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WIRELESSHART IN INDUSTRIAL ENVIRONMENT

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Thesis

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Tämän opinnäytetyön aiheena oli wirelessHART järjestelmä, sen takana oleva teoria ja sen tuomat edut kriittisten laitteiden monitoroinnissa. Toimeksiantaja oli Akzo Nobelin Albyn tehdas. Tarkoituksena oli kartoittaa wirelessHART järjestelmän mahdollisia turvallisuus- ja kustannusetuja.

Opinnäytetyössä tarkasteltiin Emersonin tarjoaman wirelessHART-verkon laitteita ja niiden ominaisuuksia, kuten millaisia antureita oli tarjolla ja millaisiin mittauksiin ne soveltuivat sekä erilaisia reitittimiä ja akkuja. Työssä käsiteltiin myös millaiseen käyttöön ne sopivat sekä antureiden käyttämät akut. Opinnäytetyön lopussa laskettiin järjestelmän rakentamisen ja kunnossapidon kustannuksia kyseiselle tehtaalle ja käsiteltiin sen tuomia hyötyjä.

Työ tehtiin selvittämällä kriittiset laitteet, joiden toimintaa haluttiin seurata edullisemmalla ja joustavammalla järjestelmällä. Työssä käytettiin tehtaalla itse kerättyä sekä internet-aineistoa.

Tuloksena voidaan todeta, että WirelessHART olisi hyödyllinen hankinta tähän kohteeseen moninaisten etujen vuoksi. Hyötynä voitiin pitää järjestelmän tuomaa turvallisuutta, koska tarve kunnossapidolle väheni. Lisäksi wirelessHART järjestelmä oli edullisempi hankkia kuin perinteinen järjestelmä.

Avainsanat: WirelessHART, Emerson, automaatio

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Abstract of Thesis

Technology, Communication and Transport

Electrical and Automation Engineering

Bachelor of Engineering

Author	Niilo Korva	Year	2019
Supervisor	Antti Niemelä, BEng		
Commissioned by	AkzoNobel, Samson Kashay		
Subject of thesis	Understanding the usability of wireless process operation devices in an industrial environment		
Number of pages	48 + 4		

This thesis describes the wirelessHART system and the theory behind it. The commissioner was Akzo Nobel, the factory of Alby. The meaning was to research the safety and the cost gains of the wirelessHART system. The thesis describes, for example, the structure and operation of the wirelessHART network. Emerson's wirelessHART network devices and their features, such as what sensors there are and what kind of measurements they fit, different gateways, and what kind of use they are suitable for and the batteries used by the sensors. In the end of the thesis, there are calculations of the building costs of the system and the maintenance costs. Also there are listed other beneficial things for the factory.

The thesis was conducted by identifying the critical devices which were to be monitored with a more advantageous and flexible system. The material used in this thesis was gathered at the site and from the internet.

WirelessHART offered a variety of benefits in terms of security and costs for this commissioner. One benefit was keeping the process safe for the need of maintenance was reduced. In addition, the wirelessHART system was more advantageous than a wired system.

Keywords: WirelessHART, Emerson, Automation

TABLE OF CONTENTS

FOREWORDS

In this section I would like to thank Samson Kashay for letting me do my thesis under his supervision in the AkzoNobel Alby Chlorate Factory.

I would also like to tell a little about the company AkzoNobel and the Alby Factory. AkzoNobel is a multinational company, which has operations in medicine, coating and chemical industry. The company headquarter is located in Arnhem in the Netherlands. They have operations in over 80 countries and they employ over 50 000 employees. The sales were around 10billion euros in 2017 and the revenue out of that was around 900million euros.

AkzoNobel Alby factory is the biggest employer after the municipality in Ånge. It produces sodium and potassium chlorate and hydrogen peroxide.

SYMBOLS AND ABBREVIATIONS

OSI	Open Systems Interconnection
ISO	International Organization for Standardization
MAC	Media Acces Control
LLC	Logical Link Control
CSMA/CD	Carrier Sense Multiple Acces/Collisin Detect
FDMA	Frequency Division Multiple Access
CDAM	Code Division Multiple Access
TDMA	Time Division Multiple Access
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
ISM	Industrial, Scientific and Medical
BPSK	Binary Phase Shift Keying
ASK	Amplitude Shift Keying
O-QPSK	Offset Quadrate Phase Shift Kaying
HART	Highway Addressable Remote Transducer
DSSS	Direct Sequence Spread Spectrum
OPC	Open Process Control
TCP/IP	Transmission Control Protocol/Internet Protocol
RSSI	Received Signal Strenght Indicator

1 INTRODUCTION

This thesis investigates the use of wirelessHART measuring devices in existing environment.

There are some Emerson Rosemount wirelessHART measuring instruments listed. There is also a third party manufactured device called Power Puck which is handy to make some more cost savings.

The thesis provides a suggestion how to measure vibrations, how to achieve a safer working environment, how to achieve cost savings in maintenance and manufacturing and how to save money by investing in a wirelessHART system.

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2 FIELD DEVICE

Field devices are electronic devices used in Automation technology. Sensors capture data and transfer it via fieldbuses to a connected field device, which in turn transmits control data through actuators to final controlling elements.

Field Devices can be divided into two different parts, the sensor and the transmitter. The sensor converts physical environment into electrically readable message, like voltage, current or impedance. The transmitter transmits the sensors measurement data, into automation system or etc.

Measurement data is captured at fixed intervals and forwarded for process control. Consequently, the devices are networked with a control and host system, usually via fieldbuses or Ethernet. Once data has been evaluated, it is used in the control system for regulation, control or visualization purposes or to display analysis and alarm data (Glossar Item 2018).

3 OVERVIEW OF TELECOMMUNICATION

Telecommunication is the transmission of signs, signals, messages, words, writings, images and sounds or information of any nature by wire, radio, optical or other electromagnetic systems. Telecommunication occurs when the exchange of information between communication participants includes the use of technology. It is transmitted either electrically over physical media, such as cables, or via electromagnetic radiation. Such transmission paths are often divided into communication channels which afford the advantages of multiplexing. Since the Latin term communication is considered the social process of information exchange, the term telecommunications is often used in its plural form because it involves many different technologies (Wikipedia 2018).

3.1 OSI layer architecture

OSI layer architecture is a model where the communication system is shared into layers. Layer thinking is based on the fact that the upper layer uses Lower layers. OSI model is the ISO international standard and it is divided into seven different floors (Beal 2018):

1. Physical layer: Defines the mechanical, physical, and operating units. The task is to convert bits into electrical pulses, light or radio road signals.
2. Data Link layer: maintains a connection between two points, detects and repairs the movement errors on the physical layer, the data flow administration: The Data Link layer does not allow more physical layer data than the recipient can handle.
3. Network layer: Provides the data network.
4. Transport Layer: Provides a communication link between two endpoints.
5. Session Layer: Manages the control functions between applications, such as connecting and related to that, transfer connection service allocation.

6. Presentation Layer: Applies to the common presentation of information between terminal devices.
7. Application layer: Provides an interface for applications to OSI-system.

3.2 The use of OSI model

The International Standards Organization (ISO) created OSI-model. It modeled network with seven layers. The layers from 1 to 4 are called the lower layers, these layers move the data. The layers from 5 to 7, called the upper layers, contain the application data. The operation principle of a network is “pass it on”, meaning that every layer takes care of their own job and they pass the data onto next layer (Beal 2018).

The data link layer divides into two layers, the media access control (MAC) layer and the logical link control (LLC) layer. The MAC layer controls how computers gain access to the network and can send data on it. The LLC layer controls packet synchronization services, error checking and flow control (ItGeared 2018).

3.3 Transfer Channel

The transfer path is the bus along which the signal is transmitted. The traditional conductive bearer has been a copper conductor, but nowadays the optical fibers have been displaced by a copper conductor.

Wired connections mean the connection between two points in which the signal passes through the cable connecting the parties to the communication.

The most common types of cable are:

1. Paired wire
2. Coaxial cable

3. optical fiber

Wireless transmission techniques can be divided, for example, according to the transfer method:

1. Microwave links and satellite connections
2. radio communication
3. Infra-red
4. laser

3.4 Takeover of the transfer channel

Methods for capturing channel, among others, polling, token and reservation. In these methods only one transmission can be on at a time, to avoid collision of messages.

3.4.1 Reservation

In the reservation method, the fastest transmitter gets to transmit. There are many techniques to do it, but the most famous is CSMA/CD (Carrier Sense Multiple Access/Collision Detect) technique. In this method there is a high change of simultaneous transmits, which end up into a collision. If a collision happens, the data will be destroyed. CSMA/CD technique is a good way of preventing these collisions from happening, it can end the transmission if collision occurs. The transmission pathway can be listened and the transmission can be started when the pathway is empty (Pruthviraj Konu 2018).

3.4.2 Polling

In Polling, the master device leads the transmission ring, it asks from every device do they have anything to transmit. If some of the devices have a message waiting to be sent, it answers by sendng the message or it quits asking for permission to send it. When master device wants to transmit something it just transmits, or asks permission before transmitting. Polling is called master-slave method, it is a very

good way to control the dataflow of your network. Also HART is based on this Polling method (Pruthviraj Konu 2018).

3.4.3 Token

This method is based on an idea that all the devices on the network ar equals, and the timeslots are shared evenly between them. When a particular device has a turn, it can point it directly to some other device. When a device sends a message to another device, it transmits the turn swift message in sequence to the next device on the network (Pruthviraj Konu 2018).

3.5 Wireless network topologies

In a wireless network, devices can be configured in different ways for their purpose in accordance with. Topologies describe different models of how devices can be networked.

