Original Research Paper

Implementation Wireless Adapter Interface Module with Gateway Device for Connection to 4-20 mA Transmitters

[1]Waleed Ishaq Hameed, [2]K. Ivica, [1]Amar Al-Jzari and [1]Yasir I. Abdulraheem

[1]*Oil Training Institute, Basrah, Iraq*
[2]*Department of ECE, Florida Institute of Technology, Melbourne, USA*

Corresponding Author:
Waleed Ishaq Hameed
Oil Training Institute, Basrah,
Iraq
Email: waleed_ishaq5@yahoo.com

Abstract: Wireless communication is emerging technology from the office world to the industrial world. It is important that this technique are applied by the users in industrial environments because the industrial communication underlies stricter conditions than office communication. In this paper, It has been designed and implemented wireless adapter interface module with gateway connected to 4-20 mA devices and the Differential Pressure (DP) transmitter is considered. The implemented system consists from wireless adapter connected to the DP transmitter and the gateway device that used as a link between the field devices and the host. The standard method deals with a two-way or bidirectional communication protocol, which eliminate the drawbacks of 4 to 20 mA standard signal in the industrial measurements that can be only transmitted or measured one parameter value. With developed method, an additional information can be transmitted using wireless signal based on frequency shift keying modulation. In addition, the system design has been implemented and proposed various configurations for field device connections. The experiment results are presenting to verify the success of the implemented system.

Keywords: WSN, Arduino, IEEE Standard 802.15.4/nRF24L01

Introduction

Over the last decade, wireless technology has been received extensive studies and it has considered as a paradigm shifter in the process industry (Vieira *et al.*, 2003). HART technology is based on the IEEE standard 802.15.4 which uses as the base for reliable wireless communication and it is built upon the known and verified Highway Addressable Remote Transducer (HART) protocol. In 2010, Wireless HART was accepted by the International Electro-technical commission (IEC) universal. It uses wireless mesh networking between field devices, in addition to other innovations, to provide secure, consistent digital communications that can meet stringent required by industrial applications industry (Song *et al.*, 2008).

In the instrumentation field, electronic and pneumatic signals are naturally used to actuate the final control element in a control loop which is commonly a control valve. An "electronic" signal is a analogue voltage or current whose magnitude represents physical measurement or controller quantity. The most common

form of signal transmission used in modern industrial instrumentation systems is the 4-20 mA DC. This is an analog signal, denotation that the DC current is used proportionately to represent measurements or control signal (Ron Helson, 2014; Caro, 2005).

For several years, the field communication standard for process equipment has been a milliamp current analog signal. The current signal varies with a range of 4-20 mA in proportion to the process variable being. In typical applications a signal of 4mA will relate to the lower limit (0%) of the calibrated range and 20 mA will relate to the upper limit (100%) of the range. For example, if the system is adjusted for 0-100 PSI, then a current signal of 12 mA (50%) will match to a pressure of 50 psi. Practically all installed systems use this standard for communicating process between process automation equipment (Heikkila, 2009; Ron Helson, 2014).

HART Field Communications extends this 4-20 mA standard to improve communication with smart field instruments. This technical preserves the 4-20 mA signal

and enables two-way digital communications. Unlike other technologies, the HART protocol keeps compatibility with existing 4-20 mA systems and provides users with a exclusively backward compatible solution (Chen *et al.*, 2010). As the need for additional process increases, deliver new measurement values to control systems without need to run more wires. With the added capability of wireless communication, the legacy of benefits this technology provides continues to deliver the operational insight users need to remain competitive (Chen *et al.*, 2010). In this paper research, it has been attempt to design and implement wireless adapter interface module with gateway connected to 4-20 mA devices and differential Pressure (dP) transmitter and sonar level transmitter. The implemented system consist from wireless adapter connected to the transmitters and the gateway device that used as a link between the field devices and the host.

Transmitters Wire Configuration

The two, three and four wire cataloging are used to define the method of connection for the transmitters.

Two Wires Configuration

It is the most economical and should be used whenever load situations will permited. The 4 mA zero current is necessary to drive the internal circuit of the transmitter and the current from 4 to 20 mA

represents the range of the measured variable. Figure 1 shows the wire transmitter configuration.

