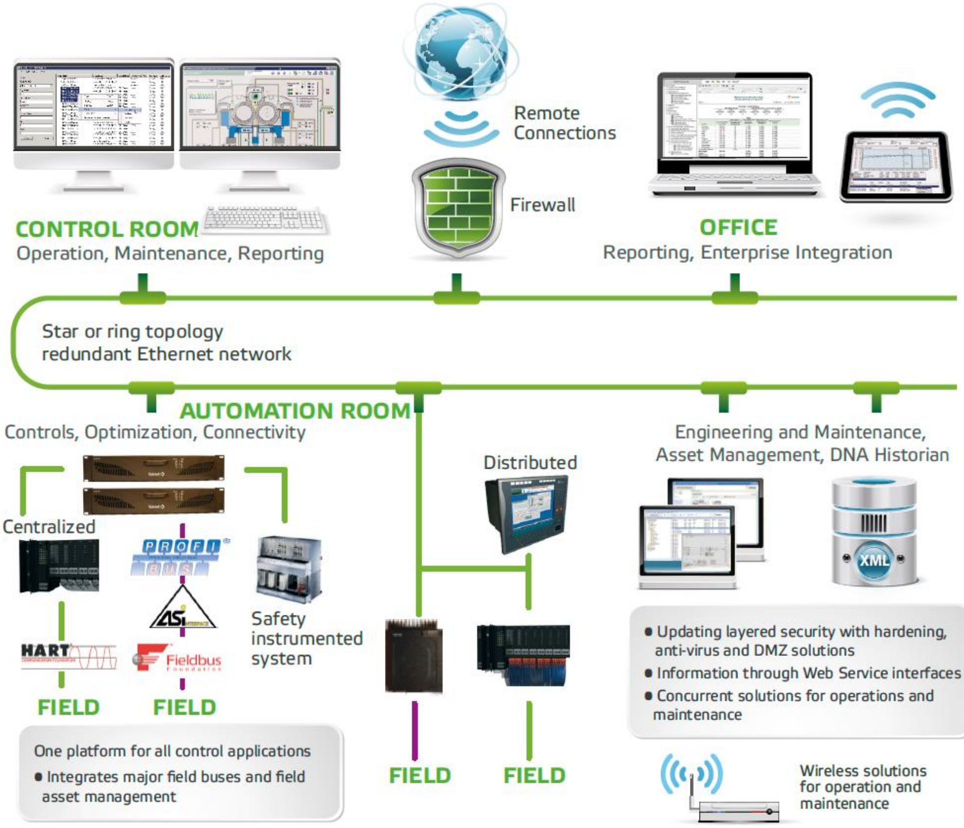


Figure 2. Valmet DNA Network

2.2 Valmet DNA Engineering Function Block CAD

Valmet DNA Engineering Function Block CAD is a tool used for designing function block diagrams for process control loops, sequences, and other process control applications. Function block diagrams are saved in one common repository located in the engineering server, which ensures that the documentation is always up to date. Valmet DNA provides function blocks for controls at all levels, including basic process control, advanced quality, drives, and optimization controls.

Workspace organization of the tool ensures a centralized repository for all diagrams on the engineering server. This shared space facilitates real-time synchronization, allowing active diagrams to be readily accessible and in sync with ongoing processes.

Valmet DNA has a level of versatility in control through its utilization of function blocks to address varying control requirements. Spanning from basic process control to advanced quality control, drives, and optimization controls, the tool offers a comprehensive solution for different operational levels. Standard features such as Fuzzy, MPC, and Java function blocks foster a unified approach to control designs throughout the entire plant.

The Sequence CAD tool further enhances the tool's capabilities by streamlining the creation of diagrams that illustrate the sequence of events. This includes the integration of controls from the process control server and other relevant functions within the control room.

The Graphics Designer tool complements these features by providing a user-friendly interface for crafting visually engaging process pictures. Leveraging a library of 3D components, such as devices, tanks, and pipelines, this tool enhances the overall design experience.

The Function Test tool serves as a graphical testing interface, displaying live data within the CAD diagram. This capability offers valuable insights into the performance of the control application, facilitating efficient testing and troubleshooting. (Valmet, 2023a)

Figure 3 shows an example of function block diagram that is in test mode.

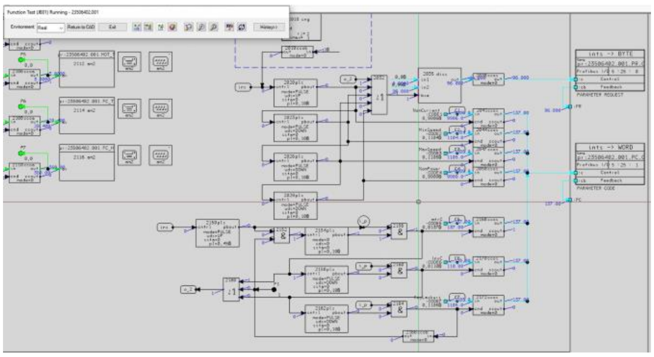


Figure 3. FBD with test mode on

3 HART TECHNOLOGY EXPLAINED

HART represents a bidirectional communication protocol facilitating data exchange between intelligent field instruments and host systems. This protocol enables diverse software applications, from handheld devices and laptops to plant control systems and safety mechanisms. Communication transpires between two HART-enabled devices, typically a smart field device and a control or monitoring system. Employing instrumentation-grade wiring and standardized termination practices ensures the reliability of communication. (Group, 2022)

HART introduces a dual communication channel paradigm, comprising analog and digital channels. The 4-20mA analog signal communicates the primary measured value (PV) in terms of current, with the host system subsequently converting this value into a physical parameter based on HART software-defined parameters. Concurrently, digital device information is conveyed through a digital signal, using Frequency Shift Keying on the same 4-20mA wiring used for analog communications. This digital signal encompasses valuable information such as primary variables, device status, diagnostics, and additional measured or calculated values. (Andrade, 2023)

Figure 4 shows how the analog and digital signals travel together in parallel.