3.5.1 Star topology

The device in star topology can’t communicate together. All the communication goes through the gateway and the gateway sends it into automation system. Star topology is a good choice for small area coverage solutions. Bad side in this method is the vulnerability of the system, when the gateway stops working, the network dies (Computer Hope 2018c).

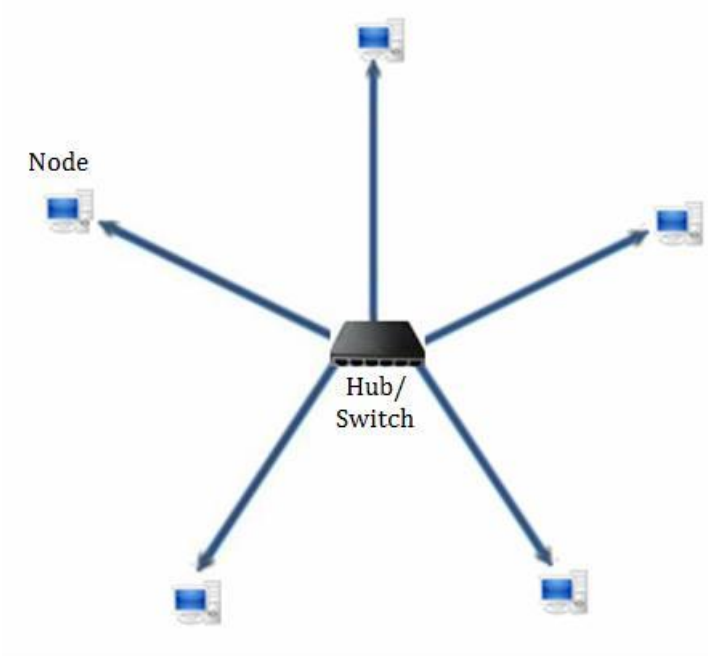

Figure: 1 Star Topology (iAnswerforu 2018)

3.5.2 Tree topology

A tree topology is a special type of structure in which many connected elements are arranged like the branches of a tree. For example, tree topologies are frequently used to organize the computers in a corporate network, or the information in a database.

In a tree topology, there can be only one connection between any two connected nodes. Because any two nodes can have only one mutual connection, tree topologies form a natural parent-child hierarchy (Computer Hope 2017a).

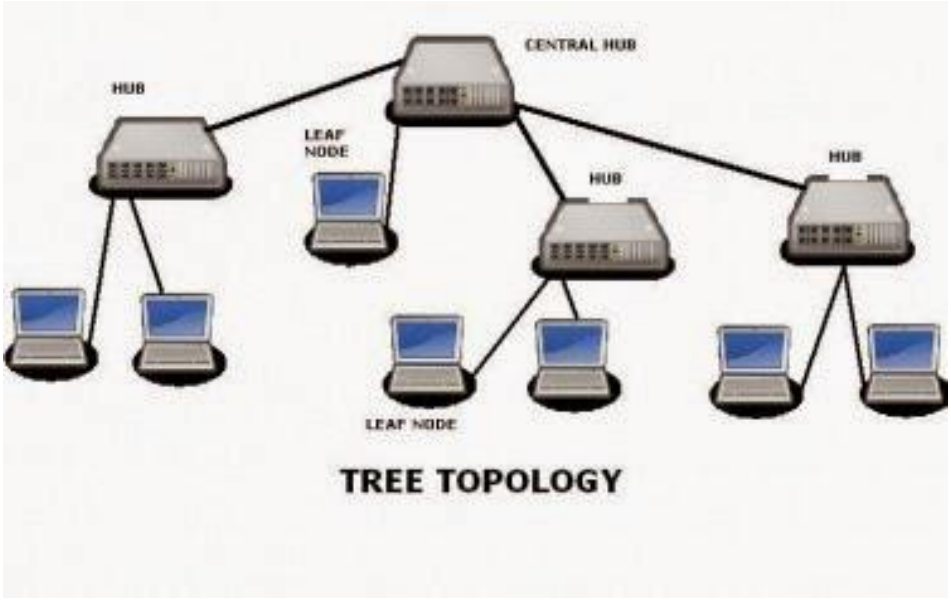

Figure: 2 Tree topology (Computer Learning Center 2018)

3.5.3 Mesh topology

A network setup where each computer and network device is interconnected with one another, allowing for most transmissions to be distributed, even if one of the connections go down. It is a topology commonly used for wireless networks. Can handle high amounts of traffic, because multiple devices can transmit data simultaneously. A failure of one device does not cause a break in the network or transmission of data. Adding additional devices does not disrupt data transmission between other devices. The cost to implement is higher than other network topologies, making it a less desirable option. Building and maintaining the topology is difficult and time consuming. The chance of redundant connections is high, which adds to the high costs and potential for reduced efficiency (Computer Hope 2018b).

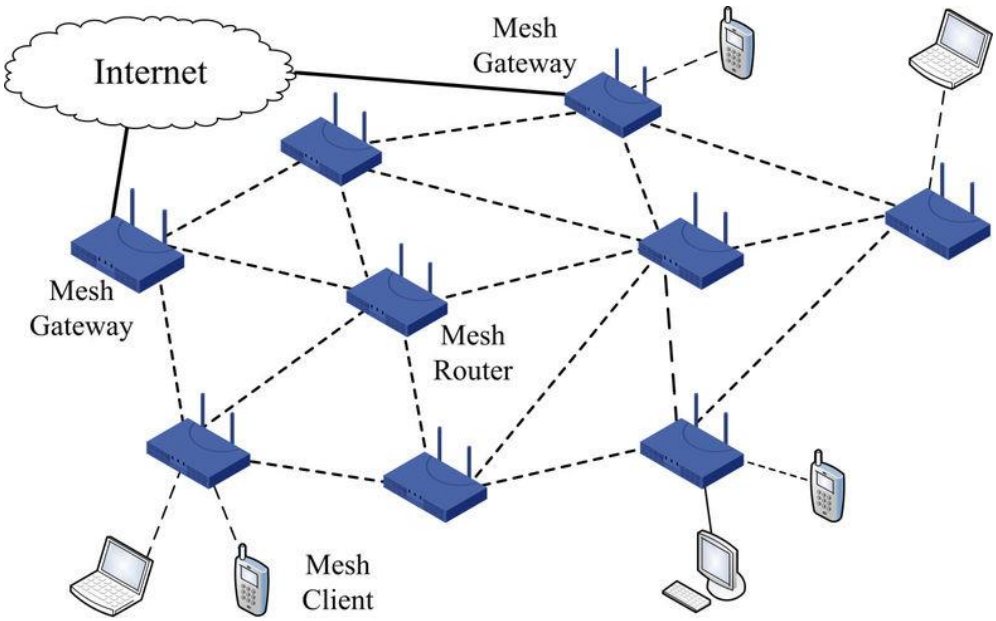

Figure: 3 Mesh topology (Fang & Yong 2012)

3.6 Channel reservation

Each wireless system receives one or more radio bands, with those the parties of the system operate. Within the system the method that determines how the current channel is shared between users. The method is called a channel reservation.

3.6.1 FDMA-method

In a system where the radio channel is divided into subdivisions (channels) and where the system distributes the radio channel for one connection to the users is used for the time being Naming Frequency Division Multiple Access (FDMA) or frequency division multiplexing. FDMA users can reserve channels for their needs in accordance with. One or more of the available channels can be reserved more to manage connections, and others used as traffic channels. For example, the old analogue NMT system worked with FDMA technology (Lou 2013).

4 TDMA-METHOD

TDMA (Time Division Multiple Access) is a technology in which time is divided between different users. The radio path has frequency division and within it time division, even if the system had only one frequency range. Time Range is based so that every device on the network gets a moment of transmission.
Speaking turns from one device to another and returns after full turn back to the first device. Thus, information is formed of time slots (timeslots) that contain samples of data from different devices. TDMA-technology requires synchronization so that the devices know their correct broadcast time (Lou 2013).

4.1.1 CDMA-method

CDMA (Code Division Multiple Access) is a channel reservation method, which was originally developed for military use. The basic principle of technology is divides the bit time of the traditional narrowband signal into the parts used for it called (chip). The number of these chips per bits may be for example, 64 or 128. Now, one bit does not consist of a change of state, but rather one 64 or 128 chips are required for presentation. The bit streams sent by the device are identified based on the chip code (Lou 2013).

5 ANTENNA

Antenna is a device designed for the transmission and reception of electromagnetic waves that transfers electrically high-frequency electromagnetic fields into the medium or, respectively, transfers the incoming electromagnetic field to the receiver. The task of the antenna is therefore to transmit the most efficient signal or to receive the incoming signal efficiently. Various antennas are surprisingly many of the applications for example, radio and television technology, various radar and satellite systems, mobile phone technologies and, WLAN from many homes. Antenna is also generated inefficiently. For example, the motor power cable can act as an antenna and cause, for example, disturbance in the measurement labels or even the motor control itself.

The antennas can be divided into two main groups, directional antennas and omni-directional antennas. Directional antennas are used when the transmission or reception direction is known. Directional antennas are, for example, parabolic mirror antennas, dish antennas used for satellite communications. Omnidirectional antennas are, for example, mast antennas used for cell phone communications (People.uta. 2018).

The directional antenna is like the cars driving lights, it points in to certain direction. The omnidirectional antenna is like a lightbulb, it spreads the light all around the room.