Three wires Configuration

Several transmitters require more power than the signal loop can supply their internal circuit. DC common wire is track from the instrument to the transmitter. This permits the transmitter to draw power it needs from the supply and produce the desired current signal at the transmitter output. Figure 2 show a three wire transmitter.

Four Wires Configuration

Four wire transmitters have their internal power supply therefore they are referred to as self-power-driven instruments. 120V AC sources is connected to the instrument. So, they require no connection to the DC supply. The disadvantage is the need for AC supply at the instrument. Figure 3 is shows the four wire configuration.

Note that, in all the configurations of the transmitter, a load is resistor of 250 Ω. Typically process controllers used in instrumentation devices are not equipped to accept mA input signals, but reasonably voltage signals. For this reason a accuracy resistor is connected across the terminals of the controllers to convert the current signal comming from transmitters into analog voltage signal so that the controllers can be understand.
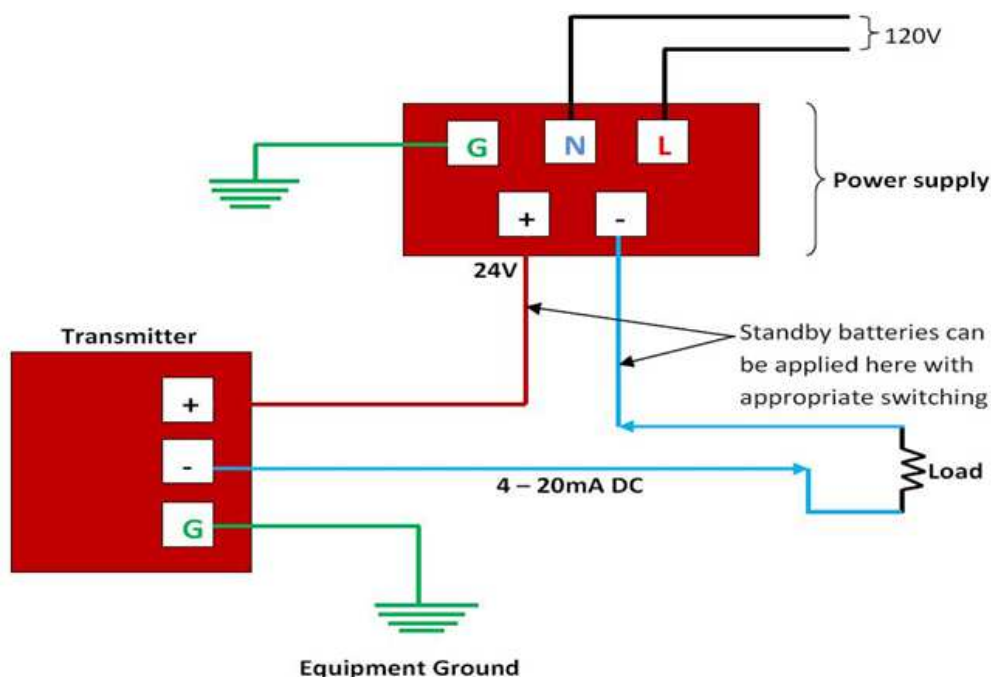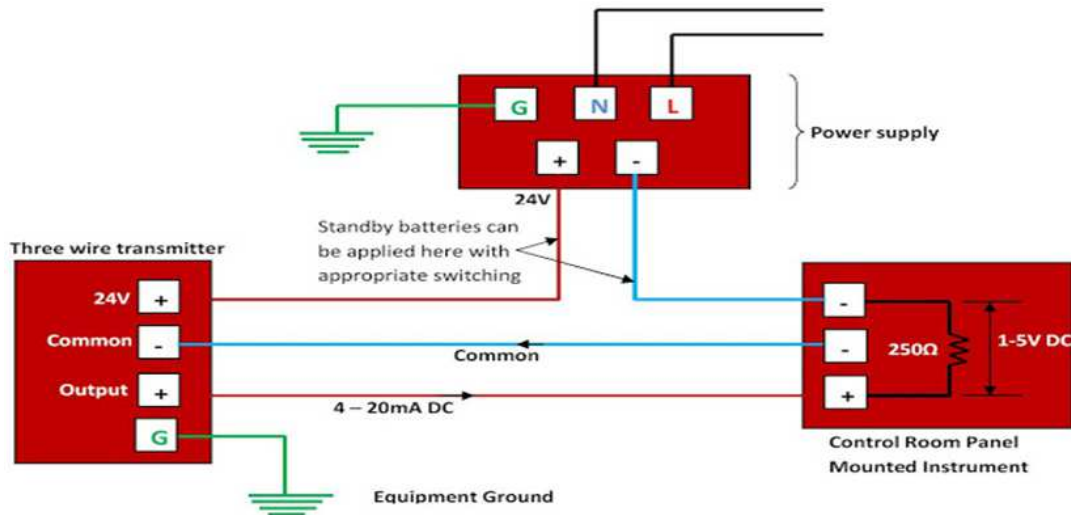