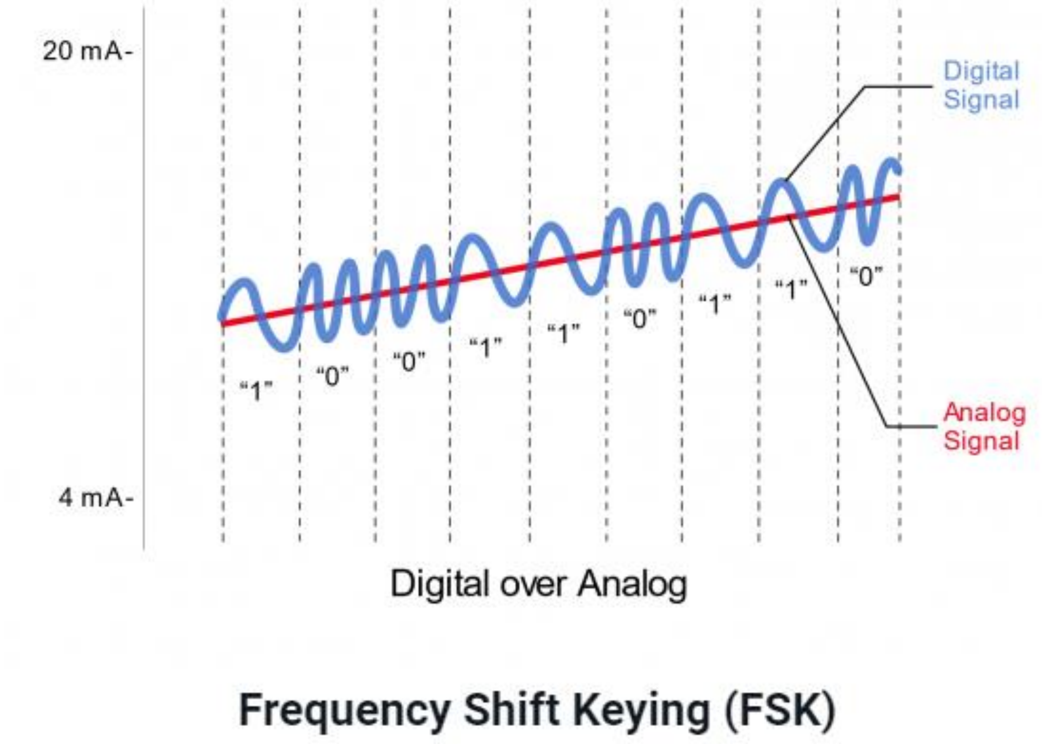


Figure 4. Frequency Shift Keying

These parallel communication channels combine to deliver a comprehensive field communication solution known for its simplicity, cost-effectiveness, and reliability.

3.1 Decoding the Mechanics of HART

At its core, the HART Protocol leverages Frequency Shift Keying (FSK) to overlay digital communication signals atop the 4-20mA signal. This integration enables two-way communication in the field, facilitating the exchange of additional information beyond the conventional process variable between a smart field instrument and external systems.

Operating at 1200 bps, the HART Protocol ensures uninterrupted communication with the 4-20mA signal. This protocol allows a host application (master) to receive two or more digital updates per second from a smart field device. The continuous phase of the digital FSK signal prevents interference with the 4-20mA signal. Consequently, the HART Protocol establishes two simultaneous communication channels: the 4-20mA analog signal and a superimposed digital signal.

The 4-20mA signal communicates the primary measured value using the industry-standard 4-20mA current loop. Additional device information is transmitted through a digital signal superimposed on the analog signal. This digital signal includes device status, diagnostics, and additional measured or calculated values. Together, these communication channels present a cost-effective, robust field communication solution that is both user-friendly and easily configurable. (Andrade, 2023)

3.2 Navigating HART Commands

The HART Protocol operates as a request-response communication protocol, signifying that each communication during normal operation is initiated by a request or command from the host communication device. The host, often a distributed control system, PLC, or PC-based asset management system, communicates with field measurement devices such as diagnostics, pressure, level, temperature, and flow transmitters.

To ensure seamless communication across diverse HART-enabled devices, the HART Protocol specifies a set of commands, categorized into three classes:

Universal commands are universally recognized and supported by all devices using the HART Protocol. They provide access to information crucial for routine operations, such as reading the primary variable and units.

Common practice commands encompass functions implemented by many, though not necessarily all, HART communication devices. They cover actions like calibrating, setting zero, or setting span.

Unique to each field device, device specific commands access setup and calibration information, along with details about the device's construction.

Defined device status indications accompany each communication response to the host, allowing the host to interpret these indicators and provide basic device diagnostic information.

In conclusion, the HART Command Set establishes uniform and consistent communication for all field devices, empowering host applications to implement necessary commands for specific applications. This approach ensures interoperability and standardized communication across diverse HART devices. (Management, 2002)

3.3 Dynamic Variables Commonly Associated with HART Communication

Primary Variable (PV) represents the primary measurement of a process or system. For instance, in a temperature control system, the PV might be the current temperature reading.

Secondary Variable (SV) is an additional process variable associated with the field device. This variable is often used to provide more information about the process or the condition of the device. It could be, for instance, a secondary temperature measurement or a related parameter.

Tertiary Variable (TV) provides further details or diagnostics. This could include variables related to device health, calibration status, or other diagnostic information.

Quaternary Variable (QV) can represent diagnostic or other related information about the quality or condition of the process or the device. For instance, it could include information about sensor diagnostics, device status, or communication quality.

These variables are commonly used in HART communication protocols and devices to monitor, control, and manage various industrial processes. (Andrade, 2023)

4 CORIOLIS MASS FLOW METER PRINCIPLES

4.1 Coriolis Effect

The Coriolis effect is a phenomenon observed in rotating systems, such as the planet Earth. It describes the deflection of the path of an object moving within a rotating system. When fluid or gas is in motion, the Coriolis effect causes the moving fluid to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere. (Britannica, 2023)

4.2 Mass Flow Meter

Coriolis mass flow meters operate on the fundamental principles associated with the Coriolis effect. These meters employ a U-shaped vibrating tube through which the fluid flows. As the fluid moves through this vibrating tube, the Coriolis effect induces a twisting or deformation of the tube, a consequence of the fluid's inertia interacting with the tube's motion. The resulting phase shift between the inlet and outlet vibrations is directly proportional to the mass flow rate of the fluid. Figure 5 shows how the outside casing and the internal workings of the mass flow meter.

Figure 5. Mass Flow meter

Sensors detect this phase shift, allowing for the calculation of the mass flow rate. Notably, Coriolis mass flow meters offer the advantage of providing direct mass measurement, ensuring high accuracy. Importantly, they remain unaffected by variations in temperature, pressure, or fluid properties. Additionally, these meters have the capacity to measure fluid density based on the vibration frequency of the tube. Figure 6 shows how the sensors are placed to calculate the frequency vibration of the tubes.

