The Design of Wireless Sensor Network for Real Time Remote Monitoring of Oil & Gas Flow Rate Metering Infrastructure

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Abstract: This research work described the design of wireless sensor network for real-time remote monitoring of oil & gas flow rate metering infrastructure. The network includes flow sensor, pumping machine, Microcontroller, WiFi and a database server. The pumping machine pumps the oil & gas then a flow sensor monitor's the flow rate and remotely report the data wirelessly to the database server for further processes, the resulting data is store on the database server in form of a real time data which can easily be access in order to know the amount of oil & gas being lifted without seeking to collect the data from the several stations manually. This system maintained near real-time visibility of flow rate measurement data; regardless of where the oil well are located and allows for inexpensive monitoring of oil and gas lifting in order to checkmates corruption in the oil and gas industry through transparency and accountability.

Keywords: Wireless sensor network, Flow rate monitoring, Pumping machine, Metering infrastructure

1. Introduction

A Wireless Sensor Network is an infrastructure comprised of sensing (measuring), computing, and wireless-based communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment. The environment being monitored can be the physical world, a biological system, or an information technology (IT) framework while the administrator is usually a civil, governmental, commercial, or industrial entity [11]. The four basic components in a sensor network are: an assembly of distributed or localized sensors, an interconnecting wireless network, a central point of information clustering; and a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining [1]. Nodes in the sensor network typically have one or more sensors, a radio transceiver or other wireless communication device, a small microcontroller and an energy source, usually a battery [1].

Wireless technology has the potential to be beneficial in many regards. Eliminating the need for cables can contribute to reduced installation and operating costs, it enables installations in remote areas, and it allows for cost efficient, temporary and mobile systems. In addition, wireless technology enables a new range of applications; particularly in the area of health, safety and environment. Networks may be composed of many different types of sensors such as seismic, thermal, visual, acoustic, radar, magnetic, infrared, and many others which are able to monitor a wide variety of ambient conditions such as: Environmental weather conditions, Pressure, Temperature, Gas, Fire, Sound, Humidity, Vibration, Electrical characteristics, Mechanical stress, Soil makeup, Object movement, Presence or absence of objects, Speed, direction, and size of an object, Location etc. Beside of monitoring and managing applications, the ambient monitoring sometimes is extremely necessary to the human and environment safety. For Oil & Gas Industry, the most common and important applications are related to the monitoring of real-time process control, safety, maintenance and production performance [10],[8].

2. Literature Survey

Single and two-phase flow characterization using optical fiber Bragg gratings (FBG): uses hydrodynamic pressure applied by the liquid or air/liquid flow to the optical fiber induces deformation that can be detected by the FBG; given that the applied pressure is directly related to the mass flow [2], It is easy for unauthorized people to disable the monitoring system by cutting the network wires and it is difficult to locate the position of the fault in a wire. Enabling Interoperability and Extensibility of Future Supervisory Control and Data Acquisition (SCADA) system: uses satellite communications which is very expensive to operate and maintain, complex to install, large and requiring significant space to install, requiring significant amounts of power to operate and unreliable in harsh weather, the system involves network collecting data from equipment sensors that transmit and receive data with a distant control center [12].

Therefore, in this research work, our main focus is to design a system prototype of a wireless sensor network which can comfortably monitor's the flow rate of the oil & gas in a real time, calculates the amount being lifted and remotely send the data to a database server which can be easily access in order to get the detail records of the oil lifted for a period of time.

3. Problem Definition

1) The issues of transparency, accountability and lack of effective oversight of oil lifting by the Nigerian National Petroleum Corporation [14].

- According to the Nigeria Extractive Industries Transparency Initiative (NEITI) audit report, one of the biggest challenges in the Nigeria oil & gas sector is the absence of metering infrastructure for measuring the quantity of crude oil flows from wellheads to export terminals [15].
- 3) Monitoring the flow rate of oil and gas manually has a high cost of operation associated with sending technicians to the remote sites to check the status of flow meters data at all well sites to maintain an accurate picture of it. Thus leading to the stigma of being expensive to operate and maintain.