Fig. 1. Two wire configuration
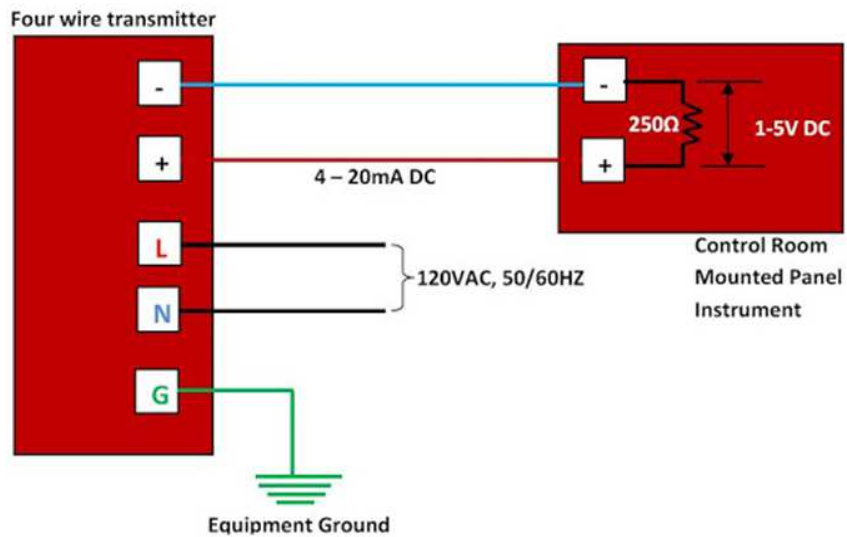
Fig. 2. Three wire Configuration
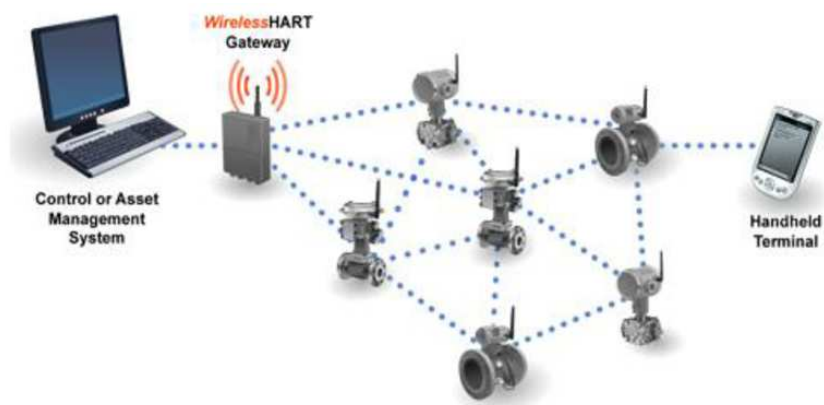

Fig. 3. Four wire configuration

Fig. 4. Wireless hart connections

Wireless HART Devices

HART Wireless devices can be distributed into communication and field devices. Communication devices involves of gateway, adapter parts and field devices as shown in Fig. 4.