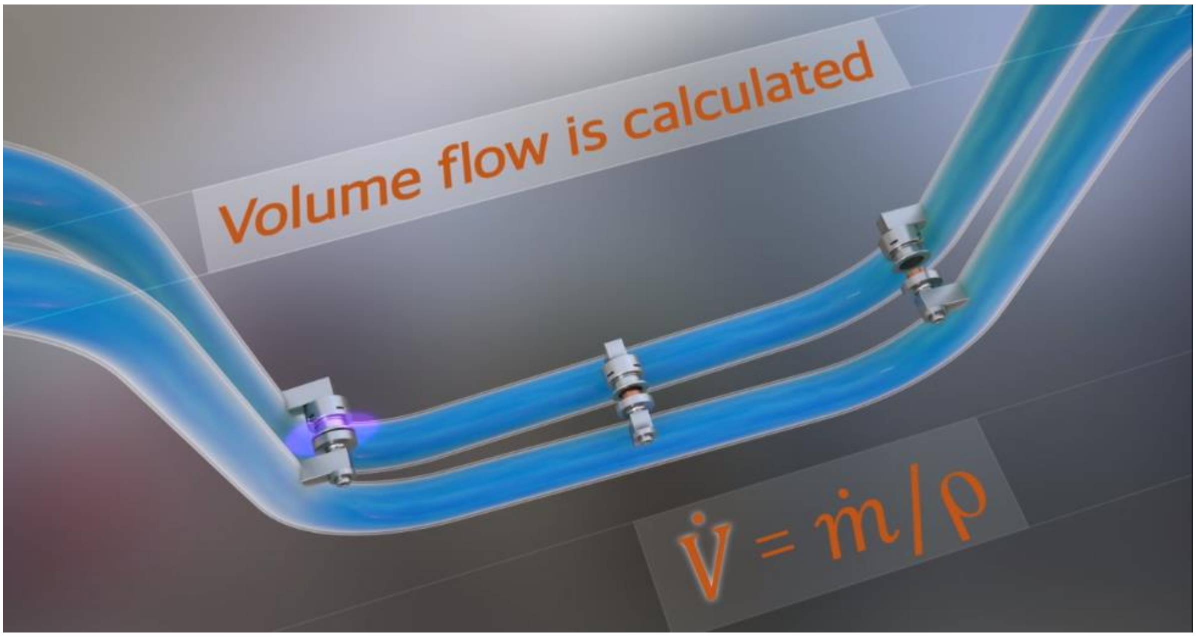


Figure 6. Mass flow tube with sensors

Coriolis mass flow meters find extensive applications in diverse industries, including chemical, petrochemical, food and beverage, and pharmaceuticals. Their suitability for measuring both liquid and gas flows further enhance its versatility and utility in various industrial processes. In essence, Coriolis mass flow meters provide a robust and precise means of directly quantifying mass flow rates, contributing to their widespread adoption in industrial applications (Co., 2023)

5 GUIDED WAVE RADAR LEVEL TRANSMITTER PRINCIPLES

Guided Wave Radar (GWR) functions as a top-down measurement system. It operates by sending low-energy microwave pulses down a metal probe, which is in direct contact with the substance being measured. As these pulses travel along the probe, they are reflected by surfaces within the tank or vessel. The reflection occurs when the microwave encounters a surface with a different dielectric constant, signaling a change in media. The time-domain reflectometry technology, GWR calculates the time it takes for the microwave pulse to travel to the surface and back. This calculated travel time is then used to determine the distance to the material's surface. By subtracting this distance from the total length of the probe, the level of the material is accurately calculated. Figure 7 shows how the radar is placed into an industrial vessel.

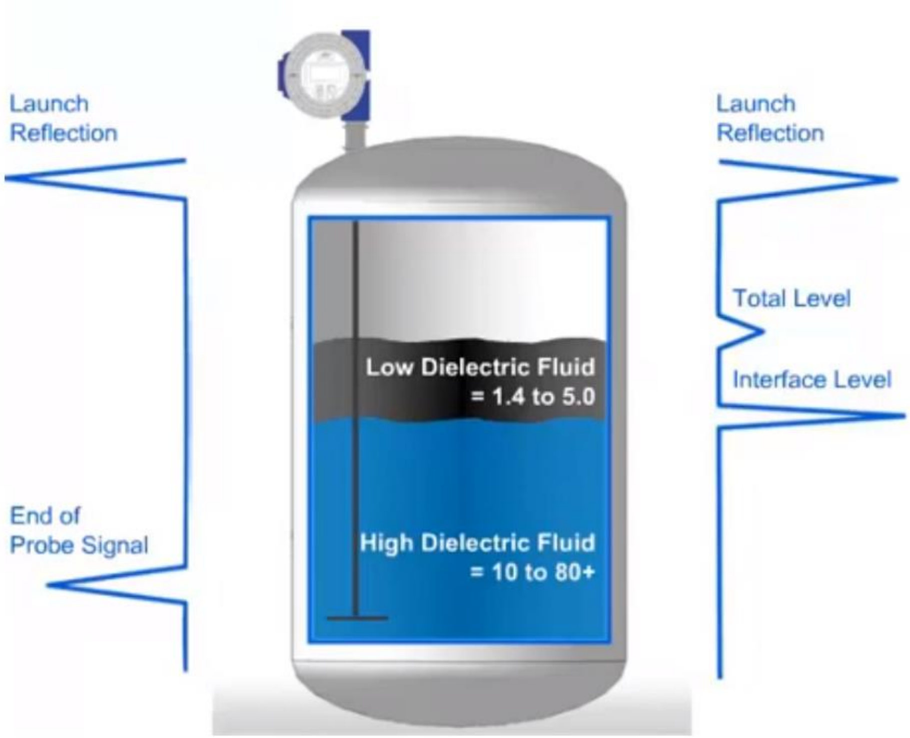


Figure 7. GWR function principles

GWR transmitters offer advantages such as high accuracy, reliability, and suitability for diverse types of process conditions. They are commonly used in industries such as pulp and paper, chemical processing, oil and gas and water treatment. GWR transmitters are particularly effective in measuring levels in tanks with turbulent surfaces, foam, and other challenging conditions where other level measurement technologies may face limitations. (Co, 2024)

6 METHODS

The testing procedures were executed within the bio-refinery DEMO environment, where the two field devices, the 2000 Series analog MVD transmitter and the Rosemount Guided Wave Radar Level transmitter model 5300, were integrated so that live testing could be done and information from the field devices gathered. This study focused more on the 2000 Series analog MVD transmitter and the Rosemount and the Guided Wave Radar Level transmitter model 5300. Figure 8 shows from left to right the power source, control node (ACN) and the I/O hardware card.

Figure 8. DEMO area connection

The manuals supplied by the customer served as essential references, offering instructions on the specific commands required to retrieve desired measurements. The FBD HART template was adapted and modified using the DNA Explorer, ensuring compatibility and customization to meet the testing needs.

Furthermore, a customized window was generated based on the client's preferences, enhancing the user interface and experience and the easiness of reading data from the HART device. This enabled efficient reading of diagnostic values, according to the client's requirements and expectations.

