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Real Time Instrument communication and networking Design to support the replacement of legacy sensor with smart sensor.

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***Abstract**: The need to acquire data real time is a priority in information technology system and process control industry. The acquisition of data via computer network, facilitate industrial process and enable easy measurement of industrial plant. However, it's important to have a data acquisition system that provides the flexibility to expand and change with the applications. The national instrument (NI) data acquisition systems are completely configured, so that we can choose the software, data acquisition (DAQ) devices, and signal conditioning that best fit the application needs. The priority of this paper is to replace the existing legacy sensors with a smart sensor and the integration of the smart sensor into industrial network architecture and implement a digital solution using any field bus standard protocol. The smart sensor is developed to address the problem of interfacing and communication protocol in our industries, such as; hardware interfacing wire and cable, Encoding and decoding of signal. But the foundation field bus is chosen as the industrial network solution that can provide transmission of additional device data alongside the measured value, such as status of the system and service information. More so, the foundation field bus is an industrial standard for distributed instrumentation and control (DICS) that enable digital communication within sensors and execute automatic control algorithms. The tree network topology is chosen for this design hence it can join multiple star topology into a bus that can connect Hub device to the network. The data or information obtained from the smart sensor is transmitted via the computer into a network where the information can be access by the manager or any authorise personnel.*

***Indexterms**: legacy sensors, smart sensor, network topology, foundation field bus, data acquisition, instrument communication.*

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I. INTRODUCTION

The acquisition of data real time has become very important in the information technology system and in our industry. Data transmitted to any computer network will facilitate industrial process and make easy access for measurement in industrial plants. This paper presents how an industrial conveying rig with six legacy sensor incorporated to it for the measurement of process control can be upgraded. These sensors are: load cell, pressure P1, P2, P3, differential pressure and temperature sensor. The transmitted signal of these sensors is analogue with range of current value of 4 – 20mA with wire connected to the power supply from the transmitter.

The need to use IQ intelligent smart sensor and actuator is becoming paramount in our industry, owing to it benefit. Moreover, hence smart sensor applications are gradually growing in our industries, there is need to overhaul existing legacy sensor and install smart sensor. The advantage of using the smart sensor and actuators in industrial control system has overridden the use of legacy sensor. The real time distributed instrumentation and control system (DICS) design as carried out in this paper work is aimed at acquiring data from sensors via the foundation field bus and transmit it through the local area network to respective authorised users PCs. The other aspect of this paper is sections as follows: section II is about the choice of network topology, while section III discussed the network design and applications, then section IV is sensor replacement and discussion. Finally, section V concludes the paper.

II. CHOICE OF NETWORK TOPOLOGY

The choice of network topology is very important in this design, hence it examine the configuration of computer system elements and their associated interconnection. The application of Kirchoff's circuit law with respect to nodal analysis is used for network topology technique. There are several types of network topology such as: Ring, Bus, Star, Tree and Mesh Network. However, the Tree network topology is selected for the purpose of this paper hence it has a support for feature expansion and can accommodate more systems on the network. A tree topology joins multiple star topologies into a bus in its simplest form, such that only hub device can be connected directly to the tree bus, and each hub functions as the root of the tree device. This bus/star hybrid approach support future expansion of the network much better than a bus (limited in the number of devices due to broadcast traffic it generate) or a star (unlimited by the number of hub connection points) alone. The tree network topology is a combination of a star network topology and a bus topology. The tree topology is a good choice for large network of computer and other field of instrument, since it divides the network into parts that can be easily managed. [1] Assert that the network size can be determine using equation (1) below which calculate the number of network node as a function of signal loss.

$$2*(A + B* K) \leq X \qquad (1)$$

Where: A is the signal loss at coupling device between any two buses (db), B is the signal loss at a node (db), K is the number of nodes on all parallel bus networks, and X is the difference between transmitted signal and minimum detectable signal at any node (db).

The tree network topology is developed in a way that it can make a set of star network topology to be connected to the central node which is linked directly to the bus. However, this design show how a set of star network topology is connected to the central node or hub is connected to the bus network topology, for easy communication. Meanwhile to avoid failure, an intelligent central node or hub is used. The diagram of the selected network topology is shown in figure 1, below.