3.1 System Overview

This research work would help in providing the means for harnessing the economic opportunities in the oil and gas sector. Through a metering infrastructure that has the capacity of monitoring the flow rate of oil and gas lifting's from wellheads to export terminals, and allow access to the data to provide transparency and accountability in managing it. Cost-effective indices for reporting the management of our oil & gas, is of significance to any accountable and transparent system. Manual processes however have not been able to fill this gap. As a need for urgent and reliable approach, a real-time system approach could be the most immediate solution; which is the focus of this work.

3.1.1. Remote Monitoring

The wireless sensor network (WSN) solution provides remote monitoring capabilities for oil and gas companies to meet this new technology, regulatory and production demands. Remote Monitoring solutions for oil and gas applications can greatly reduce, and in some cases, eliminate maintenance costs [10]. Due to the rate of production and the cost of the product, these platforms require continuous operation for maximum productivity. Example Oil & Gas Remote Monitoring applications: flow rate monitoring, Pipeline Integrity Monitoring, Tank Level Monitoring, Pipeline Pressure Relief Valve Monitoring, Refineries Pressure Relief Valve Monitoring and Wellhead Automation & Monitoring [1],[10].

4. System Architecture and Operational Framework



Figure 1: Block diagram of the system architecture

4.1 Component Selection

Several factors were considered when selecting hardware components. The first consideration was the selection of the component package to use for each part. Most of the electrical components in my design were selected in a surface mount package. This reduced the foot print required for each component and the overall space required on the printed circuit board. The power and voltage rating for each of the components was considered to make sure that none of the components would become overstressed during use. Finally, cost and availability were considered; several of the components unit sections are as follows:

- 1) Power supply unit,
- 2) DC pumping machine unit,
- 3) System unit,
- 4) Display unit,
- 5) WiFi module,
- 6) Web server unit.

4.1.1. Power Supply Unit

In our design, the power supply unit consists of three stages as shown in



Figure 2 below. The first stage is the 12V battery connected to a diode to allow only a one way flow of voltage into the circuit, stage two is the regulated voltage of 5V and the third stage is the 3.4V which is use to power the WiFi Module and was obtained from the four diodes connected in series an; each have a 0.4V dropdown i.e cumulative voltage drop down of 1.6V.



Figure 2: Circuit diagram of the system power source

4.1.2. Driver of the DC Pumping Machine

One of the most fundamental applications of a transistor is to use it as an electric switch to control the flow of power to a circuit or motor. At it cut off mode and saturation mode it can create a binary OFF/ON effect of a switch and the base terminal of the transistor controls the ON/OFF states of the transistor depending on the voltage applied to it. When the current flowing through the base of the first transistor in the circuit below is zero it turns it OFF and the R9 resistor pulls up to the 12V to allow the flow of current through the base of the second transistor to turn it ON. Current flows freely from the collector to the emitter connected to the ground and so there is a zero current flowing through the base of the third transistor; metal oxide field effect (MOSFET), turning it OFF putting the driver's device mode on switched OFF and the reverse case will put the driver's device mode on switch ON as shown in Figure 3 below.



Figure 3: Driver circuit of the DC pumping machine

4.1.3. System Unit

The idea behind this system design is to monitor the flow. rate per unit time (volume) of oil & gas in real time and essentially save the data on a server. Some of the features in the system unit include a WiFi with a combination of MRF24WBOMA and MCW1001 which support IEEE standard 802.11 and IP services. The MRF24WBOMA RF transceiver module contain integrated PCB antenna with range up to 400m. The WiFi plus click does not use the memory resources of the target microcontroller for TCP/IP stack operations, which makes this module the best choice for using with wide range of different microcontrollers; and it communicates with target board via UART interface. The flow sensor monitor's the flow rate in form of an analog output, which is converted to a digital form using analog to digital converter (ADC) in the microcontroller and a liquid crystal display (LCD) is connected to the microcontroller to display the results from the microcontroller which collect the value of the flow rate and send via Wi-Fi to the server, where it is being stored in a database. Also, the microcontroller is the heart of the whole system, it receives digital signals equivalent to the quantity of the oil measured from sensor connected to it through a conversion processes pre-programmed instructions written in C language to ensure that corresponding measurement made by this sensor are available in forms that are meaningful and useful for human analysis, interpretation and record.