6.1 2000 Series Analog MVD Transmitter HART Commands

Two commands were used to read the wanted diagnostic values of the field devices.

- Command #214 read transmitter test point diagnostics.
  This command allows the user to read the test point diagnostic values from the transmitter. Values provided include the drive gain voltage, left and right pickoff voltage and tube frequency. Also available is the current flow rate without having the transmitter flow cutoff applied. The damping on this parameter is always 8 seconds. This flow variable is not used for flow and/or totalization calculations. It is strictly used for diagnostic purposes.

- Command #215 read additional diagnostics.
  This command allows the user to read diagnostic values from the transmitter. More detailed information about these commands can be found in table one and two. (Eyre, 2011)

6.2 Rosemount Guided Wave Radar Level Transmitter Model 5300

- Command #33 read device variables.

  The Device supports four Dynamic Variables (PV, SV, TV and QV) to which the Device Variables can be mapped and read, can be seen in table three.
- Additional Device Status (Command #48)

  Command #48 returns 25 bytes of data that can be seen in table four. (Larsson, 2012)

7 RESULTS

7.1 Results of 2000 Series Analog MVD Transmitter

The first version of the 2000 Series analog MVD transmitter FBCad downloaded into the DEMO environment reassured that connection to the client and the mass flow meter was working and had the right I/O addresses. When the connection was verified, the work started on tuning the FBCad so that it would read the wanted diagnostic commands. The first eighteen diagnostic commands that were read according to IEEE 754. IEEE 754 is a standard for representing and performing arithmetic operations on floating-point numbers in computers. The floating-point numbers had values of Volts, Hertz, milliamperes, percentage, temperature, and ohms. (IEEE Standard 754 Floating Point Numbers, 2023). The rest of the diagnostic values were in format of 16-bit unsigned integers with bit zero equaling an ok status and bit one equaling an error status. Figure 9 shows how to access the HART diagnostic widow from DNA operate.

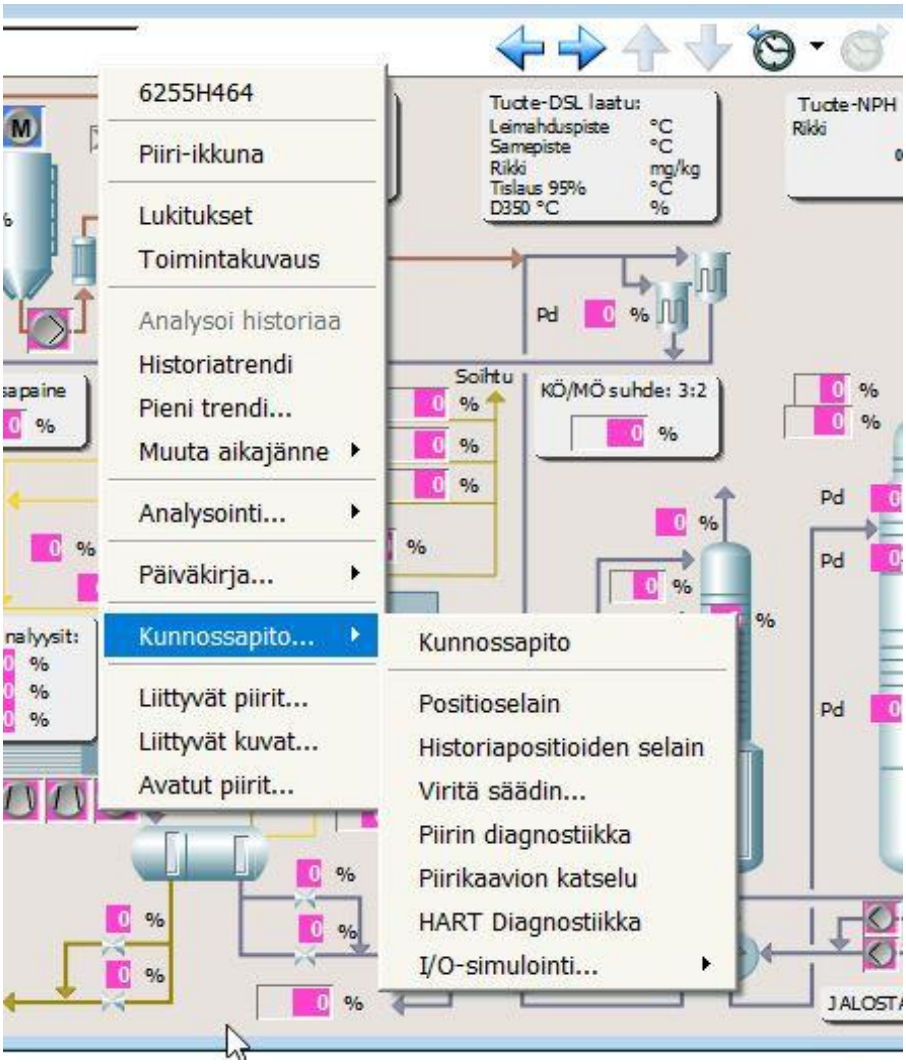
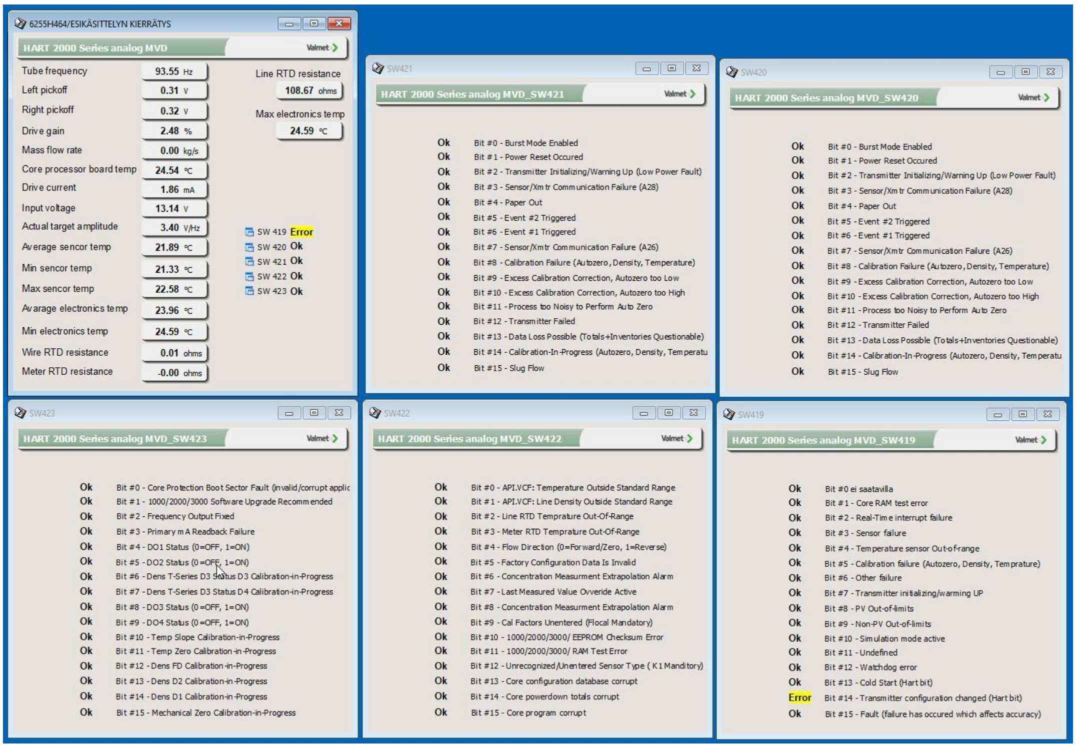