Gateway

It allows the communication to the host network (Ron Helson, 2014).

Network Manager

Builds and keep the mesh network, it identifies the best paths and manages distribution of slot time access where the Wireless divides each second into 10 msec slots. The slots access depend on the necessary process value and other access such as alarm reportage configuration variations (Ron Helson, 2014).

Security Manager

Achieves and distributes the security encryption keys. It also clamps the list of devices to join the network (Ron Helson, 2014).

Process

Contains measuring devices and the HART-enabled instrumentation (Ron Helson, 2014).

Repeater

Is a device which routes wireless messages but may have no process joining of its own. Its main use would be to cover the range of a wireless network. All instruments in a wireless HART have routing capability which makes design and execution of wireless network simply (Ron Helson, 2014).

Adapter

Is a device that takes the instrument data through a wireless network by plugging into an present enabled network to the host. The adapter could be located everywhere along the instrument 4-20 mA cable; it could be battery powered or get its power from the 4-20 mA cable (Ron Helson, 2014).

Handheld Terminal

May be come in two forms. In the first case, the handheld will be a standard FSK configuration unit, just like the one used for everyday jobs such as routine maintenance and calibration checks. In the case of wireless support, the handheld is used to link a new instrument to an existing wireless network. In the further case the handheld has a wireless connection to the gateway and then down to an instrument and could be used for reading Process vraiable or diagnostics (Ron Helson, 2014).

The Wireless HART Communication

Although millions of HART devices are installed in worldwide, in most cases the useful information can provide is deserted in the devices. An estimated 85% of all connected HART devices are not being accessed to provide device diagnostics information with only the Process Variable data via the 4-20 mA signal. This is often because of the cost and the difficulty of accessing the HART data. The digital information in HART instruments connected to analog systems is trapped and cannot simply be used by monitoring, diagnostic and management applications. Possibly the reason for this underuse of useful information is that there is a reluctance to adjust an installation by placing a HART multiplexer in the 4-20 mA control loop.

Wireless HART technology lets users to access the large amount of unused information in these installed HART devices. It also provides a simple, reliable and secure way to install new points of measurement and control without the wiring costs. On the other hand, a Wireless HART adaptor provides low cost and low risk technique to access the potentially useful information in existing smart HART instruments (Song *et al.*, 2008; Petersen and Carlsen, 2009).

A Wireless adaptor is wireless communications equipment used to adjust and upgrade smart HART instruments with the capability of Wireless HART communication. The adaptor make available host applications such as asset management, diagnostic and monitoring over the Wireless network to these useful digital information previously trapped in HART instruments connected to analog I/O only. Figure 5 below show the photo of wireless adapter.

HART Field Communications

HART Field Communications is very important technology for both users and suppliers. HART technology is a major step in the development of process control and it is an enabling technology is getting significant innovation in the abilities of field instrument systems. The enhanced communications capability of intelligent field instruments using the HART protocol, provides significantly greater functionality and improved performance over 4-20 mA analog devices. The HART Protocol use the Bell 202 Frequency Shift Keying (FSK) standard to overlap digital signals at a low level on top of the 4-20 mA as shown in Fig. 6.

