IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Volume-2, Issue-4 E-ISSN: 2347-2693

Oil Well Health Monitoring and Intelligent Controlling Using Wireless Sensor Network

Sharmila.R[1*],Suganya.A[2] and Gnanavel.G[3]
[1*,2,3]*Department of EEE, Anna University, India*

www.ijcseonline.org

Received: 09/03/2014 Revised: 29/03/2014 Accepted: 22/04/2014 Published: 30/04/2014

Abstract — Most oil pumping units (OPUs) have been using manual control in the oilfield. This existing oil- pumping system has a high power-consuming process and has incapability's of OPU's structural health monitoring. Due to the environmental conditions and remote locations of oil sites, it is expensive to physically visit for maintenance and repair. This paper develops a sensor network based intelligent control is proposed for power economy and efficient oil well health monitoring. The system consists of several basic sensors such as voltage sensor, level sensor, MEMS sensor, temperature sensor and gas sensor. The sensed data is given to the ARM controller which processes the oil wells data and it is given to the oil pump control unit which controls the process accordingly. If any abnormality is detected then the fault is informed to the maintenance manager. The malfunction is sent as an SMS to the manager's mobile via GSM.

Keywords- OPUs, MEMS, Wireless Sensor Networks

I. INTRODUCTION

In the last few years, deployed sensors have worked effectively together via wired cable links. These wired sensors are costly to deploy, operate and maintain, are not best suited for temporary installations and are difficult to set up in hostile and remote environments. Wireless Sensor Network (WSN) technology provides a faster, less costly, more flexible and more convenient option to the wired sensor systems. The field of WSN has evolved considerably due to engineering advances in Micro-Electro-Mechanical Systems (MEMS) technology which facilitated the development of smart sensors with reduced size, weight and cost. Advances in the field of internet, communications and information technologies have also contributed to development of WSNs. They project that there will be nearly 24 million wireless- enabled sensors and actuators deployed worldwide by 2016 and WSN technology would have a greater influence on applications. Wireless sensor networks consist of large amounts of wireless sensor nodes, which are compact, light-weighted, and battery-powered devices that can be used in virtually any environment.

Due to the energy constraint of individual sensor nodes, energy conservation becomes one of the major issues in sensor networks. In wireless sensor networks, a large portion of the energy in a node is consumed in wireless communications. The amount of energy consumed in a transmission is proportional to the corresponding communication distance. Therefore, long distance communications between nodes and the base station are usually not encouraged. One way to reduce energy consumption in sensor networks is to adopt a clustering algorithm. A clustering algorithm tries to organize sensor nodes into clusters. Within each cluster, one node is elected as the cluster head. The cluster head is responsible for: 1) collecting data from its cluster members; 2) fusing the data by means of data/decision fusion techniques; and 3) reporting the fused data to the remote base station.

The rest of the paper is organized as follows: The detailed proposed system is given in section II, system description in section III, development of IS in section IV, description of THS is shown in section V, and finally conclusion discussed in section VI.

II. PROPOSED SYSTEM

In this paper, a sensor network based intelligent system is proposed and applied for remote oil well health monitoring and automatic oil-pumping control. The motivation of developing this system is that 1) due to the special nature of oil exploration and oil drilling, the majority of oil pumping units (OPU) are spread over barren hills, mountains and deserts, and 2) the existing oil- pumping systems still adopt manual control. Existing manual control systems have three evident drawbacks: 1) The OPU administrators have to frequently go to the oilfield to check the OPU status and collect its health analysis data. 2) Power consumption for OPU is huge during the oil pumping process.3) Since an administrator has to take charge of a number of oil wells, an OPU malfunction is difficult to locate and repair in a reasonable time, which causes an oil production drop.