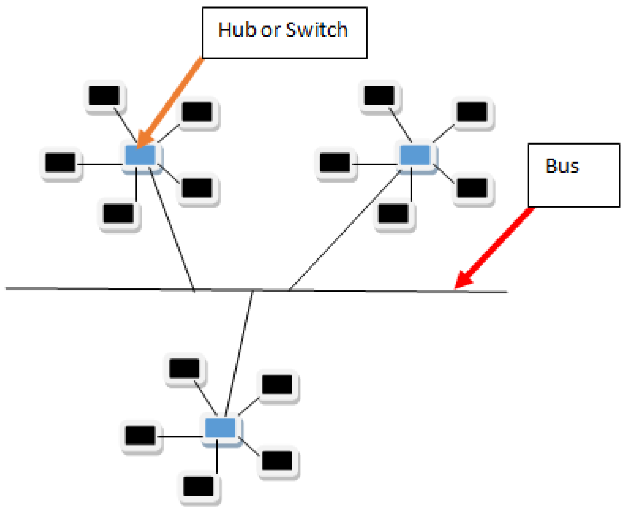

Figure 1: diagram of the star topology connected to the bus network via the hub

III. NETWORK DESIGN AND APPLICATION

The foundation field bus, a two way communication system that enable the local area network (LAN) and integrate various component of process plant equipment to existing technology with the ability to retain the feature of $4 - 20mA$ analog device, is used in this design to implement the replacement of legacy sensor with smart sensor. Field bus is use in the industry for monitoring, measurement and control of variable such as; pressure, temperature, flow rate, etc. The field bus is of great significant hence it enhances plant diagnostic and reduces the need for frequent exposure to hazardous operation area. The construction of this network as shown in figure 3 below shows how information from the smart sensors can be received on the computer via the field bus. However, figure 2 shows the block diagram of sensor analog to digital conversion.

