



LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Gareth Finnegan	Student ID number:	156038
Programme:	HNC Instrumentation Engineering		
Module:	Instrumentation, Automation and Control		
Module code:	PCEE4009	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Nigel Richards	Internal Verifier:	Jason Pointer
Assignment Title:	Temperature Measurement System and Signal Transmission	Word count (or equivalent):	2000
Submission deadline:	14/01/23	Return date of provisional marks & written feedback:	06/02/23
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

1. Explain the principles of operation for a range of industrial measuring systems and demonstrate an understanding of the requirement for interfacing sensors with conditioning, indication and analogue/digital signal transmission circuits.
2. Select an appropriate sensor for specific operation and demonstrate an understanding of their benefits and limitations with respect to measuring and control system applications.

TASK DESCRIPTION

Introduction

You are working as an Instrumentation Engineer for Solero Measurement Systems Ltd. Your line manager needs a report on how to select the most appropriate sensor with a view of incorporating them into some of the company's measurement systems.

This assignment will cover a range of sensors that are used at Solero Measurement Systems Ltd. It will discuss the key features of two different but common pressure sensors such as a diaphragm pressure sensor and a bourdon tube. It will discuss the pros and cons of each sensor and how they compare and differ from one another. It will also discuss the performance and accuracy of each type of sensor. This assignment will also cover the testing of two different temperature sensors, an RTD and a thermistor and will compare the results to one another deciding which would be best to use into a system. Different signal processing and conditioning methods will also be covered, and these will be used to transfer the signal from the selected temperature sensor. The key principles of HART protocol will also be discussed and the benefits that come along with using HART protocol.

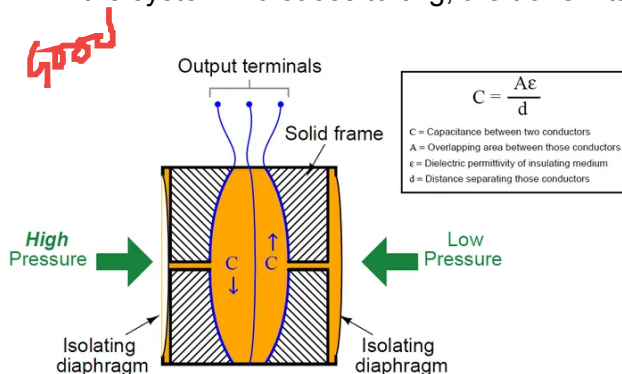
Task 1 –Sensor Functionality

The company would like you to write a report discussing the construction and key features (process variables, performance, benefit, limitations) of 2 different but common pressure sensors with respect to measuring and control system applications

There are many different types of sensors that can be used to measure pressure. The most common type that are used across site at Valero is the transmitter with a diaphragm sensor element. Figure 1 shows what the sensor looks like from the outside. The diaphragm sensor can be used to measure all types of mediums ranging from light gases to very heavy oils or liquids. The most important part of the diaphragm sensor is that they have a high and a low side. One of the main features of this type of sensor is that it can have either one or two connections to the process. If a pressure differential is required then both sides of the transmitter will be connected to the process, if the pressure inside of a vessel is required then the high side will be connected to the process and the low side will be open to atmosphere, or absolute pressure, depending on the service. The way that this transmitter works is by having a diaphragm that deflects when a pressure is applied to it. For example, when both the high side and low side are open to atmosphere, the transmitter will read 0%. A range will then be set on the transmitter via HART communication, an example of this could be setting the range 0-10kg. This means when there is no pressure on the high side, 0kg, the transmitter will read 0% (4mA). When the pressure in the system increases to 5kg, the transmitter will read 50% (12mA), as 5kg is half of the full range. When the



Figure 1: Pressure transmitter



pressure in the system reaches 10kg, the transmitter will read 100% (20mA). Figure 2 shows what happens to the diaphragm when a pressure is applied to the high side.

This leads onto the electronic side of the transmitter. according to Ted Mortenson, an Automation Engineer, the instrument is connected to a pressure transducer which converts the pressure signal into an analogue electrical voltage or a current

signal. This is done by converting the signal through capacitance where the information can be processed and transferred.