6 RADIO WAVES

A radio wave is the basic building block of radio communication. A radio wave is a series of downs and ups, like waves in the ocean. The wave (peak and valley) creates one cycle which goes on repeatedly. The wavelength is the distance of one cycle. Frequency is repeat/second, in this case it is how many cycles the wave makes in a second. The measuring unit of Frequency is hertz (Hz). The radio spectrum range is considered to begin from 3 kilohertz continue up to 300 gigahertz.

A transmitter creates radio waves and then a receiver detects them. An antenna allows a radio transmitter to send radio waves and a receiver to pick up radio waves. Transmitters and receivers are usually designed for limited range of frequencies (Mai 2018).

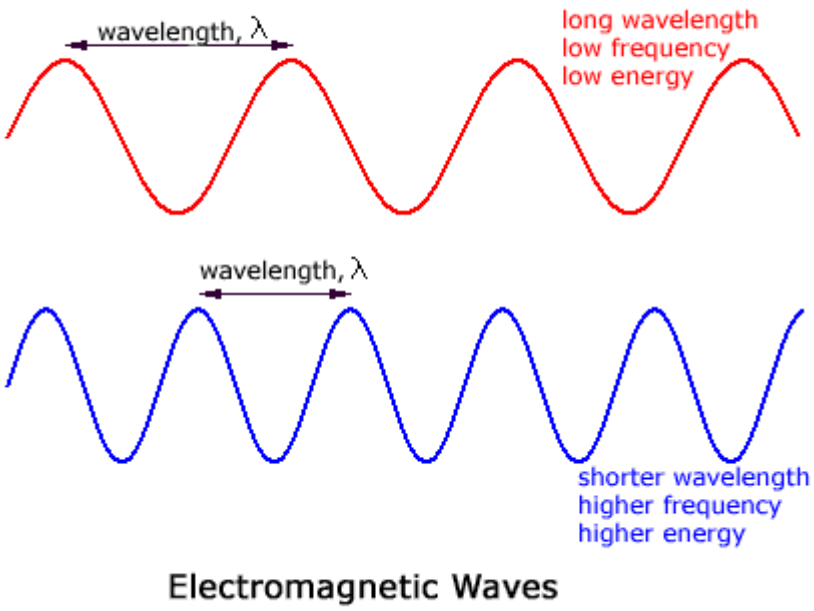

Figure: 4 Radiowaves

The higher the frequency of a radio wave, the shorter the range of the signal is. That we can easily see by comparing FM radio and your home Wi-Fi Ethernet. The FM radio signal have much lover frequency and the range is kilometers, Wi-Fi Ethernet have range only tens of meters.

7 WIRELESS NETWORKS AND STANDARDS

Wireless personal area networks (WPANs) are made to convey information among a private and intimate group of the devices in the network, over a short distance. Wireless local area network (WLAN) is different, where WPAN involves almost no infrastructure or no direct connections to the world outside the links, WLAN requires those. That is why WPAN is allowed to be a small, power-efficient, inexpensive solution for implementation for a huge group of devices (Muchiri 2010).

Table 1: Wireless networks, WirelessHART uses the IEEE 802.15.4 Standard (Pinsdaddy 2018)

Name	Subcommittee	Maximum Distances	Technology Consortia
WMAN (wireless metropolitan area network)	IEEE 802.16	Kilometers	WiMAX®
WLAN (wireless local area network)	IEEE 802.11	Hundreds of meters	Wi-Fi®
WPAN (wireless personal area network)	IEEE 802.15	Tens of meters	ZigBee® Bluetooth™ WiMedia™

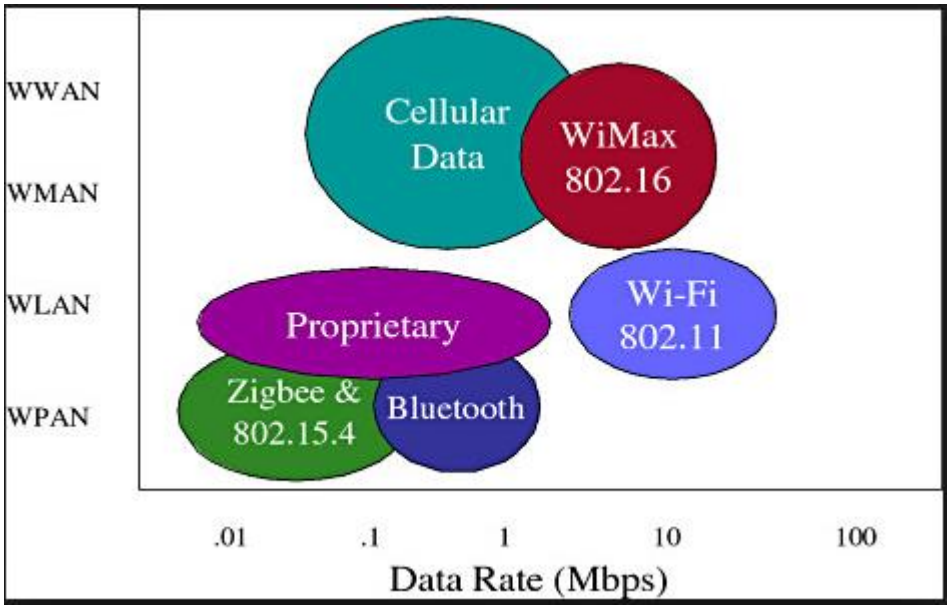

Figure: 5 Wireless networks (Joel 2007)

7.1 Frequency areas of Standard 802.15.4

WPANs operate under ISM (Industrial, Scientific and Medical) frequencies and must comply with the requirements of the authorities limits for example. transmission power. Table below shows the WPAN networks frequency ranges, channels and data rate.

Table 2: Standard 802.15.4 frequencies (Steve 2007)

Band	*Coverage*	*Channels*	*Data rate*
2.4 GHz	Worldwide	16 channels	250 kbps
915 MHz	America	10 channels	40 kbps
868 MHz	Europe	1 channel	20 kbps

7.2 Modulation

In the modulation of 868 MHz and 915 MHz, the BPSK method is used (Binary Phase Shift Keying). Optional frequencies can be used such as ASK and O-QPSK modulations (Amplitude-Shift Keying and Offset-Quadrature Phase Shift Keying). The latter uses the 2.4 GHz band.

IEEE 802.15.4 pre-defines the map table from 4-bits symbol to 32-bits chip sequences. The radio encodes these chip sequences using orthogonal quadrature phase shift keying (O-QPSK) and transmits them at 250kbps. O-QPSK PHY is mandatory when IEEE 802.15.4 is operating in the 2,4GHz band. The modulating and spreading process in IEEE 802.15.4 PHY is illustrated in picture below (Shi & Li 2016, 16).

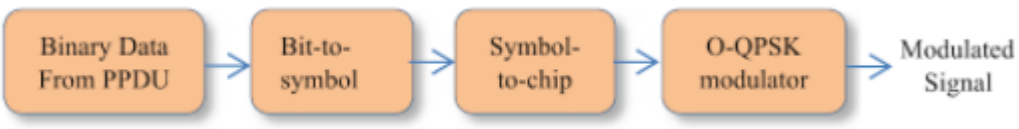

Figure: 6 Modulation and spreading functions for the O-QPSK PHYs (Shi & Li 2016, 16)

7.3 Transmission Power

The 802.15.4 radio specifies a transmitter power of at least −3 dBm (0.5mW) and receiver sensitivity of −85 dBm for the 2.4 GHz band or −91 dBm for the 915/868 MHz bands. WirelessHART network devices are able to control the transmission power step by step. The devices have a nominal transmit power of 10 dBm (10mW) and the next transmission sequence can be e.g. 0dBm (Steve 2007).

8 HART-PROTOCOL

The HART (Highway Addressable Remote Transducer) communication is two-way, industry-driven fieldbus protocol that is used between intelligent field devices and automation systems communication. The HART standard is commonly known and today most of the installed smart field devices are HART compliant.

HART is so called, master-slave-type communication protocol that was developed in the late 1980s, for configuration of intelligent field devices and for deployment. Later, in the 21st century, it became possible to transfer data to the automation system. The HART protocol is based Bell202 modem and frequency modulation, where digital signal consists of two sine frequencies. Frequency 1200 Hz corresponds to digital value "1" and 2200 Hz for "0". In the system there are two-way digital signals in the same circuit with a 4 - 20 mA standard current message. The digital signal floats above of the analog signal and its average value is zero, so it does not interfere with the analog signal. Data transfer rate is 1200 bits per second in one direction at a time. This technique enables a two-way communication between field device and the system, and sending / receiving additional information from intelligent field devices in addition to the normal process variable (Kale 2017).

With HART system the measurement circuit can be used for example. The following measures:

- Configuration: Defining the upper and lower limits of the measuring range, and the values transformation
- Tuning and calibration: transmitter calibration and reset, and again tuning using an external calibrator
- monitoring of process values: monitoring the measurement
- Diagnostics: checking the flow loop integrity and reading the alarm data.

Figure 7 shows a HART signal with a frequency value.