Figure 9. Opening of generated window

Figure 10 shows the HART diagnostic window of the MVD transmitter. The main windows show the values retrieved from the data type IEEE 754. From the main window one can open five more diagnostic windows that read addition diagnostic values in data type of 16-bit unsigned integer.



Tube frequency	93.55 Hz
Left pickoff	0.31 V
Right pickoff	0.32 V
Drive gain	2.48 %
Mass flow rate	0.00 kg/s
Core processor board temp	24.54 °C
Drive current	1.86 mA
Input voltage	13.14 V
Actual target amplitude	3.40 V/Hz
Average sencor temp	21.89 °C
Min sencor temp	21.33 °C
Max sencor temp	22.58 °C
Avarage electronics temp	23.96 °C
Min electronics temp	24.59 °C
Wire RTD resistance	0.01 ohms
Meter RTD resistance	-0.00 ohms
Line RTD resistance	108.67 ohms
Max electronics temp	24.59 °C

SW 419 Error
SW 420 Ok
SW 421 Ok
SW 422 Ok
SW 423 Ok

Ok Bit #0 - Burst Mode Enabled
Ok Bit #1 - Power Reset Occured
Ok Bit #2 - Transmitter Initializing/Warning Up (Low Power Fault)
Ok Bit #3 - Sensor/Xmtr Communication Failure (A28)
Ok Bit #4 - Paper Out
Ok Bit #5 - Event #2 Triggered
Ok Bit #6 - Event #1 Triggered
Ok Bit #7 - Sensor/Xmtr Communication Failure (A26)
Ok Bit #8 - Calibration Failure (Autozero, Density, Temperature)
Ok Bit #9 - Excess Calibration Correction, Autozero too Low
Ok Bit #10 - Excess Calibration Correction, Autozero too High
Ok Bit #11 - Process too Noisy to Perform Auto Zero
Ok Bit #12 - Transmitter Failed
Ok Bit #13 - Data Loss Possible (Totals+Inventories Questionable)
Ok Bit #14 - Calibration-In-Progress (Autozero, Density, Temperatu
Ok Bit #15 - Slug Flow

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Ok Bit #12 - Transmitter Failed
Ok Bit #13 - Data Loss Possible (Totals+Inventories Questionable)
Ok Bit #14 - Calibration-In-Progress (Autozero, Density, Temperatu
Ok Bit #15 - Slug Flow

Ok Bit #0 - Core Protection Boot Sector Fault (invalid/corrupt applic
Ok Bit #1 - 1000/2000/3000 Software Upgrade Recommended
Ok Bit #2 - Frequency Output Fixed
Ok Bit #3 - Primary mA Readback Failure
Ok Bit #4 - DO1 Status (0=OFF, 1=ON)
Ok Bit #5 - DO2 Status (0=OFF, 1=ON)
Ok Bit #6 - Dens T-Series D3 Status D3 Calibration-in-Progress
Ok Bit #7 - Dens T-Series D3 Status D4 Calibration-in-Progress
Ok Bit #8 - DO3 Status (0=OFF, 1=ON)
Ok Bit #9 - DO4 Status (0=OFF, 1=ON)
Ok Bit #10 - Temp Slope Calibration-in-Progress
Ok Bit #11 - Temp Zero Calibration-in-Progress
Ok Bit #12 - Dens FD Calibration-in-Progress
Ok Bit #13 - Dens D2 Calibration-in-Progress
Ok Bit #14 - Dens D1 Calibration-in-Progress
Ok Bit #15 - Mechanical Zero Calibration-in-Progress

Ok Bit #0 - API.VCF: Temperature Outside Standard Range
Ok Bit #1 - API.VCF: Line Density Outside Standard Range
Ok Bit #2 - Line RTD Temprature Out-Of-Range
Ok Bit #3 - Meter RTD Temprature Out-Of-Range
Ok Bit #4 - Flow Direction (0=Forward/Zero, 1=Reverse)
Ok Bit #5 - Factory Configuration Data Is Invalid
Ok Bit #6 - Concentration Measurment Extrapolation Alarm
Ok Bit #7 - Last Measured Value Ovveride Active
Ok Bit #8 - Concentration Measurment Extrapolation Alarm
Ok Bit #9 - Cal Factors Unentered (Flocal Mandatory)
Ok Bit #10 - 1000/2000/3000/ EEPROM Checksum Error
Ok Bit #11 - 1000/2000/3000/ RAM Test Error
Ok Bit #12 - Unrecognized/Unentered Sensor Type (K1 Manditory)
Ok Bit #13 - Core configuration database corrupt
Ok Bit #14 - Core powerdown totals corrupt
Ok Bit #15 - Core program corrupt