Martijn Stoppel of Sensata Technologies stated that applying digital pressure sensors with low power consumption throughout the network is a practical and cost-effective approach. This shows that these pressure transmitters require low power to operate and can be beneficial financially. Another advantage is that you can set alarms on them so if there were to be a high or low pressure, alarms can be set up to inform the operator. Another advantage is that they provide great stability and have high sensitivity. A drawback of using a pressure sensor is that they can sometimes drift meaning they need frequent calibration. Another limitation is that they aren't as reliable at high temperatures so other sensors would need to be considered in high temperature systems. They are also highly sensitive to environmental conditions so high winds and rain may affect them.

Another type of pressure sensor available is the bourdon tube. The bourdon tube is made up from materials such as phosphor bronze or stainless steel. It has a C shaped tube which is used to indicate the pressure as it fills up. As the pressure in the system being measured increases, the bourdon tube will fill up respectively

and as the tube expands it pulls a pointer around which is used to indicate the pressure. It is calibrated via the links inside of the casing. According to WIKI, bourdon tubes can withstand pressures of up to 60 bar. Figure 3 shows the internals of a bourdon tube and the components interlinking.

An advantage of using a bourdon tube is that they are very cheap and have a compact design. They also ensure safety in the measurement of high-pressure ranges as they can be installed with a manifold so they can be vented and de-pressurized slowly. They also have good measurement accuracy.

There are also some limitations with the bourdon tube which may include responding slowly to pressure changes. They are also subject to hysteresis and are sensitive to shocks and vibrations. In noisy areas the needle indication the pressure may tend to wobble making it difficult to read. Another disadvantage is that the indication is only local to the area it is in. Also, the parts inside of the gauge are mechanical parts which means they are subject to damage and wear over time so maintenance may be required.