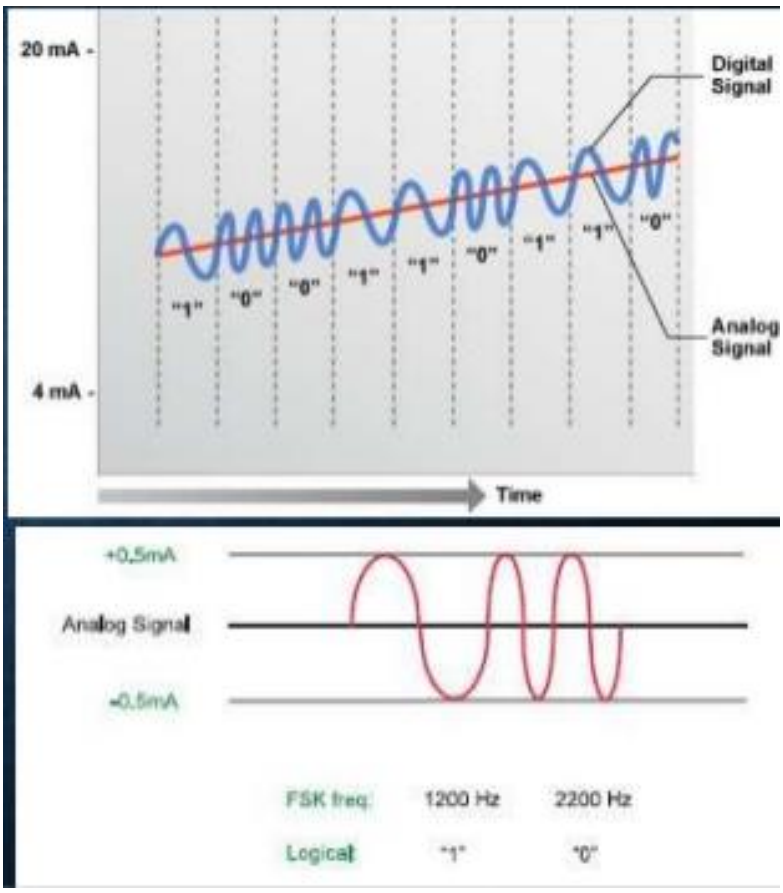

Figure: 7 Simultaneous analogue and digital signal (Kale 2017)

8.1 Protocol structure

The HART protocol is based on a seven-part OSI (Open Systems Interconnection) (Picture 2) a model developed by an international standardization organization (ISO). The OSI model provides the elements and structures for data communication systems. The HART protocol directly uses three layers of OSI model: physical, transfer, and application layers. Floor 1, physical layer, operates on the FSK principle based on Bell 202 communication:

1. Data transfer rate 1200 bits / s
2. Logic "0" frequency: 2200 Hz
3. Logic "1" Frequency: 1200 Hz

Layer 2, the transfer layer, forms a HART message and responds to the package integrity and flawlessness, and sends an error verification code to the transfer. The transfer layer also provides online access for all devices to communicate sequentially through the token-passing data transfer procedure. Since the HART protocol is a so-called master-slave type, the master device determines the shifts for the slaves to use the network. After receiving a command from the master device, the slave processes the command and sends the answer.

Layer 7, the application layer, harnesses commands and is responsible for identifying devices. The master sends a message to the slave that requires pre-defined and current values as well as any other data or parameters which can be obtained from the device. The field device handles these instructions as in the HART protocol defined. The reply message sent by the device to the master is provided with status information and the actual data (Thorsis Technologies).

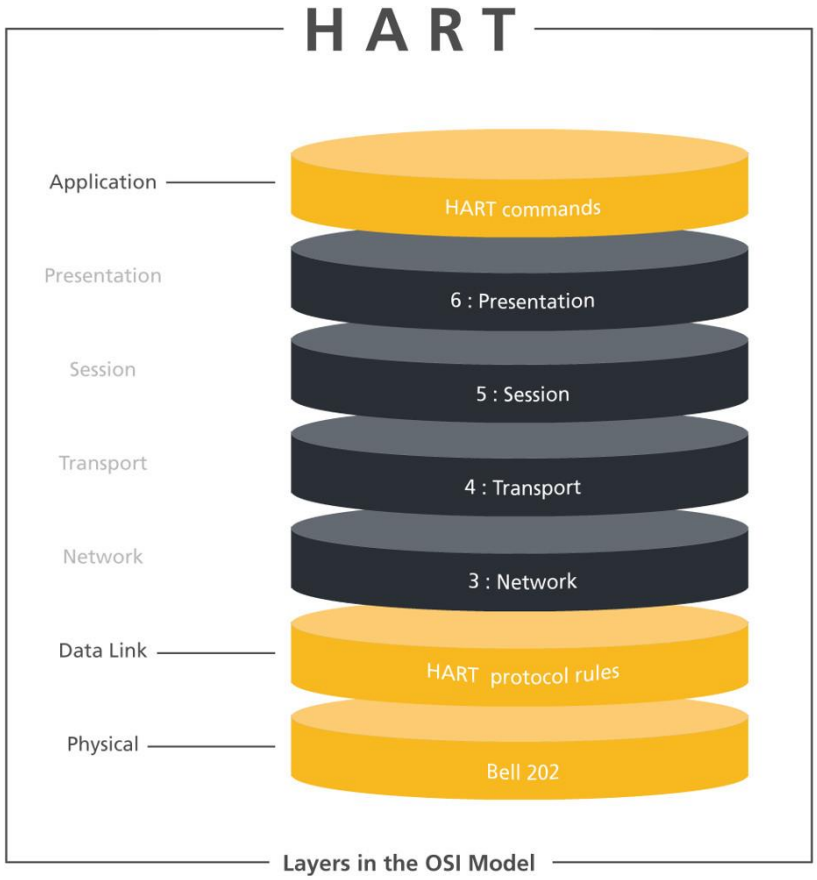

Figure: 8 HART vs OSI (Thorsis Technologies)

8.2 HART-commands

Communication between HART devices is based on commands. The HART command list guarantees consistent communication with field devices regardless of the manufacturer. The command list is divided into three different groups (HART Commands 2015):

1. All devices based on HART Protocol must recognize and support the universal commands. Universal commands provide access to information in normal operations.
2. Common Practice commands give functions used by many, but not all, devices which use HART communication protocol.
3. Device Specific commands are the devices unique functions. Command which access calibration, setup and the device construction information.

8.3 Device description

The device description is a textual description of a field device information and activities. The device description tells exactly what a device can do with the HART communication. The device description is written in a plain text format but is transformed into more efficient and a more practical code. The device description mainly describes variables, commands, methods, and menus.

All available information on the device is included in the device description,
For example, process measurements and all internal parameters such as measuring range, sensor type and device data.

For the device description there will be defined the following information from every variable: Datatype, Name, Alternate Units and possibly a description of the variable and the intended use. For each command and command response, the device description defines data structure. Methods describe a procedure for operations. They can for example, advise the user to calibrate the device again.

9 WIRELESSHART

WirelessHART network is made to be as reliable as possible. WirelessHART is also made to be compatible with other manufacturers devices so the process can stay as failure free as possible.

9.1 Network architecture

WirelessHART- architecture includes three basic elements. There are the three elements listed:

- WirelessHART field devices, which are connected to the process or other plants systems
- WirelessHART-gateway-unit, it creates a mesh network with WirelessHART devices and works as interface between the devices and the automation system
- WirelessHART control program, it takes responsibility over configuring the network, communication turns between devices and reporting about the state of network

9.2 What happens in WirelessHART network

Gateway unit communicates with automation system, it uses Ethernet and serial interface. The DustNetworkDN2510 Mote-on-Chip modulates the message into 2,4GH, DSSS and frequency hopping WirelessHART signal. WirelessHART devices which are turned on can find the network and will connect to it automatically based on Network ID and Join Key. WirelessHART devices use their neighboring devices as routers, creating a mesh network. The network is secured with 128 bit code.

In the Figure 9 is shown the structure of a wirelessHART network system. You can see the mesh network created by the process instruments and follow the roude of the data to the process automation system and to the host application.

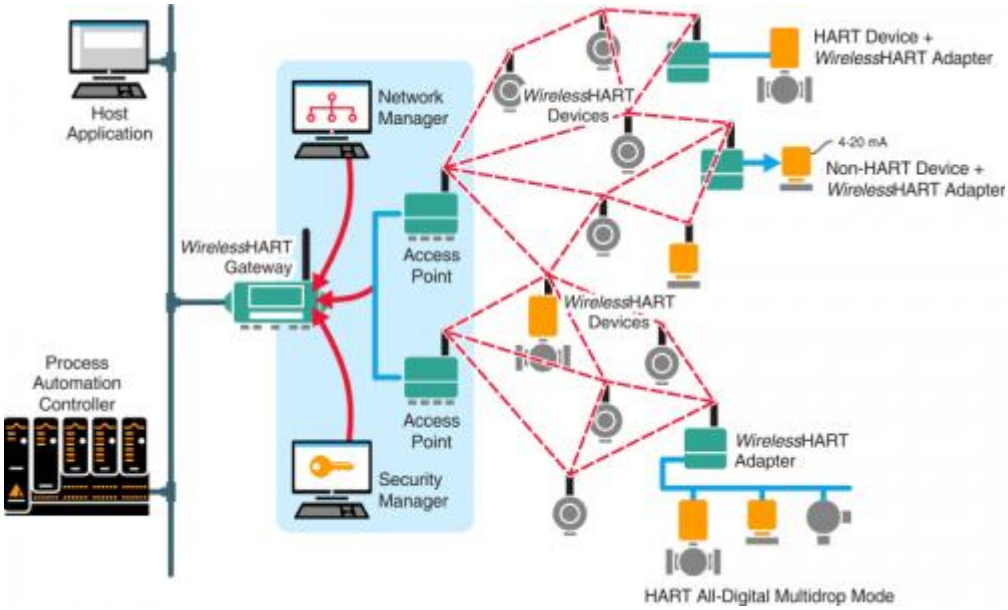

Figure: 9 WirelessHART network (Syscor 2018)

10 EMERSON WIRELESSHART DEVICES

Here are some of the many Emersons wirelessHART devices.