This enables bidierctional field communication and makes it possible for additional information. The HART digital signal communicates at 1200 bps without interrupting the 4-20 mA current signal and allows a host to get two or more digital signal updates per second from a field device. As the FSK signal is phase continuous, there is no interference with the 4-20 mA analoge signal.
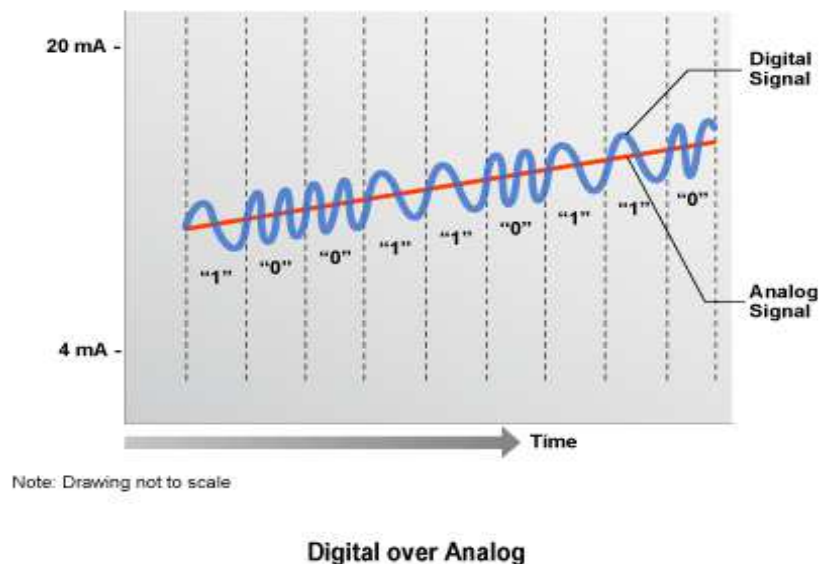
Fig. 5. WirelessHART adaptor

Fig. 6. Frequency shift keying

HART technology is a master-slave protocol, which means that the slave (smart field device) only speaks when spoken by a master. The HART Protocol can be used in several modes such as point-to-point or multi-drop for information to-from smart devices and control room and monitoring systems.

The HART Protocol provides two synchronized communication channels: The 4-20 mA signal and a digital signal. The 4-20 mA signal communicates the primary measured value. Additional device information is communicated by using a digital signal that is put on top on the analog current signal. The digital signal contains information from the device including device status, added measured and diagnostics,

etc. Together, the two channels provide very robust complete field communication solution that is easy to configure (Ron Helson, 2014)

Implementation of Wireless Adapter

The design of wireless adapter for connection to 4-20 mA transmitters are shown in Fig. 7 below. The implementation has been used the microcontroller (Arduino uno) and nrf24l01 wireless with current to voltage converter circuit.

Arduino is an electronics board based on easy-to-use hardware and software. Arduino platform are able to process the inputs and turn it into an output such as-

turning on an LED, activating a motor and publishing something online. You can tell your arduino what to do by sending a set of software instructions to the microcontroller on the board by using the Arduino programming language, the Arduino Software (IDE). Figure 8 shows an Arduino Uno board and its most important parts (Al Agha *et al.*, 2009; Schmidt, 2015).

The nRF24L01 is a chip 2.4 GHz transmitter-reciver, suitable for low power wireless applications. As shown in Fig. 9, nRF24L01 is designed for operation in the frequency band at 2.400-2.4835 GHz. To design a wireless system with the nRF24L01, simply need an microcontroller and a few external components. This radio transceiver uses GFSK modulation. It has user configur-able parameters like output power, frequency

channel and air data rate. nRF24L01 supports an air data rate of 250, 1 and 2 Mbps. The high data rate combined with two power saving modes make this transceiver suitable for low power designs (Semiconductor, 2008).

A current to voltage converter will produce output voltage proportional to the given input current as shown in Fig. 9. This circuit is required for the instrument that capable only of measuring voltages so you need to measure the current signal. A current to voltage converter is shown in Fig. 10 (Dunn, 2006). The output voltage signal range from 1 to 5 volts, although various models of controllers can use different voltage ranges and therefore require different resistor values. If the voltage range is 1-5 volts and the current range is 4-20 mA, the resistor value must be 250 ohms.
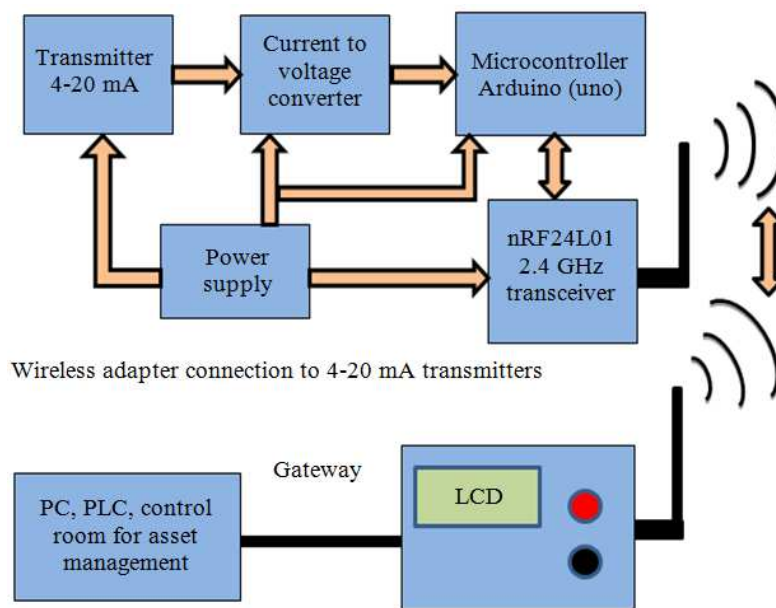