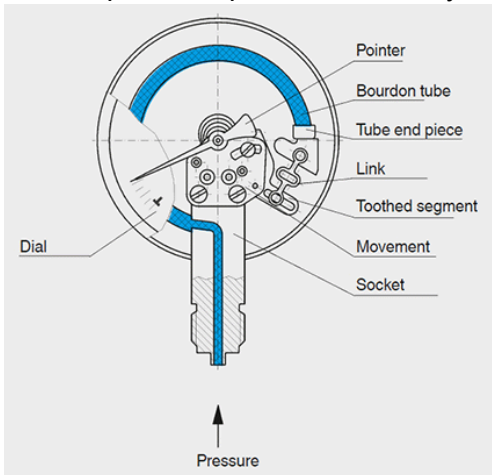


Figure 3: Bourdon tube

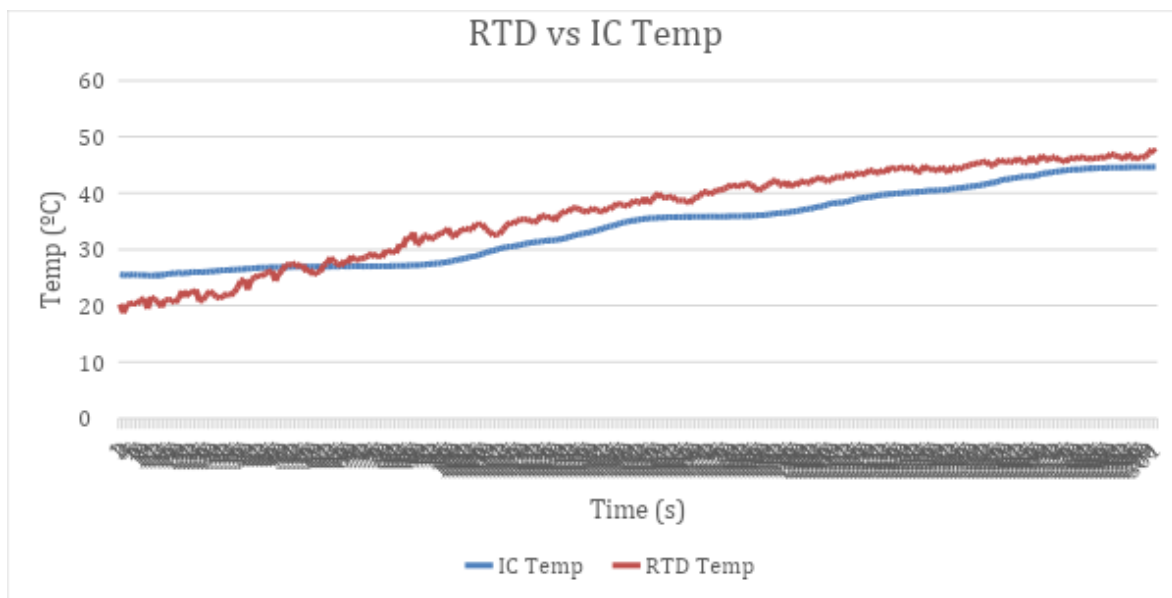


Figure 4: Bourdon tube Gauge

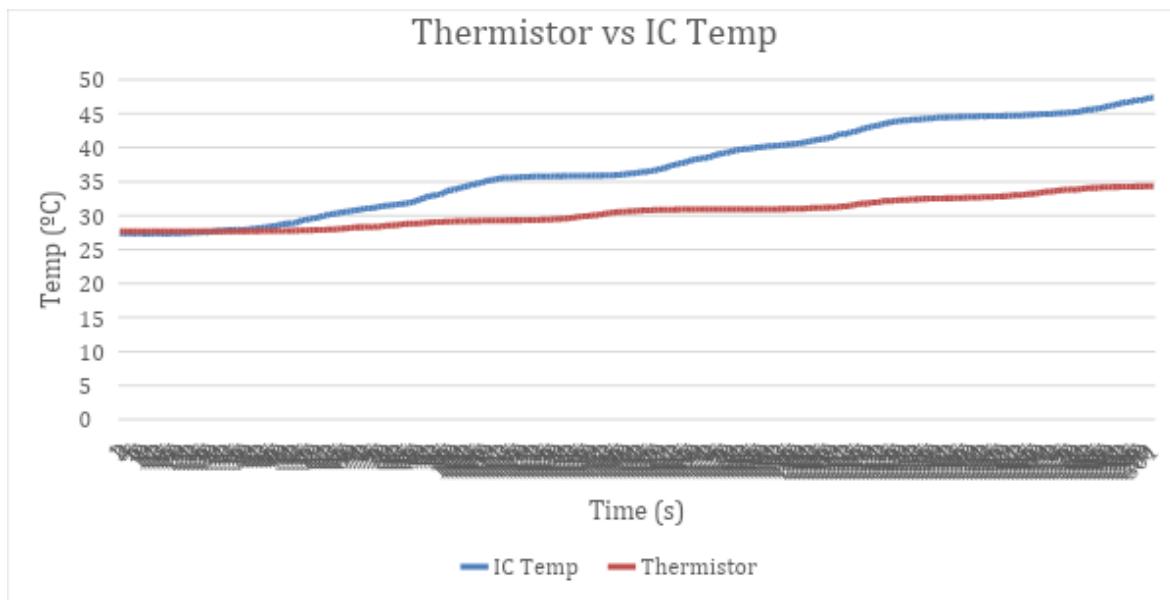
Task 2 – Sensor Testing

The company have shortlisted 2 Temperature sensors (Thermistor & RTD-both supplied) for incorporating into a system but want to investigate the accuracy and performance of each by using a resistor device as a low-level heating element operating over a five-minute period. The measurements will be compared with the results of an IC temperature sensor which is currently being used by the company. Using graphs as required analyse and compare of the results, referring to accuracy, sensitivity, errors and response to recommend the most suitable sensor.

There are a few different ways that the temperature can be measured, and it is important that the right type of sensor is used in the right situation. For example, if high temperatures up to 1000°C were needed to be measured a thermocouple or RTD would be considered as opposed to a thermistor. Tests were carried out to compare the RTD and thermistor to determine the accuracy and performance of them whilst monitoring a low-level heating element. The tests were carried out over a 5-minute period and have been compared to an IC temperature sensor.