The receiver section consists of a personal computer system (PC) using .net process web server running in the system being responsible for receiving all the acquisition terminal data and according to the area code sets all data in the database. The WEB server functions system adopts base station structure with a PC terminals service program which is used for accessing the server to obtain a latest data of each district at anytime and anywhere dynamically as soon as possible. The Display unit is an output of the microcontroller (PIC16F877A), it's a 16 x 2 LCD display capable of displaying different characters and symbols of the measured data. This LCD is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector, it is often utilized in battery powered electronic devices because it uses very small amounts of electric power.

The flow sensor connects to the outlet of the DC pump machine through a pipe and is plug to a 5V, it's used to monitors the oil & gas flow rate and pass to the microcontroller which take in as an analog pulse signals from flow sensor and converts it into digital signal for further processes. The microcontroller then reads the measured signals, calculates, displays the result on the LCD display and reports the data remotely to the database server the wireless network (WiFi). through Also. the microcontroller also has the capability of controlling the pumping machine by either decreasing it speed by the switch connected to Ra0 or incrementing it by the switch connected on Ra1 and the switch connected to Ra2 and Ra3 are used to clear the EEPROM menu which hold data and to activate it respectively. The power supply block regulates the 12V from the battery power source to a 5V which is needed to power the microcontroller, flow sensor and the LCD display. The DC pump machine is power by 12V from the battery, while the wireless network (WiFi) module power by 3.4V. The layout of the functional blocks diagram of the system architecture is shown in Figure 1 above and the functional circuit diagram of the system is as shown in Figure 4 the below.



Figure 4: Circuit diagram of the system

4.2 Software Development for Sensor Node

Sensor node software in particular lends itself well to an iterative form of development. As with any real-time embedded system, the code must be optimized to perform within certain parameters. Due to the sensitivity of the performance, efficiency, and lifetime of a wireless sensor network (WSN) to the algorithms controlling network configuration, an iterative design, implementation, and test phase is required [5]. Since the applications of wireless sensor networks (WSNs) vary so greatly, the algorithms involved in a specific type of WSN must be optimized through a large amount of calculation and design. The development pattern for node application suggested in favor of the highly iterative design pattern. The design method closely follows standard software engineering practices of node's component interface optimization performed during

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the design stage show in Figure 5 below. Evaluation through the monitoring of results leads to additional iterations. The development pattern results in a specific application for the node comprised of specially tailed parts. This design process can also be done for more nodes to obtain an integrated wireless sensor networks in hierarchical cluster-based architecture with intrusion detection system (IDS) as another defensive- security level to the wireless sensor networks security infrastructure which it can detects unsafe activities and unauthorized login/ access; and when attacks occurred, even new attacks such as anomalies; it can notifies by different warnings and operates required actions(mainly predefined actions) [7].



Figure 5: Node Software Development Process

4.2.1 Flow-Rate Analysis

The flow sensor is an electronic and computational device which drives and monitors the flow-rate and which calculates the measurement data [6].

It was noted from the datasheet that; the flow sensor which was used in the design has a frequency giving as:

$$C = C \times Q \times T$$
$$Q = \frac{F}{C \times T}$$

Where: F = frequency measured in Hertz,

F

C = constant variable,

T = time measured in second,

Q = volume of flow rate measured in Litre/Minute.

The output signal is giving as 450 Pulses/Litre.

Therefore, frequency is giving as 450 Pulses/Second and the flow range = 1- 60Litre/Minute.

The overall wireless sensor network (WSN) system architecture for a single node and multiple nodes is shown in the Figure 6 and Figure 7 respectively below.



Figure 6: The proposed wireless sensor network system architecture diagram of a single node.



Figure 7: The proposed wireless sensor network system architecture diagram of multiple nodes

5. Conclusion

This research work describes a real time system of oil and gas flow rate remote monitoring of daily production over a wide network of oil and gas sites. It uses a sensor to monitor the flow rate, displays the data records from a microcontroller on a liquid crystal display (LCD) and remotely sends to a database server via a wireless network. The result is displayed in a real time through a computer user interface, which can be accessed by the stakeholders or any authorize users. Thus, limited information can also be accessed on an opened source on the website online by the publics. This system provided a metering infrastructure for measuring the quantity of oil from wellheads to export terminals to improves transparency and accountability for oil and gas lifting's. It reduces the costs associate with sending technicians to remote sites to check the status of oil and gas flow rate monitoring.

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