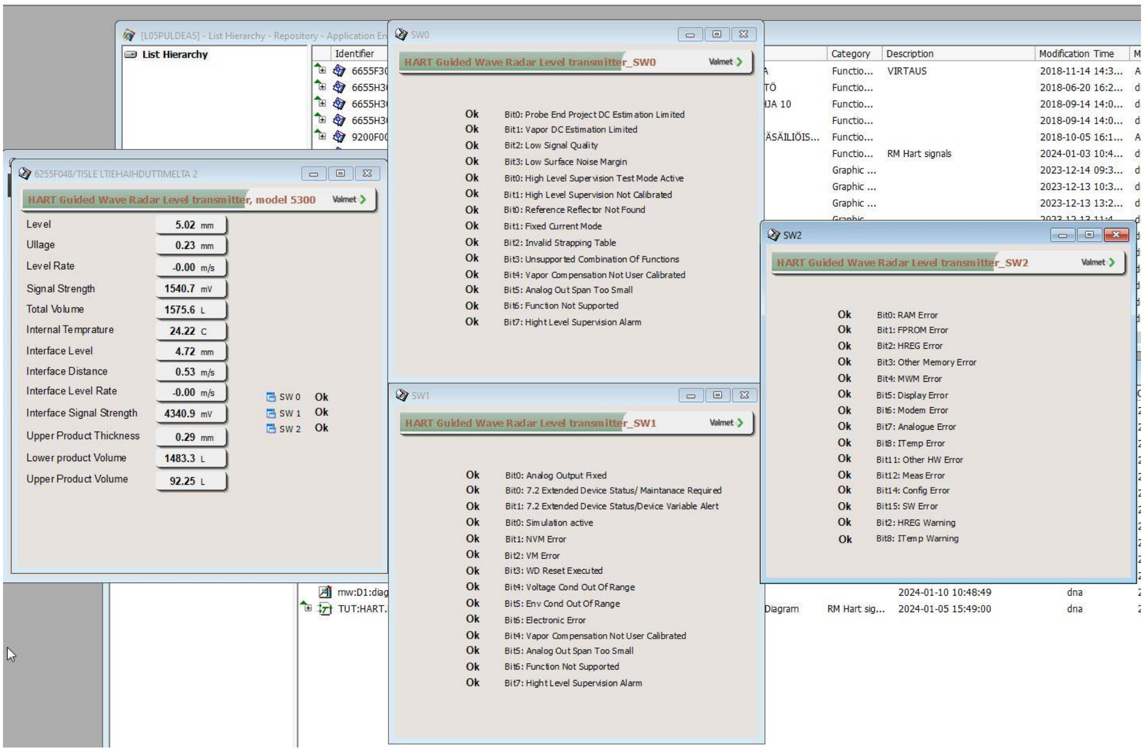
Ok Bit #0 ei saatavilla
Ok Bit #1 - Core RAM test error
Ok Bit #2 - Real-Time interrupt failure
Ok Bit #3 - Sensor failure
Ok Bit #4 - Temperature sensor Out-of-range
Ok Bit #5 - Calibration failure (Autozero, Density, Temprature)
Ok Bit #6 - Other failure
Ok Bit #7 - Transmitter initializing/warming UP
Ok Bit #8 - PV Out-of-limits
Ok Bit #9 - Non-PV Out-of-limits
Ok Bit #10 - Simulation mode active
Ok Bit #11 - Undefined
Ok Bit #12 - Watchdog error
Ok Bit #13 - Cold Start (Hart bit)
Error Bit #14 - Transmitter configuration changed (Hart bit)
Ok Bit #15 - Fault (failure has occured which affects accuracy)

Figure 10. 2000 series analog MVD transmitter generated window with diagnostic data

The amount of diagnostic data received from the 2000 series analog MVD transmitter from this new FBcad set to ninety-eight individual readings.

7.2 Results of Guided Wave Radar Level Transmitter Model 5300

Using the same methods as in the 2000 series analog MVD transmitter the diagnostic data was read from the GWR transmitter. The first thirteen device variable analog commands were with 4-20 mA output. The analog output unit classes were length, velocity, volume, temperature, and EMF. The rest of the diagnostic values were in format of 8 and 32-bit unsigned integers with bit zero equaling an ok status and bit one equaling an error or warning status. Figure 11 shows the HART diagnostic window of the GWR transmitter.



6255F048/TISLE LTIEHAIHDUTTIMELTA 2

HART Guided Wave Radar Level transmitter, model 5300

Level	5.02 mm
Ullage	0.23 mm
Level Rate	-0.00 m/s
Signal Strength	1540.7 mV
Total Volume	1575.6 L
Internal Temprature	24.22 C
Interface Level	4.72 mm
Interface Distance	0.53 m/s
Interface Level Rate	-0.00 m/s
Interface Signal Strength	4340.9 mV
Upper Product Thickness	0.29 mm
Lower product Volume	1483.3 L
Upper Product Volume	92.25 L

SW 0	Ok
SW 1	Ok
SW 2	Ok

SW0

HART Guided Wave Radar Level transmitter_SW0

Ok	Bit0: Probe End Project DC Estimation Limited
Ok	Bit1: Vapor DC Estimation Limited
Ok	Bit2: Low Signal Quality
Ok	Bit3: Low Surface Noise Margin
Ok	Bit0: High Level Supervision Test Mode Active
Ok	Bit1: High Level Supervision Not Calibrated
Ok	Bit0: Reference Reflector Not Found
Ok	Bit1: Fixed Current Mode
Ok	Bit2: Invalid Strapping Table
Ok	Bit3: Unsupported Combination Of Functions
Ok	Bit4: Vapor Compensation Not User Calibrated
Ok	Bit5: Analog Out Span Too Small
Ok	Bit6: Function Not Supported
Ok	Bit7: Hight Level Supervision Alarm

SW1

HART Guided Wave Radar Level transmitter_SW1

Ok	Bit0: Analog Output Fixed
Ok	Bit0: 7.2 Extended Device Status/ Maintanace Required
Ok	Bit1: 7.2 Extended Device Status/Device Variable Alert
Ok	Bit0: Simulation active
Ok	Bit1: NVM Error
Ok	Bit2: VM Error
Ok	Bit3: WD Reset Executed
Ok	Bit4: Voltage Cond Out Of Range
Ok	Bit5: Env Cond Out Of Range
Ok	Bit6: Electronic Error
Ok	Bit4: Vapor Compensation Not User Calibrated
Ok	Bit5: Analog Out Span Too Small
Ok	Bit6: Function Not Supported
Ok	Bit7: Hight Level Supervision Alarm

SW2

HART Guided Wave Radar Level transmitter_SW2

Ok	Bit0: RAM Error
Ok	Bit1: FPROM Error
Ok	Bit2: HREG Error
Ok	Bit3: Other Memory Error
Ok	Bit4: MWM Error
Ok	Bit5: Display Error
Ok	Bit6: Modem Error
Ok	Bit7: Analogue Error
Ok	Bit8: ITemp Error
Ok	Bit11: Other HW Error
Ok	Bit12: Meas Error
Ok	Bit14: Config Error
Ok	Bit15: SW Error
Ok	Bit2: HREG Warning
Ok	Bit8: ITemp Warning

Figure 11. Guided Wave Radar Level transmitter model 5300 generated window with diagnostic data

8 ANALYSIS

Examining the 2000 Series analog MVD transmitter and the Rosemount Guided Wave Radar Level transmitter model 5300 through a functional block diagram for HART diagnostic data retrieval emphasizes the practical significance of this data in a maintenance context. It is crucial for optimal operation of the biodiesel plant and ensuring product quality.