The above graph shows the results over a 5-minute period for the RTD compared to the IC temperature sensor. At the start of the test, it is apparent that the RTD is slightly slow to react with the increase of temperature and takes around 55-60 seconds to catch up with the temperature. Once it reaches the actual temperature it overshoots for around 70 seconds until it starts to bring the reading closer at around the 150 second mark. Here the temperature flattens out and the RTD follows respectively. At around the 270 second mark the RTD is reading almost perfectly within a few degrees' tolerance. It also shows that the RTD is settling out and becoming less noisy.



The above graph shows the results for the thermistor against the IC temperature sensor over a 5-minute period. At the start of the test, the thermistor read the temperature very accurately to within a degree. However, after about 45 seconds as the temperature increased the thermistor was slow to react. The temperature slowly increased on the IC temp and the thermistor failed to keep up and slowly fell behind. After around 2 minutes there was about a 5-degree difference which was brought closer for about a minute but then the thermistor slowly dropped off for the final two minutes and finished about 13 degrees behind the IC temp.

According to Omega Engineering, RTD's typically have an accuracy of $\pm 0.1^{\circ}\text{C}$. According to the graph, the accuracy tended to be a bit greater than 0.1°C until the end where it started to settle out. If the tests were carried out for longer, the RTD may have shown greater accuracy over a longer period. Omega Engineering also states that thermistors are the most accurate type of sensors also having an accuracy of $\pm 0.1^{\circ}\text{C}$. However, our results contradict this as our results show that over the 5 minutes the RTD had much greater accuracy. According to Pratima Bajpai (2018), RTD's have a sensitivity of around $0.00385\Omega/\Omega^{\circ}\text{C}$ whereas the thermistor has an sensitivity of $0.1\Omega/\Omega^{\circ}\text{C}$. The results show that the thermistor had a higher error value as at the end of the 5-minute test the different between the actual temperature and the temperature the thermistor was reading was around 13°C . On the other hand, the error margin of the RTD compared to the IC temperature was a lot less around $2-3^{\circ}\text{C}$. This brings the conclusion that although the thermistor has a smoother response curve, the better sensor to use in this situation would be the RTD as it is a lot more accurate over the 5-minutes and is has a quicker response to change.

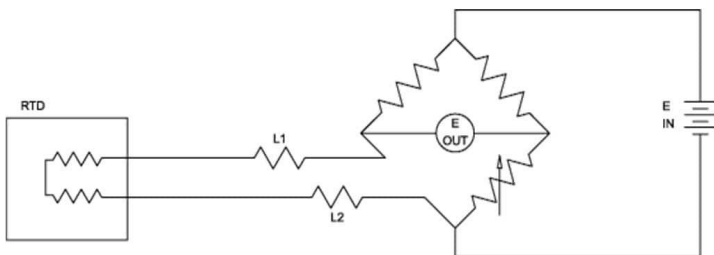
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Task 3 – Sensor Design

If your chosen temperature sensor was to be incorporated in to the system it will need some form of signal processing. Explain the need for signal conditioning and processing in order to fully utilise the sensor in a practical application. Justify a suitable measuring circuit that will convert the resistance of the sensor to a comparative current value. (Input range: User defined Output range: 4 to 20 mA)

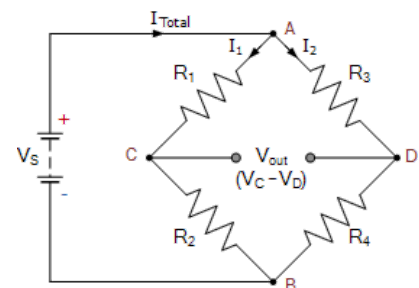
For the system to operate efficiently, the signal will need to be conditioned and processed so that it can be understood and read. Signal conditioning is used so that the signal can be amplified and converted into a signal that is easier to read and compatible with PLC's or other control systems. Signal conditioning also helps to acquire a precise reading which improves the accuracy and control of a system.