Figure: 10 Rosemount™ 3051S Wireless In-Line Pressure Transmitter (Rosemount Online Store. 2018)

Rosemount 3051S Wireless In-line Pressure Transmitter optimizes your gage and absolute pressure measurement performance. Made for direct threaded connection, manifold or seal system solutions. This pressure transmitter offers reliable measurement (Rosemount Online Store 2018).

Figure: 11 AMS 9420 or (CSI 9420) Wireless Vibration Transmitter (Emerson 2018)

The AMS 9420 Wireless Vibration Transmitter is easy to connect to any machine. It delivers vibration information. The AMS 9420 is ideal for vibration monitoring applications in hard-to-reach or cost prohibitive locations (Emerson 2018).

Figure: 12 Rosemount™ 928 Wireless Gas Monitor (Emerson 2018)

The Rosemount 928 Wireless Gas Monitor has tool-less hot-swappable gas sensor, which provides a warning to protect personnel and minimize down time (Emerson 2018).

Figure: 13 Emerson™ Wireless 775 THUM™ Adapter (Emerson 2018)

Makes any HART® device wireless. It retrofits onto existing 2-, 3- or 4-wire HART devices. The THUM Adapter wirelessly transmits HART measurement and diagnostic information from new or previously inaccessible measurement points (Emerson 2018).

There are also:

- Rosemount 3051 Wireless Pressure Transmitter
- Rosemount 2051 Wireless Pressure Transmitter
- Rosemount 3051S MultivVariable Wireless Pressure Transmitter
- Rosemount 702 Wireless Discrete Transmitter
- Rosemount 702 Plunger Arrival
- Rosemount 705 Totalizing Transmitter
- Rosemount 648 Wireless Temperature Transmitter
- Rosemount 848T Wireless Temperature Transmitter
- Rosemount 248 Wireless Temperature Transmitter
- Rosemount 708 Wireless Acoustic Transmitter
- Rosemount 3308A Wireless Guided Wave Radar Level Transmitter
- Rosemount 2160 Wireless Vibrating Fork Liquid Level Switch
- Fisher 4320 Wireless Position Monitor
- Roxar CorrLog Wireless Corrosion Monitoring Transmitter
- Roxar SandLog Wireless Sand/Erosion Monitoring Transmitter 1 Element Probe

10.1 Batteries

Batteries are the heart of the wirelles automation sytem, they are the key factor in the costs and reliability. Here are shown some the battery possibilities for Wirelles HART instruments.

Figure: 14 Emerson™ 701P SmartPower™ Module – Black (Rosemount Online Store 2018)

The Emerson 701P SmartPower™ Module - Green or Black provides up to 10-years maintenance free operation and replacement without transmitter removal making the job quick. It is very safe and it can stand harsh environment (Rosemount Online Store 2018).

According to Rosemount Online Store (2018), the Black Power Module is designed for use with:

- Rosemount 702 Wireless Discrete Transmitter
- Rosemount 705 Wireless Totalizing Transmitter
- Rosemount 3051S Wireless Pressure Transmitter
- Rosemount 648 Wireless Temperature Transmitter
- Rosemount 848T Wireless Temperature Transmitter
- Rosemount 248 Wireless Temperature Transmitter (Aluminum)
- CSI/AMS 9420 Wireless Vibration Transmitter
- Rosemount Analytical 6081 Wireless Transmitter for pH and Conductivity
- Rosemount 2160 Wireless Vibrating Fork Liquid Level Switch
- Rosemount 3308 Wireless Guided Wave Radar Level and Interface Transmitter

Figure: 15 Power Pucks® for Emerson Rosemount Wireless Transmitters Perpetua 2018)

“Power Pucks harvest thermoelectric energy and convert heat of its environment into electric energy for Emerson wireless transmitters.
There are mounting parts which allow it to be mounted on most of the surfaces, like flat and curved surfaces with temperatures up to and over 427 degrees Celsius. Depending on the wireless transmitter, a warm-to-the-touch heat source can be enough to power the transmitter with its highest update rate (Perpetua 2018). This device is used with a black power module.

Figure: 16 Emerson™ 701P SmartPower™ Module – Blue (Emerson 2018)

The Emerson™ 701P SmartPower™ Module - Blue have higher capacity and it is specially made for the use of the AMS/CSI 9420 Vibration transmitter (Emerson 2018).

Figure: 17 Emerson™ 701P SmartPower™ Module – Green (Emerson 2018)

The Emerson 701P SmartPower™ Module - Green or Black provides up to 10-years maintenance free operation and replacement without transmitter removal making the job quick. It is very safe and it can stand a harsh environment (Emerson 2018.)

According to Emerson (2018), the Green Power Module is designed for use with:
- Rosemount 708 Wireless Acoustic Transmitter
- Rosemount 3051 Wireless Pressure Transmitter
- Rosemount 2051 Wireless Pressure Transmitter
- Rosemount 248 Wireless Temperature Transmitter

10.2 Gateway

All communication in the WirelessHART network is goes through the gateway. Gateway routes data to specific destinations, e.g. for the field devices or the network administrators. The gateway like the wired system uses communication standard HART instructions. The gateway can be connected to automation systems using RS485 serial interface and Modbus RTU protocol or Ethernet connection and OPC or Modbus TCP / IP protocol ((Emerson 2018.)

Figure: 18 Emerson™ Wireless 1410 Gateway (Emerson 2018)

This Gateway is engineered for smaller networks. This wireless gateway connects WirelessHART networks with host systems and data applications its also small sized and it can be mounted on a DIN-Rail. This device offers 2 network capacity options A: 25 devices and B: 100 devices (Emerson 2018.)

Figure: 19 Emerson™ Wireless 1420 Gateway (Emerson 2018)

This device connects wirelessHART network with host systems and data applications. This wireless gateway has a network capacity of up to 100 devices and is mostly used for installations without a junction in outdoor locations. Connects easily to legacy host systems, additional devices can be added quickly without the need for configuration of the communication paths (Emerson 2018.)

11 WIRELESSHART NETWORKS

The key feature of the WirelessHART network is self-organization and that is one of the reasons why a mesh topology was selected as a network type. Every network device has the ability to detect neighboring devices, to measure the radio signal intensity, acquire synchronization and frequency hopping data, and finally establish routes and connections with neighboring equipment. WirelessHART-network is a set of devices that share the same domain and password, and which are synchronized with each other. There is always at least one gateway unit in a network that supplies timing and configuration information to the devices. In addition to the actual data messages, there are time slots that are intended network configuration, neighborhood device detection, and network listening to subscription requests. Also the update speeds for these slots are defined by the length of the frame. When devices are communicating normally in the network, packets are transmitted by codes that "advertise" the network settings such as frame length, open time slots and frequency channels, network ID and time.

To connection of the device to the network: The device is listening for a moment frequency A then frequency B and then frequency C. The device detects the neighbor and locks at network time (synchronization) and then listens just the beginning of the time slots, just to determine if it is necessary to receive a message. Listening different frequencies the device builds a list of its neighbors. The lists contain devices, which are in the range of the radio and have sent messages. The neighbor list also contains information of the strength of the received signals (RSSI). The device then selects the neighbor and sends a network connection request. Finally, the device receives an activation command from the neighboring device and connect to other devices on the network.

Distances between the devices with direct view can be maximum about 200 meters and in the so-called “factory labyrinth” 100-200 meters. Extended antenna with a direct view, can reach up to 800 meters. Here the device must be installed at a height of at least 5 meters. When starting the network the gateway must be on and after that you connect the power on to the nearest device and so on. This

method where you start from the nearest one and continue to the most remote, minimizes the potential connection problems between devices.

In one network there are usually only one gateway, but if there are two, they are positioned very close to each other, and they all have to be connected with the same devices. It is possible to make multiple networks in one location, so covering the whole plant, is not a problem.

12 EMERSON TOOLS

Emerson tools are tools for planning an estimating a wirelessHART network. These tools are provided by Emerson on their own website. These are very easy to use and gives the user a good picture of his needs considering wirelessHART. There is a planning tool for planning the network, the power module estimator is for estimating the life span of the power modules used by the wirelessHART devices, the wireless Estimator is for estimating the costs and time saving the between wired and wireless HART.

12.1 Emerson planning tool

The planning tool is very easy to use, it doesn't have too many parameters, but it does the job. Here is a little introduction for the planning tool and what I did with it.

When designing and estimating the network, I was using average range of 76meters for all devices. It is possible that it is less or more. In case it is less, two or three networks are needed, meaning 1 or 2 more gateways are required. The result shown in Figure 20 and the rest of the figures (21, 22 , 23) tell which parameters I used. The istruments are placed as in the appendix 1.