The functional block diagram allows the extraction of HART diagnostic data from both devices, providing valuable insights into their health and performance. For the 2000 Series analog MVD transmitter, diagnostic data includes details on signal integrity, device health, and potential issues impacting accurate measurements.

Similarly, to the Rosemount Guided Wave Radar Level transmitter model 5300 HART diagnostic data offers crucial information about the system's health. This encompasses insights into radar signal integrity, measurement probe health, and potential issues affecting level measurement accuracy.

In a maintenance context, having access to this diagnostic data is essential for early issue detection and efficient troubleshooting. Real time monitoring enables maintenance personnel to identify potential problems proactively. The diagnostic data assists in pinpointing issues, making the maintenance process more targeted and effective.

The functional block diagram provides a comprehensive overview by using HART signal diagnostic data from both devices. This approach enhances the ability to make informed decisions regarding maintenance activities. Analyzing and following the history of the data supports maintenance personnel in understanding the overall health of the field devices, facilitating strategic decision-making.

The optimal operation of the biodiesel plant relies on efficient maintenance practices enabled by the HART diagnostic data, contributing to cost savings. By minimizing downtime and optimizing maintenance efforts, this approach ensures not only the reliable and continuous operation of the field devices but also contributes to maintaining product quality within the biodiesel production process. Consistent and well-maintained equipment directly influences the overall quality of the biodiesel produced, reinforcing the importance of integrating HART diagnostic data for both maintenance and product quality assurance.

9 DISCUSSION

The function block diagram can be modified to read diagnostic data from other field devices broadening the scope of field device care. The possibility of incorporating to other process areas provides better maintenance and runnability of other industrial plants. Time will also be saved as the maintenance personnel will not have to physically attach a HART communication device to the field device to read addition HART diagnostic data.

Also analyzing a larger pool of diagnostic data becomes imperative to understand the condition of the field devises. This large amount of data offers insights into various aspects of the production environment, ranging from pressure and temperature to flow rates and beyond. The importance of analyzing this extensive diagnostic data lies in its potential to uncover correlations, trends, and anomalies that might otherwise go unnoticed. For instance, identifying patterns in temperature fluctuations across different devices might reveal inefficiencies or areas for improvement in the production process. Analyzing a large amount of diagnostic data becomes a key tool for optimizing operational efficiency, troubleshooting issues, and enhancing the overall reliability of the industrial setup. The analysis of the data received from the field devices mentioned in this thesis is a basis for another thesis subject.

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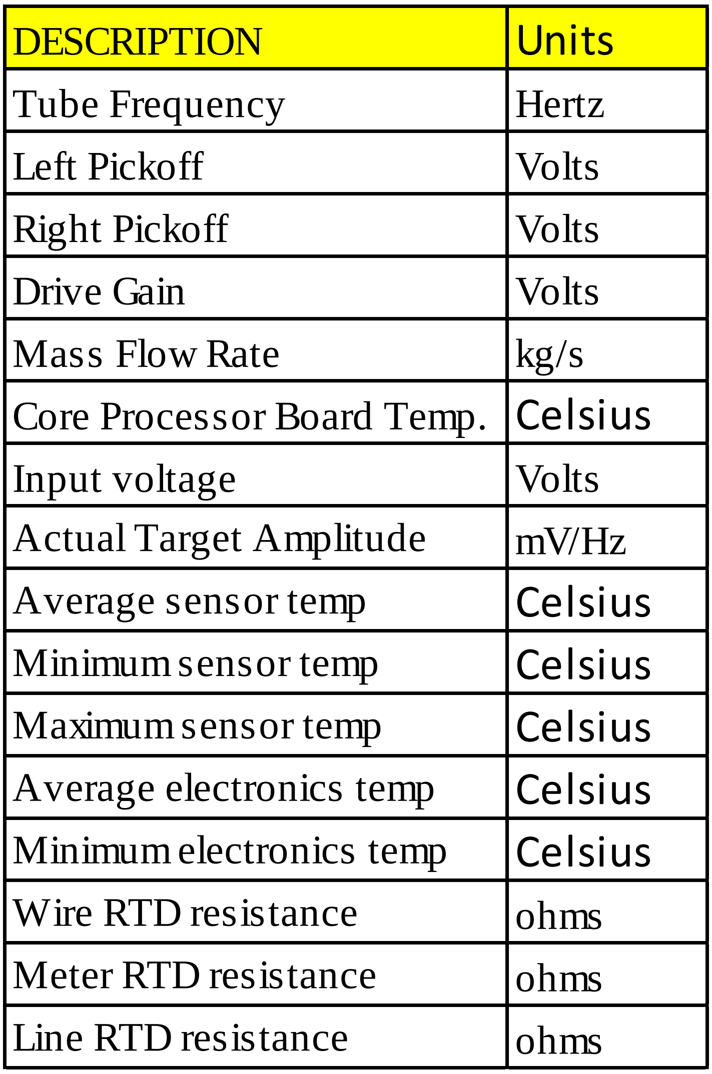
APPENDIX



DESCRIPTION	Units
Tube Frequency	Hertz
Left Pickoff	Volts
Right Pickoff	Volts
Drive Gain	Volts
Mass Flow Rate	kg/s
Core Processor Board Temp.	Celsius
Input voltage	Volts
Actual Target Amplitude	mV/Hz
Average sensor temp	Celsius
Minimum sensor temp	Celsius
Maximum sensor temp	Celsius
Average electronics temp	Celsius
Minimum electronics temp	Celsius
Wire RTD resistance	ohms
Meter RTD resistance	ohms
Line RTD resistance	ohms

Table 1. IEEE 745 diagnostic units

STATUS WORD 419	***STATUS WORD 420***
Bit #0 – Core EEPROM Checksum Error (Config, Powerdown, Program)	Bit #0 – Primary mA Output Saturated
Bit #1 – Core RAM Test Error	Bit #1 – Secondary mA Output Saturated
Bit #2 – Real-Time Interrupt Failure	Bit #2 – Primary mA Output Fixed
Bit #3 – Sensor Failure	Bit #3 – Secondary mA Output Fixed
Bit #4 – Temperature Sensor Out-of-Range	Bit #4 – Density Outside Limits
Bit #5 – Calibration Failure (Autozero, Density, Temperature)	Bit #5 – Drive Overrange/Partially Full Tube
Bit #6 – Other Failure	Bit #6 – PIC/Daughterboard Communication Failure
Bit #7 – Transmitter Initializing/Warming Up	Bit #7 – External Input Failure
Bit #8 – PV Out-Of-Limits	Bit #8 – Core EEPROM Checksum Error (Config, Powerdown, Program)
Bit #9 – Non-PV Out-Of-Limits	Bit #9 – Core RAM Error
Bit #10 – Simulation Mode Active	Bit #10 – Sensor Not Responding (No Tube Interrupt)
Bit #11 – Undefined	Bit #11 – Temperature Sensor Out-of-Range
Bit #12 – Watchdog Error	Bit #12 Input Over-Range
Bit #13 – Cold Start (HART bit)	Bit #13 – Frequency Output Saturated
Bit #14 – Transmitter Configuration Changed (HART bit)	Bit #14 – Transmitter Not Characterized (Flocal or Sensor Type)
Bit #15 – Fault (Failure has occurred which affects accuracy)	Bit #15 – Real-Time Interrupt Failure