To overcome these three disadvantages of the existing manual control system, a sensor network based automatic control system is proposed for CPU management and oil well health monitoring. This proposed system consists of three-level sensors: the first level sensors (FLS), the intelligent sensors (IS) and the third level sensors (TLS). A set of FLS, i.e., five sensors, are commonly used for an oil well's data sensing, which includes oil level sensor, temperature sensor, a gas sensor, a voltage sensor, a current sensor and an MEMS sensor. The IS is developed mainly

Corresponding Author: *Sharmila. R*
Department of EEE, Anna University, India

for an oil well's data elementary processing, typical data storage/indication, data/status transmission up to the TLS and command transmission down to the OPU motor. The software- defined (SD) TLS is designed for hundreds of oil well's data storage/management, data processing, malfunction diagnosis; oil pumping stroke-adjustment command transmission down to a specific IS for power economy andb the malfunction report to the maintenance staff via global system for mobile communications (GSM) short message service.

III. SYSTEM DESCRIPTION

The proposed system is comprised of developed TLS, each of which wirelessly communicates with hundreds of IS. Each IS is designed with the capability of data transferability with a set of FLS, its adjacent IS and its corresponding TLS as well as the capability of command transmission down to its OPU motor. Each group of FLS, including a temperature sensor, a gas sensor, a voltage sensor, a current sensor and an oil pressure sensor, are used for data sensing from an OPU, which convert all measurements into electrical signals and then transport them into its corresponding IS.

The developed IS having the following features:

- Setting of oil well static parameters: manual input, edition and interface indication;
- Reception, storage and indication of sensing data from FLS;
- Elementary processing of sensing data, such as calculating the maximum value, the minimum value and the average value, etc., or such as calculating the active power, the reactive power and system efficiency of the current OPU, etc.;
- Significant malfunction detection and indication/alarm based on the elementary processing of data, such as short circuit, missing phase and over current;
- Relay protection: the power will be cut off when the phase is missing or over current occurs;
- Relay data/status transmission from another IS to FLS when there is a communication failure between another IS and FLS;
- Receiving TLS command and transmitting it to OPU motor for stroke adjustment and power efficiency.

On the other hand, the capability of the developed SD TLS can be summarized as follows:

- Storage (using database) and indication of data from all IS, where data commonly consists of OPU static parameters, significant malfunction reports, sensing data and elementary processing data;
- Conducting a regular data request on all its IS every eight hours via a developed wireless communication protocol, where all IS, one after another, transmit their data to TLS;
- Further data processing for recommending/transmitting the optimal pumping stroke to the IS for power economy as well as more oil production;
- Sending the detected oil well malfunction out to the maintenance staff using GSM SMS.

IV. DEVELOPMENT OF IS

A. System Description of IS

A group of FLS in our proposed system consists of a temperature sensor, a level sensor, a voltage sensor, an oil level sensor, a MEMS sensor while the IS mainly contains two components: the designed control board and the frequency converter. Five kinds of sensing data from FLS are imported to it IS. The IS usually transmits oil well static parameters (At the initial stage), significant malfunction reports (if necessary), dynamic sensing data and elementary processing data directly to the TLS. As a special case, when the wireless communication between the IS and the TLS fails, the IS sends data to its adjacent IS for relay transmission up to the TLS.

On the other hand, when acquiring a pumping stroke adjustment command from the TLS, the control board executes this command by transporting the corresponding control logic down to the frequency converter, which has the capability of changing power frequency as well as the OPU's pumping stroke.

B. Design Diagram of IS

Fig. 1 shows the block diagram of the proposed IS. The IS consists of the following five modules: a central processing unit (CPU) module, a sensing module, a relay protection module, a wireless communication module and a user interface module.

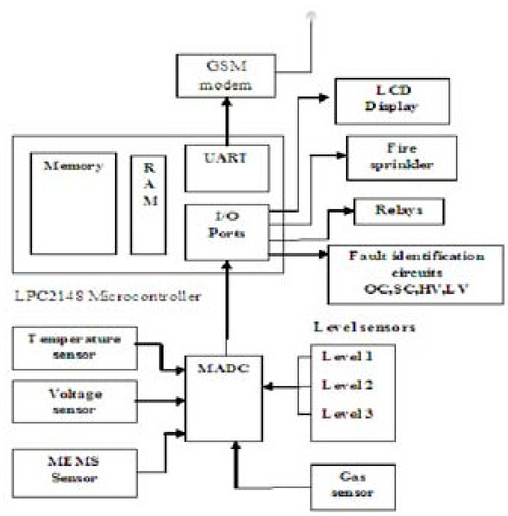


Fig.1. Block diagram of IS

1) CPU Module:

The CPU in our system is the ARM LPC2148 microcontroller based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine microcontroller with embedded high speed flash memory ranging from 32 kB to 512 kB. Serial communications interfaces ranging from a USB2.0 full-speed device, multiple UARTs, SPI, SSP to I2C-bus and on-chip SRAM of 8 kB up to 40 kB.32-bit timers, single or dual 10-bit ADC, 10-bit DAC, and PWM channels. Evidently, this module, i.e., CPU, is in charge of all data analysis and processing for all I/O ports.

2) Sensing Module:
Sensing module contains a temperature sensor, a gas sensor, a voltage sensor, a current sensor, an oil level sensor. This temperature sensor is employed to measure temperature of the oil well. The gas sensor is used to detect the pipeline leaks in the oil well. The voltage sensor and the current sensor are to measure the instantaneous voltage and the current of power supply, respectively. The level sensor will check the level and send the data to the microcontroller based upon the level it ON and OFF pump

3) Relay Protection Module:
Relay protection module consists of a circuit breaker, a contactor and a connection circuit. This module is used for detecting the motor operation by analyzing sensing data from the voltage sensor and the current sensor. Once a malfunction, such as a short circuit, a phase missing or an over current, occurs on the motor power, relay protection module will immediately cut off the power supply.

4) Interface Module:
Interface module includes 4*4 keyboard, 128 64 LCD, indicator lights, a buzzer, power switch, start button and stop button. This module is the interface between staff and IS, by which OPU can be started or stopped, the stroke of OPU can be changed, OPU parameters can be preset, sensing data can be inquired and the malfunction information can be acquired.

5) Wireless Communication Module:
GSM module is used for wireless transmission between third level sensor and intelligent sensor. Sensing data and OPU parameters are sent to network center by using this GSM module.

C. Embedded Software Development of IS
The operating system (OS), a preemptive real- time multi-tasking OS, is utilized as a platform for the IS embedded development. Once the CPU chip powers up, both the development. Once the CPU chip powers up, both the hardware initialization and the software initialization are executed. After OS system initialization, the kernel dispatches tasks to be implemented.

The proposed IS, embedded software development for the CPU contains 4 tasks and 4 interruptions.4 tasks consist of sensing data collection from FLS, data elementary processing, significant malfunction scan and user interface response. Sensing data collection indicates collecting dynamic sensing data and automatically storing these data in the IS. Data elementary processing means to process the raw sensing data to acquire the required typical data, such as the maximal/minimal/average value, the active/reactive power and the system efficiency, etc... Significant malfunction scan is to detect the severe malfunctions, such as short circuit, missing phase and over current, and report them. Also, the user interface is in charge of the external input, the maximal oil production with optimal power efficiency. Therefore, the optimal pumping stroke is obtained by maximizing the oil production or the system efficiency.

Furthermore, Fig.2 lists all 4 interruptions, including timer interruption, A/D interruption, communication interruption and keyboard interruption. Timer interruption is to precisely control sampling rate. A/D interruption guarantees the sampling process. Communication interruption is used for data wireless transmission to other sensors and for data/command reception from other sensors. Keyboard interruption guarantees that the external input can be responded to in time.