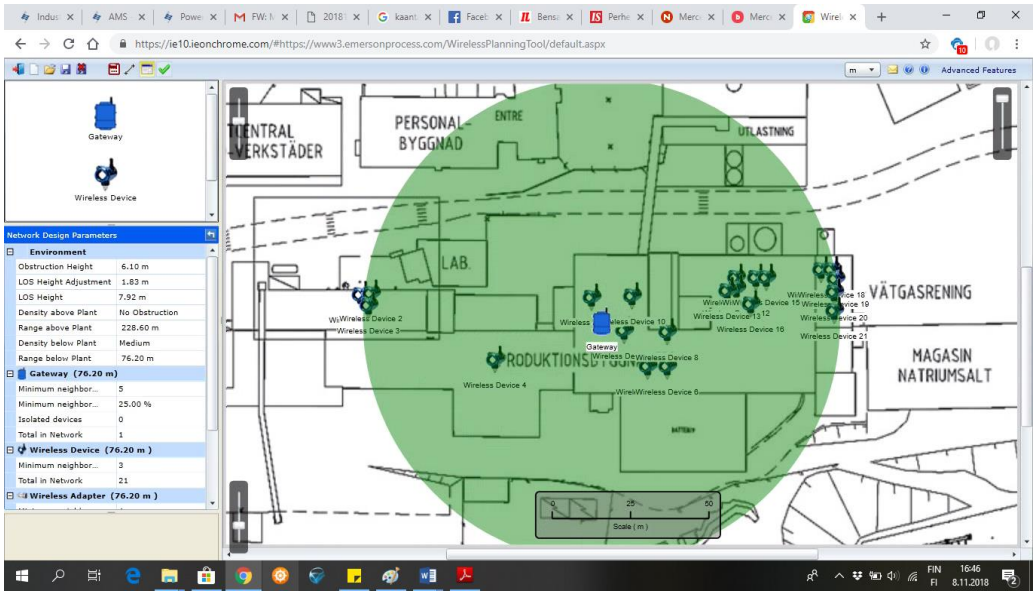

Figure: 20 This is what the network looks like (Emerson 2018)

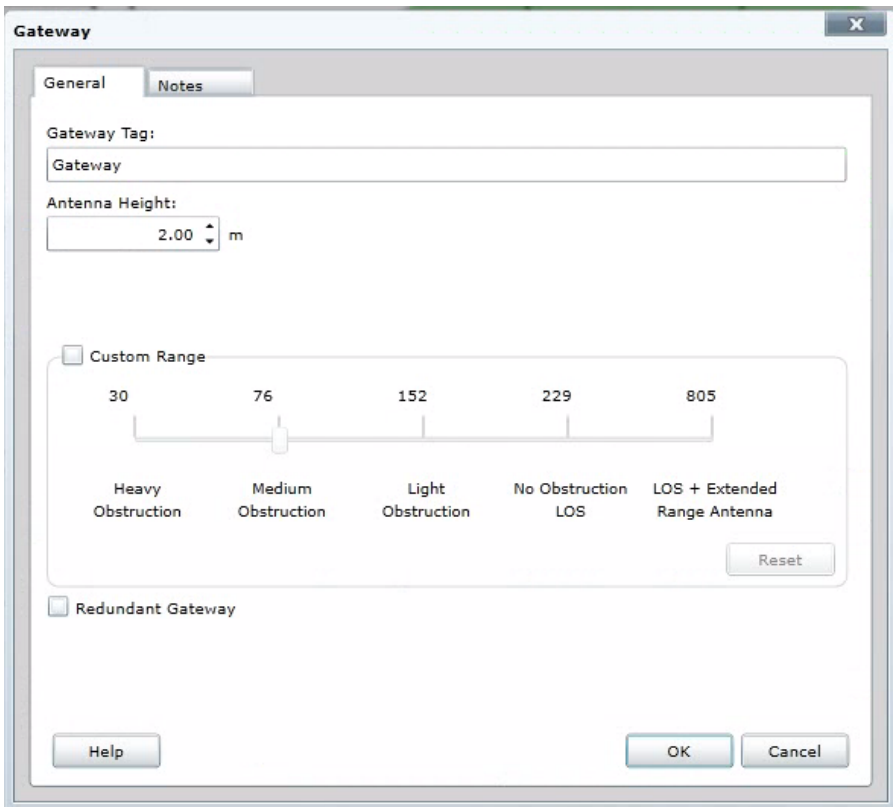

Figure: 21 Settings of the Gateway used in the figure 20 (Emerson 2018)

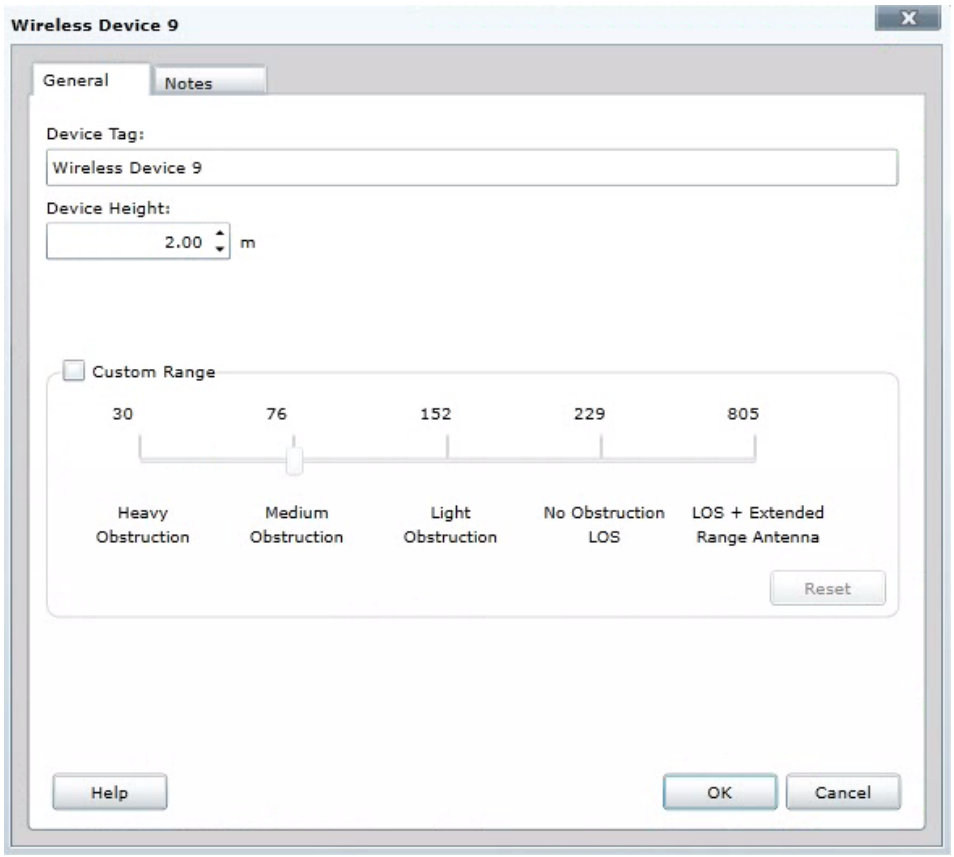

Figure: 22 Settings of the wireless measuring devices used in the figure 20 (Emerson 2018)

Environment	
Obstruction Height	6.10 m
LOS Height Adjustment	1.83 m
LOS Height	7.92 m
Density above Plant	No Obstruction
Range above Plant	228.60 m
Density below Plant	Medium
Range below Plant	76.20 m
Gateway (76.20 m)	
Minimum neighbor...	5
Minimum neighbor...	25.00 %
Isolated devices	0
Total in Network	1
Wireless Device (76.20 m)	
Minimum neighbor...	3
Total in Network	21

Figure: 23 Some more settings used in the figure 20 (Emerson 2018)

12.2 Emerson power module estimator

The Emrson Power module Estimetor is an easy to use program to simulate your devices batterylife. The average battery life is one year, and the lifespan of wireless device is around 12-16years, the battery will be changed around 12times during that time. It will cost a lot of money, but now there is a solution to reduce costs on batteries.

The battery life of AMS9420 wireless device with 20minute update rate in low temperature (-40Celsius). See Figure 24 The battery life of AMS9420 wireless device with 20minute update rate in room temperature (21Celsius). See Figure 25. The battery life of AMS9420 wireless device with 20minute update rate in high temperature (86Celsius). See Figure 26.

Power Puck is a device that changes heat energy in to electricity, also powers and recharges the device battery. It is not Emerson product, but they will sell it when asked. Perpetua is the manufacturer of this handy device.