The first step of signal conditioning is the conversion stage. The conversion stage is used to convert the signal that the sensor outputs to the right type of signal required. This can be done in several ways and the way it is done with an RTD is by using a Wheatstone bridge. A Wheatstone



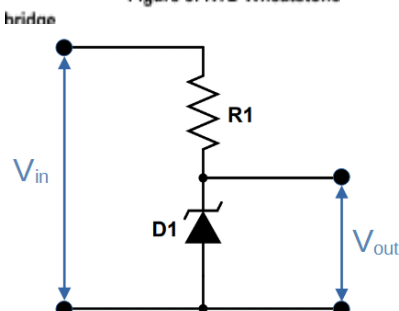
bridge is used to accurately measure unknown resistance values which is why it has been selected to convert the signal from the RTD. Figure 5 shows a drawing of a Wheatstone bridge that has been connected to a 2-wire RTD. The RTD acts as one of the variable resistors in the circuit. The aim of

the Wheatstone bridge is to get the resistance signal from the RTD and convert that into a voltage that can be converted into a 4-20mA signal. It does this by having two series-parallel arrangements of resistances that are connected between voltage supply and a ground. When the resistors in the circuit are balanced, the voltage output should be 0 as the two parallel balances should have no potential difference. Figure 6 shows how a Wheatstone bridge is normally drawn with nothing connected to it. When a RTD is connected to it, the circuit becomes unbalanced once a temperature is detected as the resistance on the RTD increases. The output voltage can then be converted to a 4-20mA signal using a 250Ω resistor.



The next stage of the signal processing is the protection. There are many different protection devices that can be used to protect the circuit. One protection device that

Figure 5: RTD Wheatstone



can be used is the Zener diode. A Zener diode can be introduced into the circuit and can be used to stop high surges of voltage. A Zener diode will have a set breakdown voltage and if the instrument sensor has a high surge of voltage, then the Zener diode will break and act as a short circuit and ground the high surge of voltage. This prevents the high voltage from damaging any PLC equipment on

the safe side of the circuit. Figure 7 shows a circuit drawing of a Zener diode.

The next stage of the signal of the signal processing is the amplification. The amplification stage is used to amplify the signal that has been converted so that it can travel longer distances and be easier to read. One type of amplification method that can be used is an operational amplifier. The standard Op-amp has 5 connection which include the inverting and non-inverting input, the positive and negative supply voltage and the output. A circuit drawing of an Op-amp can be seen in figure 8. The amplification required can be adjusted by the supply voltage that is applied to the circuit. The Op—amp takes the input signal, amplifies it depending on the voltage applied and produces an increased output signal that is stronger than the input signal. This can also be useful to reduce noise levels from the circuit creating an even more accurate signal.

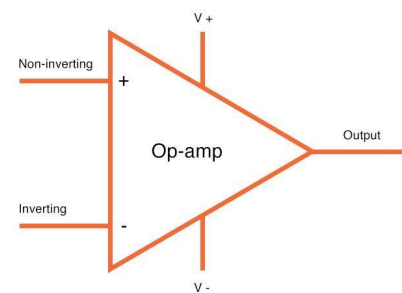


Figure 8: Op-amp diagram

Figure 7: Zener diode

Task 4 – Signal Transmission

Finally, the company would like you to produce a short report explaining the key principles and benefits of the HART Protocol as part of a signal transmission system.

HART protocol stands for Highway Addressable Remote Transducer and is used to communicate with signals at a low level on top of the 4-20mA. The HART technology has a master/slave protocol. This means that the field transmitter will only speak when spoken to by a HART device. There are two modes in which the HART protocol operates in which is point-to-point or multidrop. The communications happen between two HART-enabled devices such as the HART transmitter in the field and a control system. On Valero we use charms that communicate with the field device. There are two communication channels open with HART protocol and these include the 4-20mA analogue signal and a digital signal. The 4-20mA signal is the measured reading that the sensor will output and the digital signal carry's the information such as the device status, diagnostics and additional measured values.