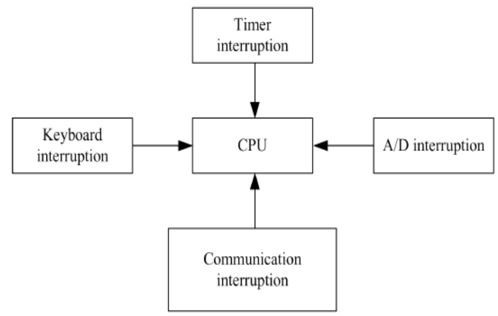


Fig.2. Interruptions

V. DEVELOPMENT OF TLS

A. System Description of TLS
This subsection aims at clarifying the connection between the TLS and its radio station, i.e., GD230V-8, as well as its GSM module. As shown in Fig. 2, the TLS includes three components: 1) a user interface for interaction; 2) some embedded algorithms for wireless communication between the TLS and the IS, a regular data request on all managed IS, a malfunction diagnosis, a pumping stroke adjustment and GSM SMS; and 3) a database for data storage. The wireless data, usually including dynamic sensing data and significant malfunction reports for one specific OPU, is acquired via the communication protocol and is then stored in its database. After thorough malfunction detection in the TLS, once a malfunction is identified, it is immediately sent to the maintenance staff via a GSM AT command, which generates a corresponding short message transmission. Furthermore, after a thorough data processing, if one OPU needs a different pumping stroke to improve power efficiency or increase oil production, a pumping stroke adjustment command will be sent down to its IS, by which the corresponding OPU's pumping stroke can be changed

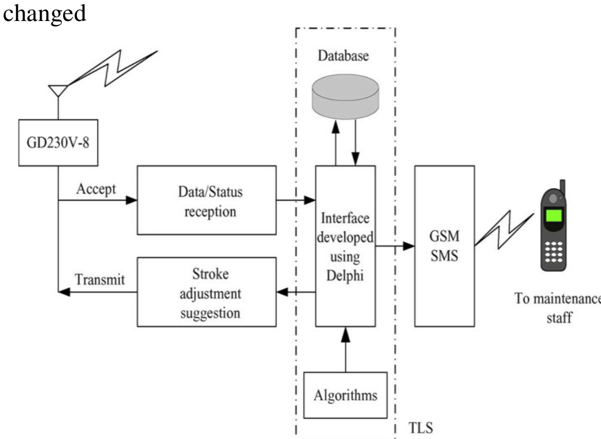


Fig. 3.System description of the

TLS. B. Malfunction Diagnosis

The paper considers the 9 most important oil well malfunctions , including (1) underground oil shortage, (2) gas effect, (3) oil pump on the touch, (4) oil pump under the touch, (5) wax deposition, (6) pumping rod broken off, (7) plunger stuck, (8) oil pump serious leakage and (9) no malfunction.

C. *Pumping Stroke Adjustment*

Pumping stroke adjustment is another significant feature the proposed sensor network based automatic control system can offer. The OPU is a huge power- consuming device and automatic pumping stroke adjustment may save a considerable power. Due to the constraint of the motor belt, the OPU s pumping stroke availably ranges from 2 to 10. The recommended pumping stroke always leads to an optimal performance for maximal oil production with optimal power efficiency.

D. GSM SMS

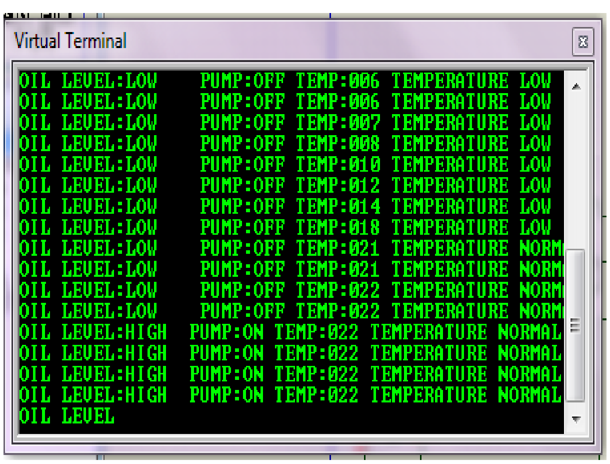
Short Message Transmission Using AT Commands

There are two modes for short message transmission of the Siemens GSM module TC35i: TEXT mode and PDU mode. TEXT mode is for English SMS while PDU mode has capability of both English SMS and Chinese SMS. Both modes utilize the AT commands for short message communication. The PDU mode is selected for our application. The entire short message transmission consists of four steps: 1) setting the telephone/cell phone number of the short message center using the command: AT+CSCA, 2) changing to the PDU mode using the command: AT+CMGF, 3) encoding the short message to PDU code; and 4) sending the whole PDU code using the command: AT+CMGS.