STATUS WORD 421	***STATUS WORD 422***
Bit #0 – Burst Mode Enabled	Bit #0 – API.VCF: Temperature Outside Standard Range
Bit #1 – Power Reset Occurred	Bit #1 – API.VCF: Line Density Outside Standard Range
Bit #2 – Transmitter Initializing/Warming Up (Low Power Fault)	Bit #2 – Line RTD Temperature Out-Of-Range
Bit #3 – Sensor/Xmtr Communication Failure (A28)	Bit #3 – Meter RTD Temperature Out-Of-Range
Bit #4 – Paper Out	Bit #4 – Flow Direction (0=Forward/Zero, 1=Reverse)
Bit #5 – Event #2 Triggered	Bit #5 – Factory Configuration Data Is Invalid
Bit #6 – Event #1 Triggered	Bit #6 – Concentration Measurement: Unable to fit curve data
Bit #7 – Sensor/Xmtr Communication Failure (A26)	Bit #7 – Last Measured Value Override Active
Bit #8 – Calibration Failure (Autozero, Density, Temperature)	Bit #8 – Concentration Measurement Extrapolation Alarm
Bit #9 – Excess Calibration Correction, Autozero too Low	Bit #9 – Cal Factors Unentered (Flocal Mandatory)
Bit #10 – Excess Calibration Correction, Autozero too High	Bit #10 – 1000/2000/3000 EEPROM Checksum Error
Bit #11 – Process too Noisy to Perform Auto Zero	Bit #11 – 1000/2000/3000 RAM Test Error
Bit #12 – Transmitter Failed	Bit #12 - Unrecognized/Unentered Sensor Type (K1 Manditory)
Bit #13 – Data Loss Possible (Totals+Inventories Questionable)	Bit #13 – Core configuration database corrupt
Bit #14 – Calibration-In-Progress (Autozero, Density, Temperature)	Bit #14 – Core powerdown totals corrupt
Bit #15 – Slug Flow	Bit #15 – Core program corrupt

STATUS WORD 423
Bit #0 – Core Protected Boot Sector Fault (invalid/corrupt application)
Bit #1 – 1000/2000/3000 Software Upgrade Recommended
Bit #2 – Frequency Output Fixed
Bit #3 – Primary mA Readback Failure
Bit #4 – DO1 Status (0=OFF, 1=ON)
Bit #5 – DO2 Status (0=OFF, 1=ON)
Bit #6 – Dens T-Series D3 Calibration-in-Progress
Bit #7 – Dens T-Series D4 Calibration-in-Progress
Bit #8 – DO3 Status (0=OFF, 1=ON)
Bit #9 – DO4 Status (0=OFF, 1=ON)
Bit #10 – Temp Slope Calibration-in-Progress
Bit #11 – Temp Zero Calibration-in-Progress
Bit #12 – Dens FD Calibration-in-Progress
Bit #13 – Dens D2 Calibration-in-Progress
Bit #14 – Dens D1 Calibration-in-Progress
Bit #15 – Mechanical Zero Calibration-in-Progress

Table 2. 16-bit unsigned integers diagnostics

Variable Name		Unit Class
Level		Length Unit
Ullage		Length Unit
Level Rate		Velocity Unit
Signal Strength		EMF Unit
Total Volume		Volume Unit
Internal Temperature*		Temp Unit
Interface Level		Length Unit
Interface Distance*		Length Unit
Interface Level Rate		Velocity Unit
Interface Signal Strength		EMF Unit
Upper Product Thickness		Length Unit
Lower Product Volume		Volume Unit
Upper Product Volume		Volume Unit

Table 3. Device Variables

32-bit Unsigned Int.		8-bit Unsigned Int.		8-bit Unsigned Int.		32-bit Unsigned Int.		8-bit Unsigned Int.		8-bit Unsigned Int.		8-bit Unsigned Int.	
Bit0:	RAM Error	Bit0:	Simulation active	Bit0:	Analog Output is saturated	Bit2:	HREG Warning	Bit0:	Reference Reflector Not Found	Bit0:	High Level Supervision Test Mode Active	Bit0:	Probe End Projection DC Estimation Limited
Bit1:	FPROM Error					Bit8:	ITemp Warning	Bit1:	Fixed Current Mode	Bit1:	High Level Supervision Not Calibrated	Bit1:	Vapor DC Estimation Limited
Bit2:	HREG Error		Set when					Bit2:	Invalid Strapping Table			Bit2:	Low Signal Quality
Bit3:	Other Memory Error		**IREG.Status.DeviceStatus:**					Bit3:	Unsupported Combination Of Functions			Bit3:	Low Surface Noise Margin
Bit4:	MWM Error		**Sim_Mode0_Active**					Bit4:	Vapor Compensation Not User Calibrated				
Bit5:	Display Error							Bit5:	Analog Out Span Too Small				
Bit6:	Modem Error		**Sim_Mode1_Active**.					Bit6:	Function Not Supported				
Bit7:	Analogue Error	Bit1:	NVM Error					Bit7:	High Level Supervision Alarm				
Bit8:	ITemp Error												
Bit11:	Other HW Error		Set when										
Bit12:	Meas Error		**IREG.DevError.HREG_Error**										
Bit14:	Config Error		**IREG.DevWarn.HREG_Warning**										
Bit15:	SW Error		**Default_HREG_Used** is set										
			IREG.DevError.FPROM_Error										
		Bit2:	VM Error										
			Set when										
			IREG.DevError.RAM_Error										
		Bit3:	WD Reset Executed (Always zero)										
		Bit4:	Voltage Cond Out Of Range (Always zero)										
		Bit5:	Env Cond Out Of Range										
			Set when										
			IREG.DevError.ITemp_Error										
		Bit6:	Electronic Error										
			Set when										
			IREG.DevError.Other_Memory_Error										
			IREG.DevError.MWM_Error										
			IREG.DevError.Display_Error										
			IREG.DevError.Modem_Error										
			IREG.DevError.Analogue_Error										
			IREG.DevError.Other_HW_Error										

Table 4. 8 and 16-bit unsigned integers diagnostics