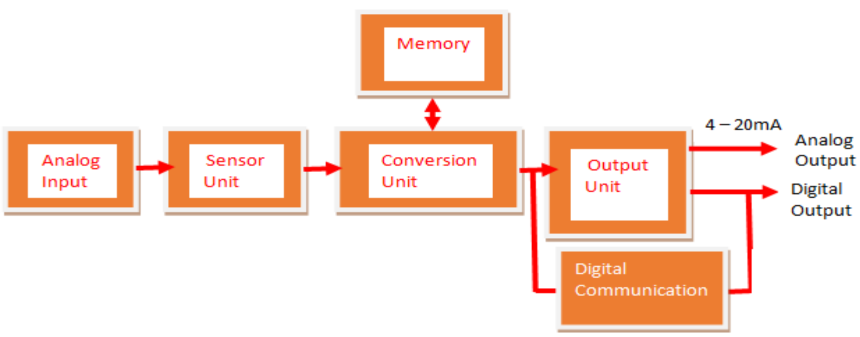

Figure 2: Block diagram of sensor unit

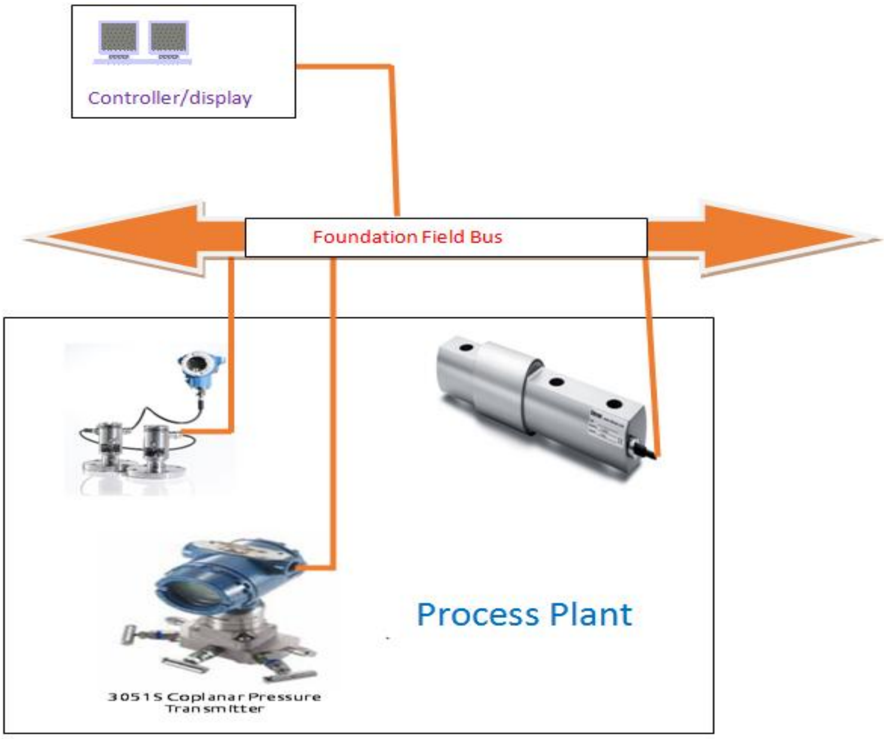

Figure 3: Process plant sensor installation

The implementation of real time networking and distributed instrumentation in the process control industry, manufacturing, and production industry is of great need. However, the network for the system must be secure to avoid hacking and or attack. [2] Assert that attack on sensor network can either be external or internal which can be active or passive. However, passive attack occur when an unauthorised person get information from the sensor. Meanwhile, this type of attack can be overcome by using encryption [3] and [4]. [5] Highlight that internal attack on individual sensor can prevent the network from useful function. The standard for smart sensor is a rule, regulation or specification that is set to lower risk and increase production. The IEEE 1451 is a set of standard which is developed to overcome some of the difficulties of incorporating smart sensor feature into transducer and to developed interoperability between components of smart sensor system. However, sensor depends on the network topology application [6]. The block diagram of the design is shown in figure 4 below, while the complete architecture is shown in figure 5.

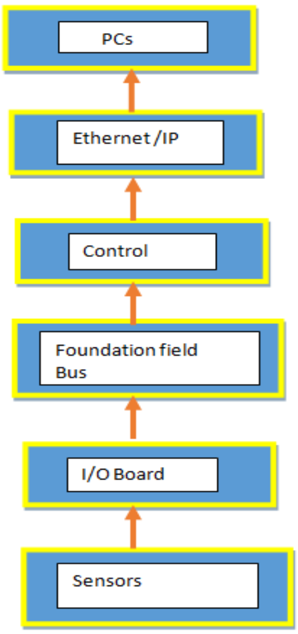

Figure 4: The foundation field bus network block diagram

The foundation field bus is an intelligent system with High Speed Ethernet (HSE) open command interface for access to the server and all H1 and HSE data available on the server and also application package that gives information to the manager information systems (MIS). However, the server provide the platform for application package such as; HMI, configuration, diagnosis, etc. The foundation field bus subsystem integration has a communication between control level and linking device H1 field level with quick data exchange and high performance control back bone of (100Mbit/s) and has standard accessories and cable with HSE device redundant and interfaces. It also has a standard function block plus flexible function block.