Malfunction Transmission via GSM SMS

The malfunction transmission to the related maintenance staff is accomplished using GSM SMS which calls the sub function of GSM short message transmission using AT commands. Once the OPU malfunction is identified, the COM1 port is then continuously checked until it is idle. Furthermore, calling the sub function of GSM short message transmission sends the OPU malfunction name to all maintenance staffs one by one.

Simulated result



VI. CONCLUSION

In Oil industry, a safety and efficiently operation depends of a constant monitoring and management of a range of parameters and a variety of ambient condition, like temperature, pressure, vibration, gas, fire, tank level, gas leakage, equipment condition, mechanical stress, object speed, etc. WSN technology introduces significant benefits in cost, ease of deployment, flexibility and convenience in relation to the wired alternative that is well established in the industry. Significant research points to projection of widespread deployment of WSN in industrial automation. The use of wireless sensor network reduce maintenance and installation costs and unplanned system failure, give the possibility to access and control remotely in dangerous environments. The use of energy harvesting improves these benefits to provide a self-powered solution. Because of these characteristics, WSN systems using energy harvesting became a feature commonly adopted in Oil & Gas industry. The proposed system oil well health monitoring and control based on WSNs is verified with different levels of severity.

References

[1] T. Becker, M. Kluge, J. Schalk, K. Tiplady, C. Paget, U. Hilleringmann,and T. Otterpohl, "Autonomous sensor nodes for aircraft structural healt monitoring," *IEEE Sensors J.*, vol. 9, no. 11, pp. 1589–1595,Nov. 2009.

[2] M. J. Whelan, M. V. Gangone, and K. D. Janoyan, "Highway bridge assessment using an adaptive real-time wireless sensor network," *IEEE Sensors J.*, vol. 9, no. 11, pp. 1405–1413, Nov. 2009.

[3] C. Cheng, C. Tse, and F. Lau, "A delay-aware data collection network structure for wireless sensor networks," *IEEE Sensors J.*, vol. 11, no.1, Apr. 2011.

[4] Q. Ling, Z. Tian, Y. Yin, and Y. Li, "Localized structural health monitoring using energy-efficient wireless sensor networks," *IEEE Sensor J.*, vol. 9, no. 11, pp. 1596–1604, Nov. 2009.

[5] F. Hu, Y. Xiao, and Q. Hao, "Congestion-aware, loss-resilient biomonitoring sensor networking for mobile health applications,"IEEE J. Sel. Areas Commun., vol. 27, no. 4, pp. 450–465, Apr. 2009.

[6] N. A. Bertoldo, S. L. Hunter, R. A. Fertig, G. W. Laguna, and D. H. MacQueen, "Development of a real-time radiological area monitoring network for emergency response at Lawrence Livermore National Laboratory,"*IEEE Sensors J.*, vol. 5, no. 4, pp. 56–573, Apr.2005.

[7] F. Hu, Y. Xiao, and Q. Hao, "Congestion-aware, loss-resilient biomonitoring sensor networking for mobile health applications," *IEEE J. Sel. Areas Commun.*, vol. 27, no. 4, pp. 450–465, Apr. 2009.

[8] M. Venugopal, K. E. Feuvrel, D. Mongin, S. Bambot, M. Faupel, A.Panangadan, A. Talukder, and R. Pidva, "Clinical evaluation of novel interstitial fluid sensor system for remote continuous alcohol monitoring," *IEEE Sensors J.*, vol. 8, no. 1, pp. 71–80, Jan. 2008.

[9] R.Nathiya and S.G.Santhi, "Energy Efficient Routing with Mobile Collector in Wireless Sensor Networks (WSNs)", International Journal of Computer Sciences and Engineering, Volume-02, Issue-02, Page No (36-43), Feb - 2014.