Daniel Janner stated that in point-to-point mode, a single loop of current is established communicating a HART device and the monitoring system. The main variable, which the transmitter will be reading from the process, travels along the 4-20mA analogue signal and the additional digital information travels over the loop. A drawing of point-to-point mode can be seen in figure 9.

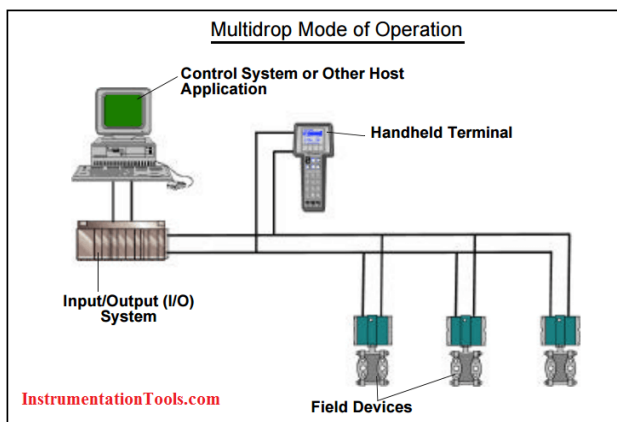
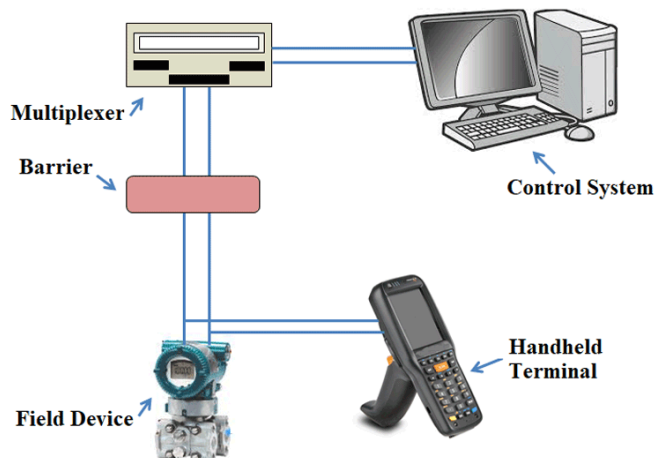


Figure 10: Multidrop mode

Daniel Jenner also stated that in multidrop mode, HART devices can be set up in parallel and can share a single signal transmission line. In this set up, each device remains fixed at 4mA and only data traffic occurs through the digital channel. Each device has its own unique HART address that is used to communicate between the PLC and the field device. 64 devices can be connected in multidrop mode. Figure 10 shows an diagram of multidrop mode.

One benefit of using HART protocol is that the combination of 4-20mA signal transmission along with digital communication allows flexibility when selecting different transmitters, valve positioners and other instrument devices. It allows them to communicate with each other allowing a smoother and efficient control system. the protocol also allows flexibility when selecting the manufacturer as the different brands can connect with each other via HART. The protocol also brings back additional information about the devices and can determine if there is a fault with the device. The HART protocol is also very useful if the instrument is in a noisy environment. Settings on the instrument can be adjusted to compensate for the noise, resulting in a more accurate reading.

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STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills		
Research with appropriate sources was evident however referencing convention was inconsistent	20	10
2. Knowledge and Understanding Skills		
A very good grasp of the underlying concepts & principles	35	27
3. Cognitive and Intellectual Skills		
RTD evaluation was sound with good justification - good to see using data and applying insight,	10	7
4. Practical Application Skills		
Nice to see reference to workplace Some evidence of problem solving and applying knowledge to solution	25	13
5. Transferable Skills for Life and Professional Practice		
Work coherent and well structured Lacking depth in areas	10	6

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		63 %
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

Moodle Feedback – Gareth Finnegan – Assignment 1

1. Good links to practical applications and workplace.
2. You mention Ted Mortenson, Janner, and Martijn Stopel - should have use Harvard convention>e.g. Mortenson(2020) states...
3. "According to WIKI"? Not referenced. If wikipedia then there may be better sources.
4. Some good answers here. Some reference to work place. Good understanding overall. lacking depth in areas.
5. Some benefits of HART addressed