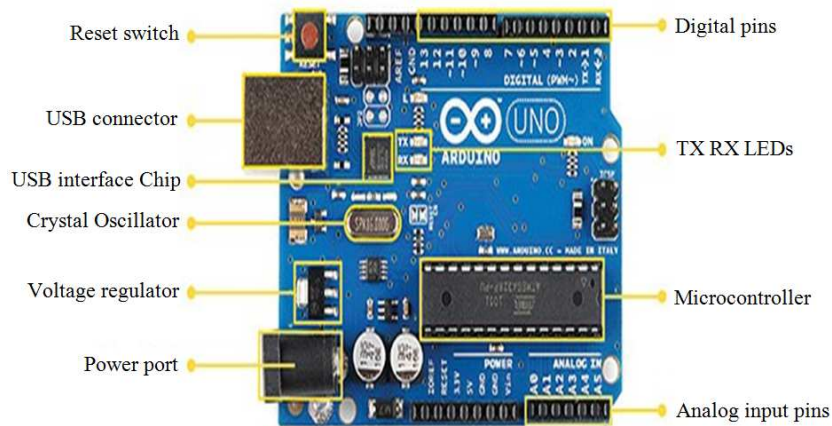Fig. 7. The design of wireless adapter with gateway device

Fig. 8. Arduino Uno board
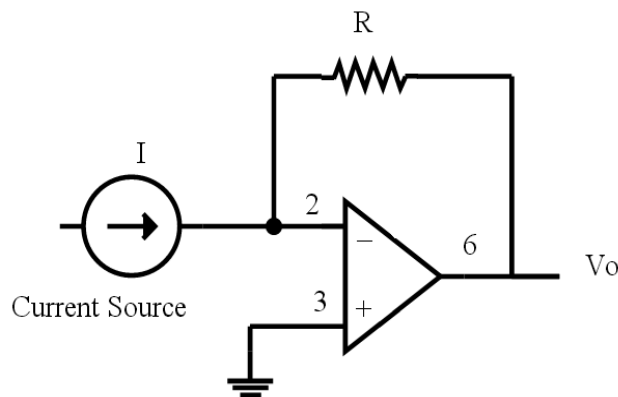
Fig. 9. nRF24L01 2.4GHz transceiver

Fig. 10. Current to voltage converter

The gateway allows communication and link between wireless field devices and host applications that connected to Serial, an Ethernet, or other plant communications network; management of the wireless field network and security.

Results

Figure 11 and 12 below show the hardware implementation prototype of wireless adapter with gateway device that can be connecting to the PC, PLC and control room for asset management. Figure 13 show the testing of the system when connected to the differential pressure transmitter (siemens type) and sonar level transmitter in the measurement lab. The features and specifications of wireless adapter has been shown in Table 1.