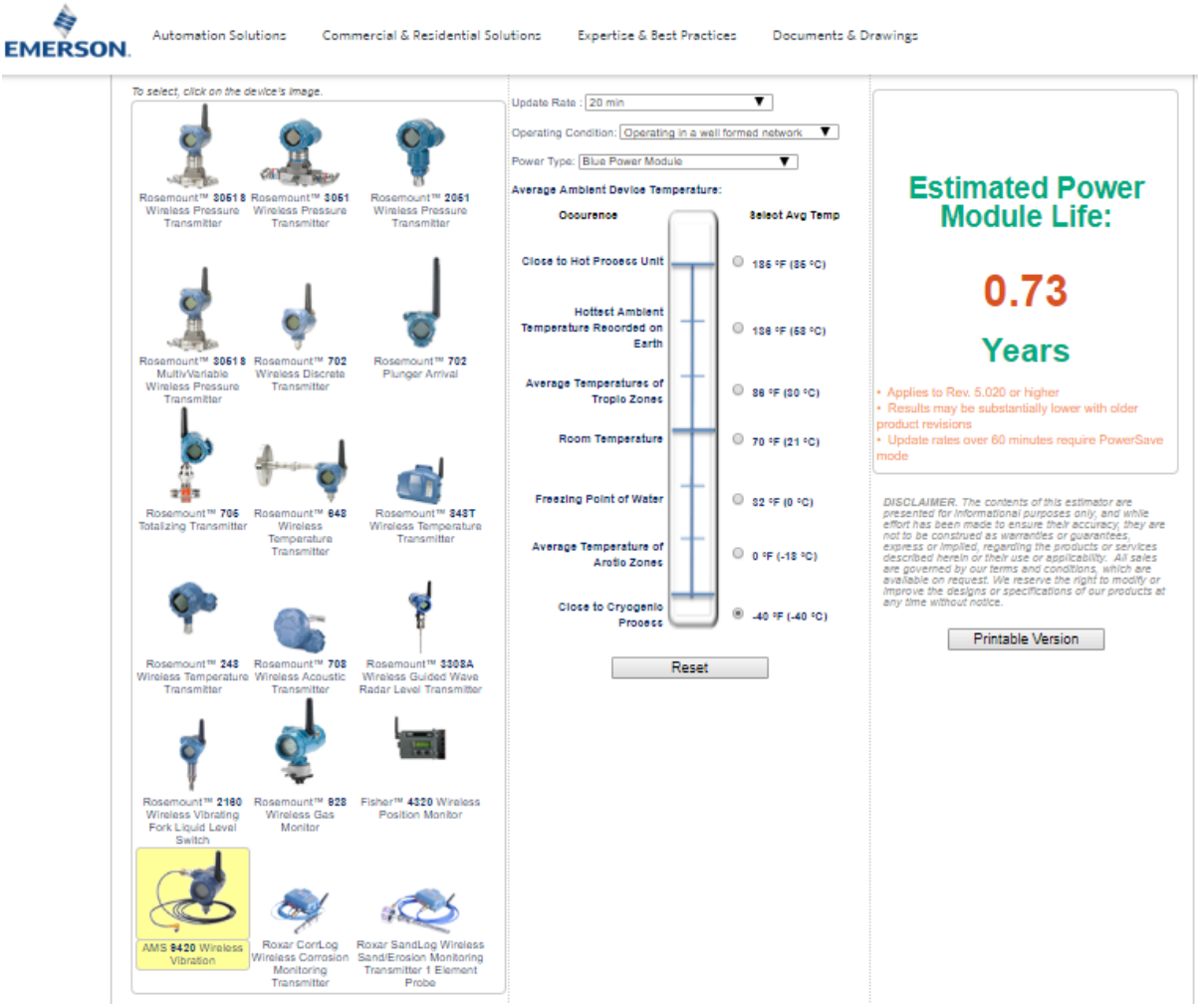

Figure: 24 AMS9420 Batterylife (Emerson 2018)

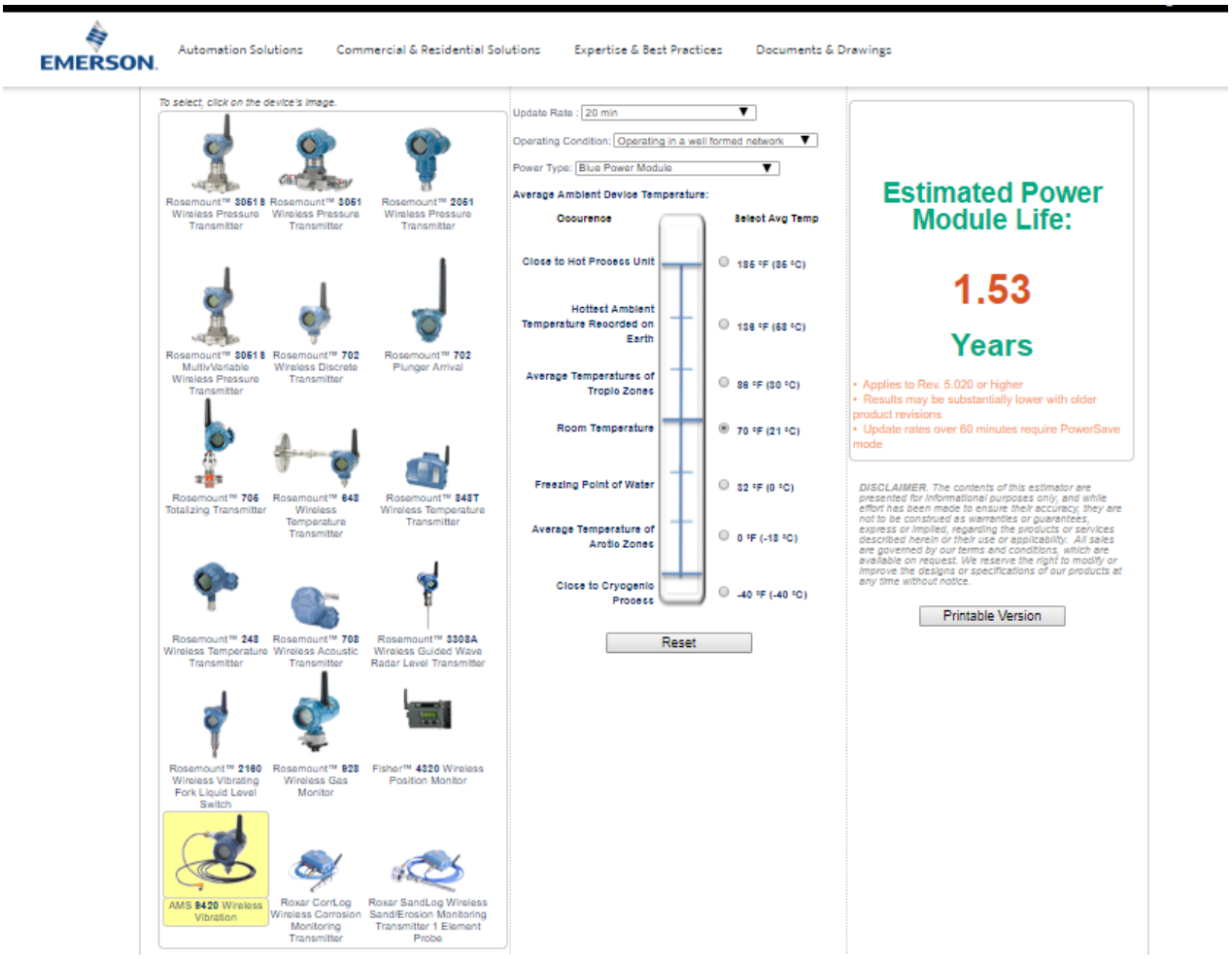

Figure: 25 AMS9420 Batterylife (Emerson 2018)

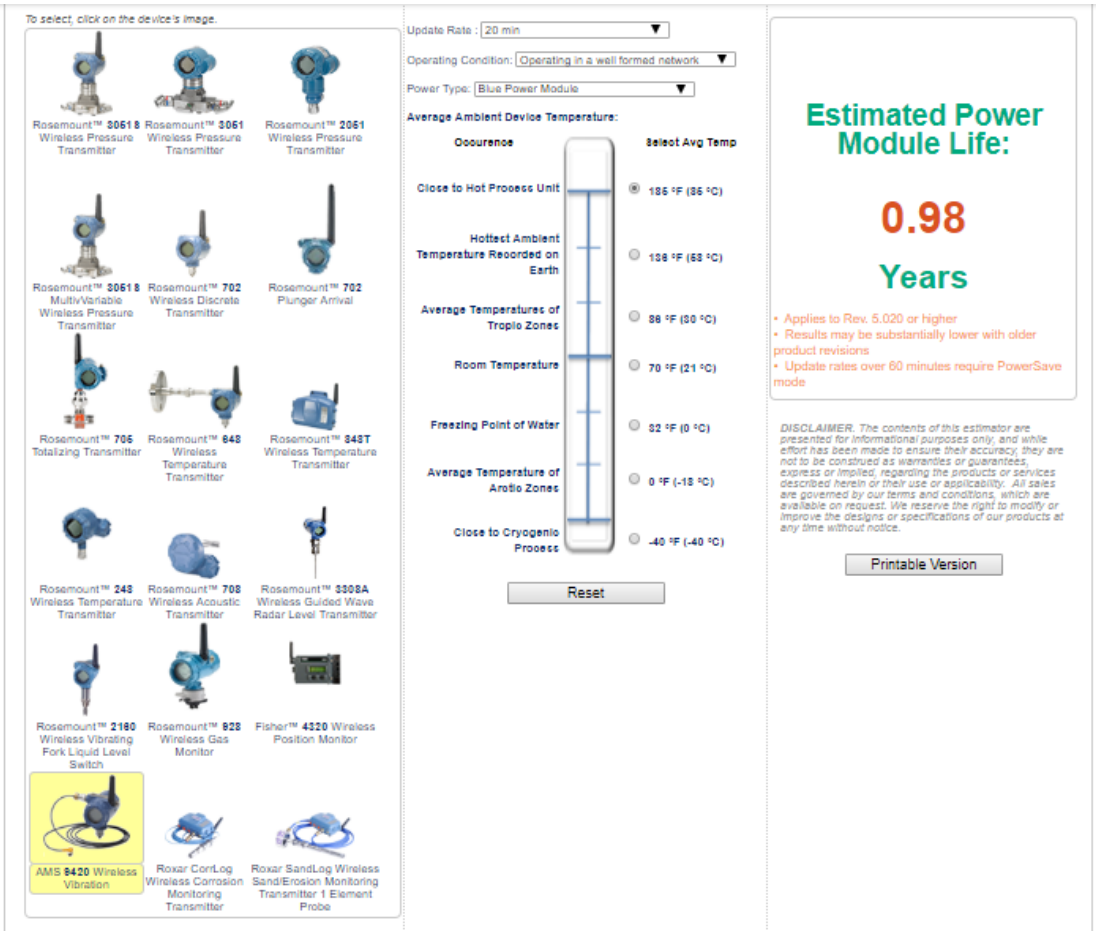

Figure: 26 The AMS9420 Batterylife(Emerson 2018)

12.3 Emerson Estimator

Emerson Estimator is an easy to use program. You can change the parameters the way you want to achieve as accurate cost and building time calculations as possible.

All the figures (27, 28 and 29) are connected together. You can change all the parameters the way you want. This estimation made by me is based on what is believed to be average. In figure 28 are shown the costs, you can change the values the way you want. The average costs were used since the estimator program already had those in, shown in this picture. In figure 29 are shown the results summary and saving details of the Emerson Estimator. The estimator indicates that in your factory you are able to achieve 142thousand euros savings in money and 207hours in man work.