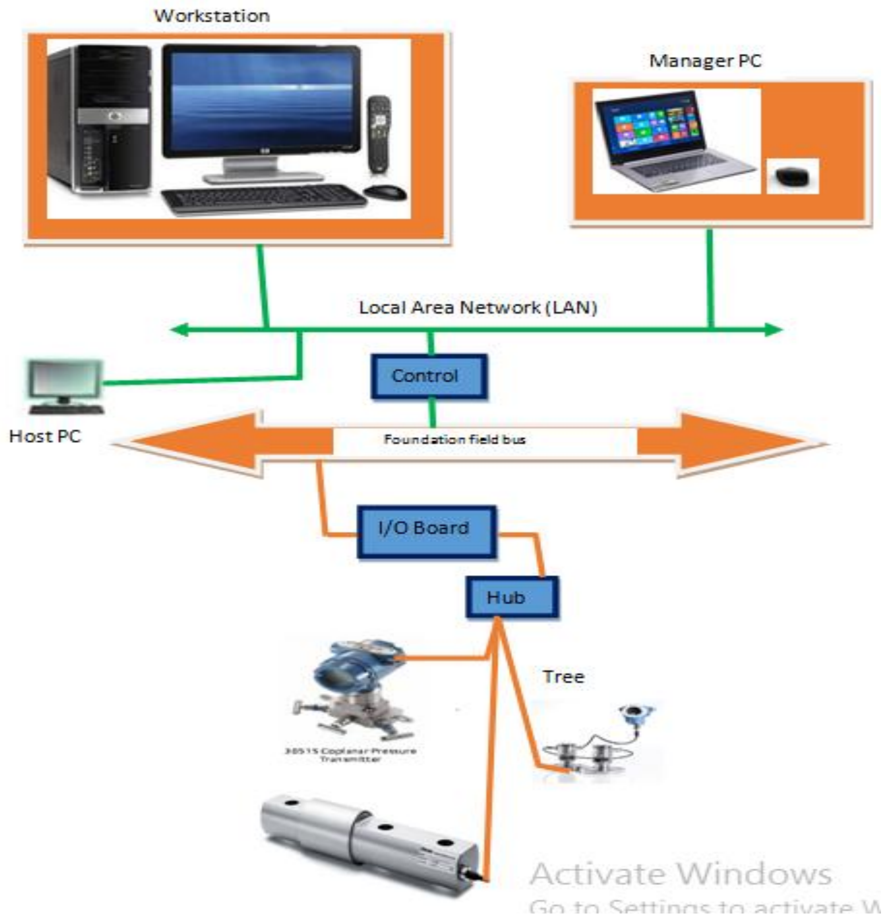

Figure 5: Real time instrument communication and networking architecture

The foundation field bus installation of figure 5 above used the tree topology network. However, the tree topology used in this design, consist of a single segment connected to the hub which is connected to the input/output board that is connected to the foundation field bus.

IV. SENSOR REPLACEMENT AND DISCUSSION

The smart sensor that is very effective and highly reliable, and has the ability to measure several conditions (load cell, differential pressure, and temperature) is used to replace the legacy sensor as implemented in figure 5. The type smart sensor incorporated in this design includes:

(a) DIGITAL LOAD CELL SMD70 SYSTEM: the digital load cell SMD70 system of the bending beam or the share load cell are probably the most commonly used load cells as they are extremely versatile and can be used in wide variety of application. They are particularly suitable for incorporation into weighting instrumentation, such as scale dynamometer and tensile testing machines. This load cell ranges up to 300kg and is environmentally sealed to IP68 with high accuracy.

(b) PRESSURE TRANSMITTER: the Rosemount 3051S coplanar pressure transmitters are use in the industry for pressure measurement. The coplanar platform allows seamless integration with manifolds primary elements, and seal solution with 4-20mA wireless foundation field bus.

(c) DIFFERENTIAL PRESSURE: the differential pressure smart sensor (Endress+Hauser FMD 71dp) level transmitter is incorporated in this design. The Delta bar FMD71 level transmitter is of two pressure sensor modules, that is connected electronically to a single transmitter, using a Ceraphire ceramic sensor in the pressure sensor modules, the transmitter calculates the differential pressure from both sensors and transmits the level, volume or mass via 4-20 mA with HART as a standard two-wire loop-powered device.

The existing legacy sensor and their ideal smart sensor as use in this design is provided in table 1 below.

	EXISTING LEGACY SENSORS		REPLACEMENT SMART SENSORS		
S/N	DEVICE	DESCRIPTION	REPLACEMENT	DESCRIPTION	QUANTITY
1	Load cell	I/P Range of 0- 200kg Analogue of 0-10V	Eilerson Digital load cell SMD70	MD (converter to foundation fieldbusPA/foundation field bus transmitter model SMD70)	1
2	Pressure sensor	I/P Range of 0-10bar, Analogue O/P of 4-20mA	Rosemount 3051S coplanar pressure transmitter	Foundation fieldbus functionality, O/P of 0.98 to 20.7bar	3
3	Differential pressure sensor	I/P Range of 0-100mbar,Analogue O/P of 4-20mA	Endress+Hauser differential pressure delta bar FMD71	O/P of 100-100mbar Hart or in tensor profibus protocol and foundation field bus HI	1
4	Temperature sensor	I/P Range of 100 deg C, Analogue output of 4-20mA	Endress+Hauser iTEMP TMT84 temperature transmitter	O/P is foundation field bus of Range 200- 850ºC	1

Table 1: existing legacy sensor with the ideal smart sensor

The complete real time instrument communication and networking architecture as shown in figure 5, demonstrate how the smart sensors (Load cell, pressure transmitter, and temperature transmitter) are install using the tree topology network and hub it via the input/output board to the foundation field bus. The foundation field bus acquires information from each sensor and transmits it through the control unit to the local area network (LAN). The sensors information can then be access by the authorised users (work place, manager, etc.) with the aid of an IP address.

V. CONCLUSION

The study and research conducted proves so glare that the legacy sensor need to be replaced with a smart sensor that can be integrated to the foundation field bus network architecture as discuss in this paper. Meanwhile, the smart sensor gives precise information and is less time consuming. The smart sensor is in compliance with the foundation field bus that can transmit information via a network as shown in figure 5.The foundation field bus reduces instrument wiring; also, the foundation field bus integration with smart sensors reduces cost. More so, smart sensors saves time, and actually facilitate rapid production with enhance efficiency, high accuracy and precision. The design of the network architecture and replacement of the legacy sensor with the smart sensor that can communicate with the foundation field bus is carried out successfully in this paper.

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