The experimental results of receiving data for level and pressure transmitters are shown in Fig. 14 and 15 below. As shown by the results, the adaptor transfer the value of the pressure and the level in the same time to the getway device and then display the measured value in the serial moniter.
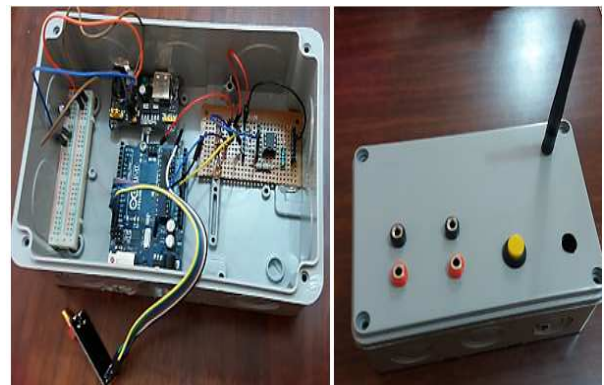

Fig. 11. Wireless hart adapter

Note that the values change with time when the process variable changed. The adaptor can sent six signals (measured value) in the same time.

WirelessHart adapter Configuration

Several Configuration for connection the adapter with field device are shown in Fig. 16-18.
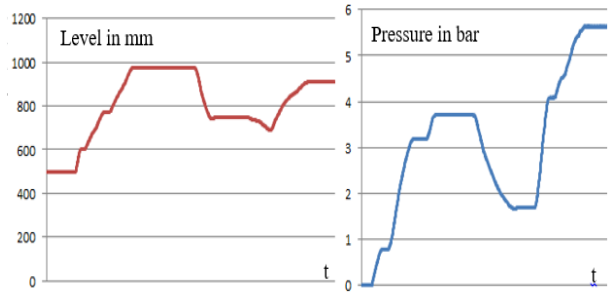
Fig. 12. Wireless gateway device

Fig. 13. Connections between dp and level transmitters and wireless adapter

Fig. 14. Serial monitor for receiving data

Fig. 15. Changing of pressure and level
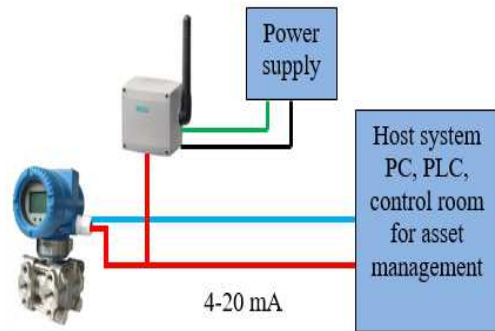

Fig. 16. Separate power supply Configuration
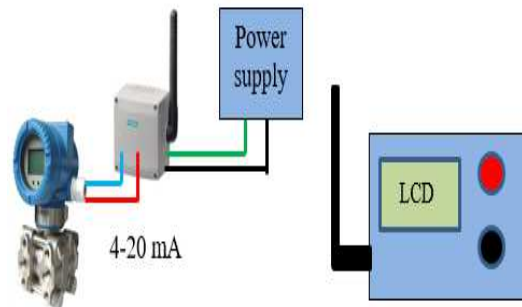
Fig. 17. Integration devices with wireless network Configuration