In addition there is the safety aspect. When the vibrations are measured by the automation system, it is not needed for humans to go in and make the measurements. It also saves money.

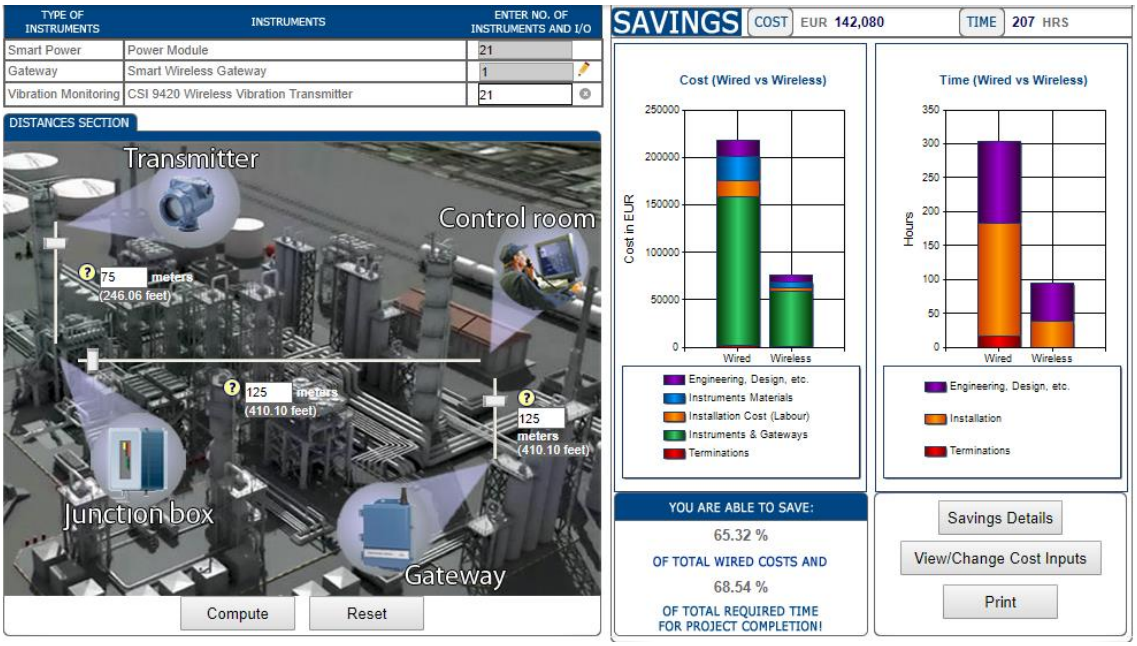

Figure: 27 Emerson wireless Estimator (Emerson 2018)

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Process Management

COST Values used in the computation are enumerated below. For other values, please enter (value) on the field corresponding the cost.

Labor Cost	EUR / Hour
Installation & Commissioning	100
Engineering & Design	200
System Configuration	150
Procurement	75
Quality Check	75

Average Material Cost

Materials	EUR / Hour
Wired	
Cost of multi pair cable (EUR/m)	25
Cost of multi pair cable glands x 2	10
Cost of instrument cable (EUR/m)	10
Cost of instrument cable glands x 2	10
Cost of Cable Tray and accessories (EUR/m)	75
Cost of Junction box and accessories (EUR)	1000
Intrinsic barrier	160
Cost of analog input / HART card	141
Wireless	
Cost of Gateway serial or Ethernet cable (EUR/m)	20
Cost of Gateway serial or Ethernet cable glands x 2	5
Cost of Gateway power cable (EUR/m)	20
Cost of Gateway power cable glands x 2	5
Cost of systems serial card	100

Figure: 28 Cost values used in the costs calculation (Emerson 2018)

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RESULTS SUMMARY

SUMMARY	WIRED		WIRELESS	
	COST	TIME	COST	TIME
Total Cost & Installation Time	217,519	302	75,439	95
Cost & Time Per Point	10,358	14	3,592	5

SAVINGS DETAIL

By using Emerson Wireless devices, YOU CAN SAVE...

79.77 % *of Installation Materials Cost*
76.66 % *of Installation Cost (Labour)*
98.67 % *of Terminations Cost*
56.09 % *of Engineering & Design, etc. costs*

And how much time can you save?

76.67 % *of total hours to install the devices*
99.17 % *of the time to set the terminations*
53.26 % *of the time to complete the Engineering, Design, Procurement, Quality Check, commissioning & Configuration of the system.*

Figure: 29 Results Summary (Emerson 2018)

13 CONCLUSION

Based on the research, it is beneficial to purchase this system in order to make the work place safer and on top of that have some savings.

The safety aspect comes from the fact that workers do not need to go into the factory, to measure the vibrations and exposing themselves to used chemicals and other hazards associated with process dynamics. It will not take so much time to build the system. When building, they do not need to go to dangerous and high places to mount the wiring.

Reliability aspect comes from sustained measurements. From the data gathered, it is easy to see how fast the electric motors are wearing, so it is easier and cheaper to plan maintenance for them, instead of reactive maintenance you can do proactive maintenance. There will be less break downs during manufacturing, because you know the condition of your motors at all times.

Savings will come from more reliable manufacturing. Customers will be more satisfied when the product is delivered on time. Less energy and raw materials are needed and the quality will be more stable when the manufacturing is continuous, also the wireless system itself is cheaper to install than the wired option.

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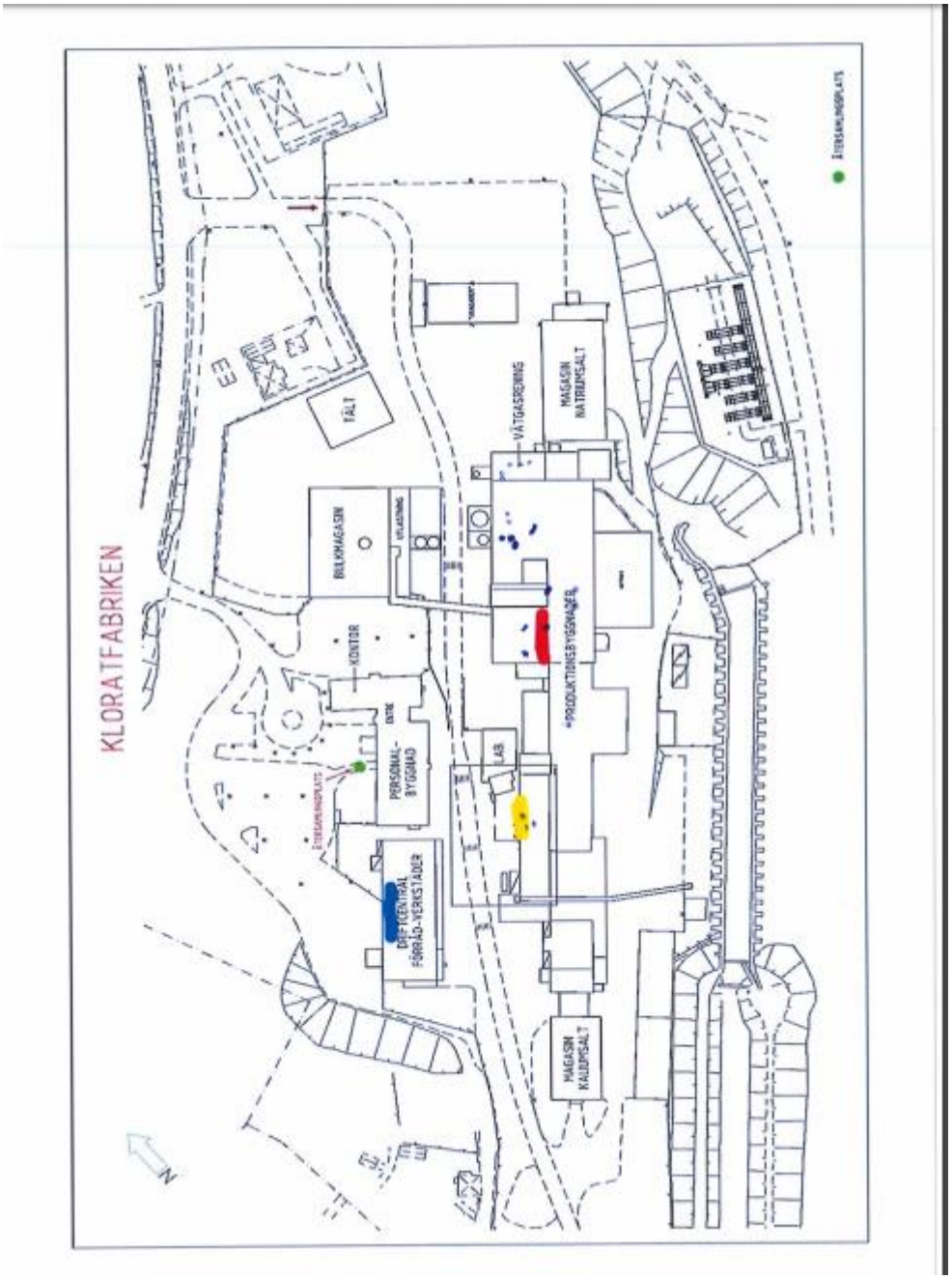
APPENDICES

Appendix 1. Photo



This is picture of the factory from above. The places where measuring is needed are marked with a pencil, there are 21 places marked. Blue spot is the control room, yellow spot is a cross connection, also the red spot is a cross connection.