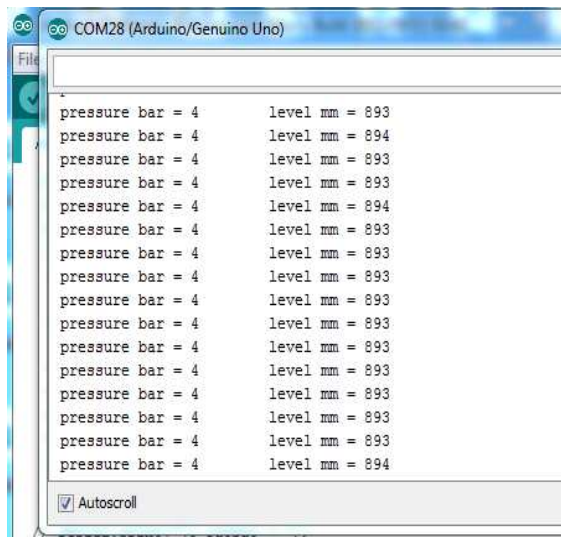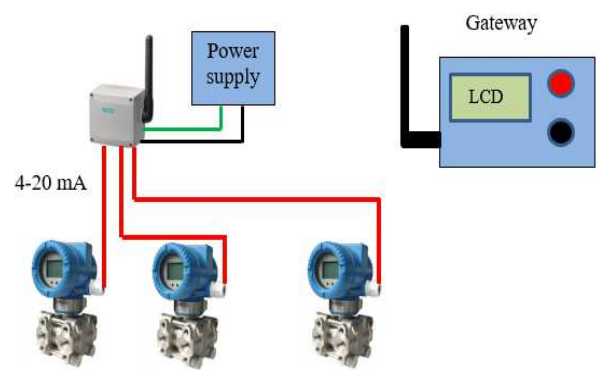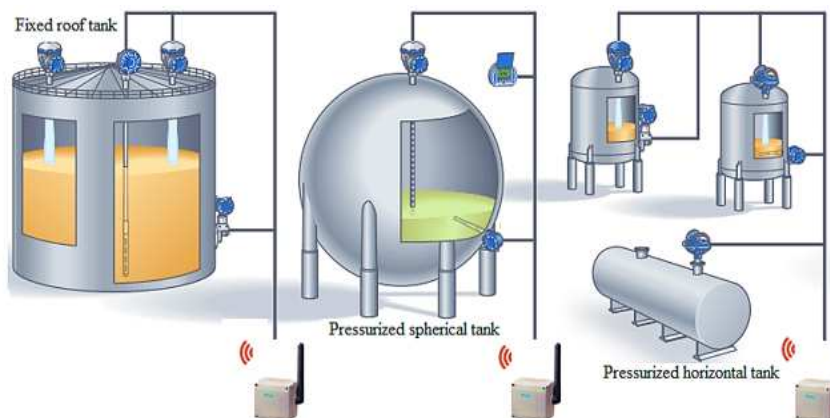Fig. 18. Several devices per adapter Configuration

Fig. 19. Tank gauging system with wireless communication

Table 1. Features and specifications

Measuring principle	Wireless adapter
Function	Intelligent Wireless interface module for connection to 4...20 mA/HART devices
Input	One point-to-point connection with a 4-20 mA device, or multi field devices can be connected.
Output	Transmission rate: Nominal 250 kBits/s frequency: 2.4 GHz Transmission range: Outdoor 1000 m, indoor 250 m
Auxiliary power supply/Loop power supply	Battery pack or 24-230V AC/DC external power or DC power unit.

Application on Tank Gauging System

Tank gauging is the measurement of liquids in large storage tanks with the purpose of quantifying the volume and mass of the product in the tanks. The oil and gas industry generally use static volumetric assessments of the tank content. This involves level, temperature and pressure measurements. There are different ways of measuring the liquid level and other properties of the liquid. The measurement method depends on the type of tank, the type of liquid and the way the tank is used. Besides precision level gauging, temperature measurements are essential in assessing tank contents accurately. All liquids have a thermal expansion coefficient and proper volume compensation needs to be applied when transferring volumes at different temperature conditions. A pressure measurement of the liquid head is often added to provide a current assessment of the average observed density and to calculate the product mass. Modern tank gauging systems digitize the tank measurement and digitally transmit the tank information to a control room where the liquid volume and mass information is distributed to users of the inventory data. Figure 19 shows the overall system when wireless adapter has been used (EPM, 2017; Assare-Mokwah, 2017).

Conclusion

The aim of this research work is to develop a method to connect the field devices to the host side or control room wirelessly. In order to achieve this, the components and subsystems have to be analyzed and validated. The designed model can then be implemented and used to do this functions. The benefits of the system are to reduce the connection costs (no wires). Process monitoring control and ability management and finally safety environmental monitoring. In addition, Implementing and testing such wireless system with the field devices in the oil company and develop host system that deals with the many wireless adapters and gateway device by Connect several field devices per one wireless adapter.

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Author's Contributions

Waleed Ishaq Hameed: Performed laboratory work, also participated in analyzing data and contributed to writing of the manuscript.

Amar Al-jzari: Participated in analyzing data and contributed to writing of the manuscript.

K. Ivica: Participated in analyzing and contributed to writing of the manuscript.

Yasir I. Abdulraheem: Contributed to writing of the manuscript.

Ethics

This work has not been published elsewhere.

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