# Research of Petroleum Well Fuel Pump Measurement & Control System Based on Internet of Things Technology

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***Abstract*—In order to realize remote automatic measurement and control of all petroleum well fuel pumps which are located in different regions of the crude oil production enterprises, this paper discusses and designs a petroleum well fuel pump measurement & control system based on internet of things technology. The measurement & control system uses a three-tier (perception layer, network layer and application control layer) form of the IOT (Internet of Things) structure, and then the function and feature of all layers are analyzed. As a focus, the hardware components and the control theory of the sensor instrument node and the aggregation instrument node, which are existed in the measurement & control system, are given and discussed also. In the end, programming flow chart of the node microcontroller and main design software module content of the IOT center computer are depicted and proposed. The enterprise experiment result shows that the system has the advantages of easy operation and maintenance, low labor intensity, high time efficiency of measurement & control and high precision with the traditional manual inspection methods of the petroleum well fuel pump to compare.**

***Keywords - Internet of Things, Measurement & Control System, Sensor Instrument Node, Aggregation Instrument Node***

## I. INTRODUCTION

Fuel pumps are an important requisite external power transmission equipment for wells. As most of the wells are distributed in the desert and wild mountains, Oil-Fields enterprise management of its use field instruments to show monitoring, and carry out the early warning management by artificial way of power line patrol, that is inspectors daily check the operation of the group of oil wells ,record the relevant data, access to the pumps phase of the time running the flow pressure as well as temperature and other information[1]. With the oil field production and transmission pipe network is more and more wide， and the number of wells continues to expand, This approach gradually shows the lack of management, which shows great intensity of work labor, and shows some shortcomings of problem processing lag, for example :if the operating pressure of oil pump is abnormal, manual inspection line found that processing is not timely, it could cause the pipeline to burst, further, it causes a series of serious problems, such as property loss of oilfield enterprises and environmental pollution.

The internet of things is "things connected to things in the Internet", it is the automatic information acquisition equipment through various sensing devices, ZigBee wireless sensor network technology, 4G network transmission technology, RFID technology, video recognition technology, infrared sensors, GPS, laser scanners and etc. , intelligent network system, according to the agreement, and the need to realize the interconnection of the network of things, for information exchange and communication, in order to achieve intelligent identification, positioning, tracking, monitoring and management of intelligent network system[2] .

## II. DESIGN OF PETROLEUM FUEL PUMP MEASUREMENT & CONTROL SYSTEM BASED ON INTERNET OF THINGS ARCHITECTURE

Measurement & control of petroleum well fuel pumps data is the foundation for the construction of the digital intelligent oil fields. The goal is to detect the running status and parameters of the well fuel pump equipments in real time and transmit the running data to the Internet of Thing control center through the intelligent correspondent node, and dedicated 4G network. On the one hand, the central machine analysis and process through the upper intelligent control software, if necessary, makes decision-making control, and then output to the equipment control agencies by a dedicate 4G network. On the other hand, the central machine can make gathered data store to the database server through the algorithm transforms and normalizes, at the same time, through the pubic 4G network or internet network for mobile terminals or desktop terminal users. Based on Internet To Things architecture of the equipment composition structure shown in Figure 1, the system is used a hierarchical design method to achieve real-time data collection and monitoring of pipeline pressure, flow and temperature and so on. It has the advantages of low cost ,automatic monitoring ability, which consists of 3 layers: the perception layer, the network layer and the application control layer.

### *A. The perception layer*

The sensor signal of oil pump of the measurement and control in the oil field mainly include: various parts of the value switch of components inlet and outlet pressure of pumps, inlet and outlet temperature of pumps, the pump output flow and the pump body temperature an so on. The perception layer is composed of zigbee wireless subnet of pumps and wells in several areas. The zigbee wireless subnet consists of sensor instrument nodes, aggregation instrument nodes with zigbee correspondence module (zigbee wells

control correspondence instrument, also called gateway nodes). In this system, aggregation instrument node is the transfer station for each oil well's external correspondence, and its core component is the ZigBee wireless transceiver module. Aggregation instrument is a relatively independent processing unit, If the external network failure can not be connected with the Internet of things control center machine, if the external network fault occurs and can not connect with the Internet of things control center machine. It can automatically control the running state of the local oil pump according to the logical rule library running in the node. In addition, it can store the local measurement & control data for a period of time, and can query local sensors to display real-time or historical running data.

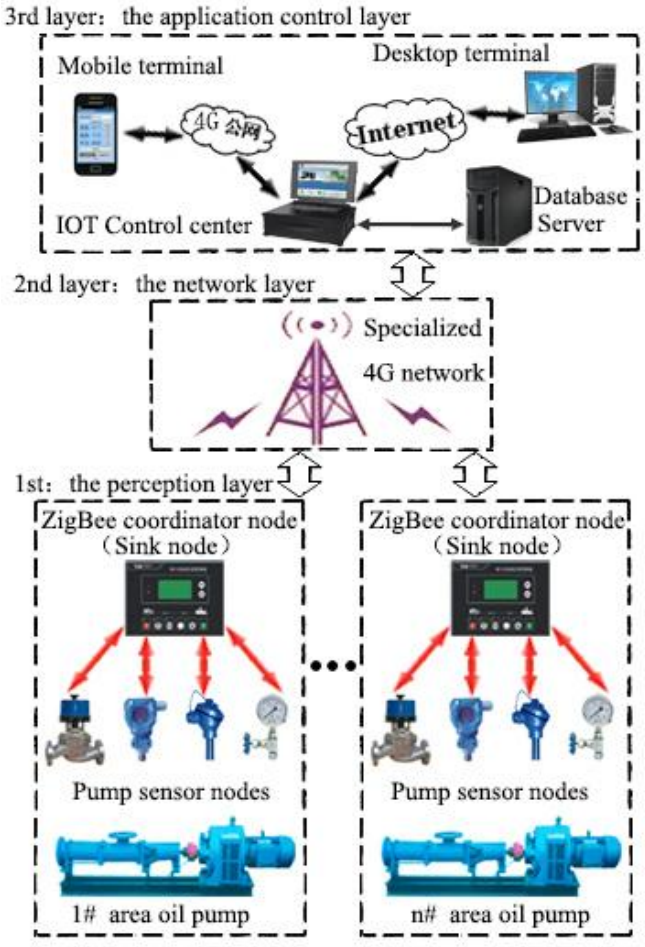


Figure 1. Organization structure of the system based on internet of things technology

### B. *The network layer*

The network layer mainly completes the reliable transmission of the oil pump collection information or the central control signal of the Internet of things. In essence it is based on WLAN (Wireless Local Area Network, WLAN) wireless mesh protocol to form a larger network of aggregation instrument nodes, thus monitoring the oil pump in multiple regions. Its specific function is that mainly receives the information of the perception layer aggregation instrument node and can transmit to the control application layer by appropriate algorithm encryption as required, in addition, the information and control output of the application layer are transferred back to the aggregation instrument nodes of the perception layer, and the network layer acts as a bridge. As the oil wells of oilfield enterprises are mostly in the wild areas, these places often do not have public correspondence 4G network, so it is necessary to set up a dedicated wireless correspondence network to serve the system.

### C. *The application control layer*

The application control layer is the highest level in the functional structure diagram of the system. It is the remote control center of the system. It realizes the automatic safety control of the oil pump on the basis of receiving and analyzing the information of each well. The application control layer is mainly composed of central machine of internet of things, database server, desktop terminal, mobile terminal and so on. The central machine of the Internet of things generally has wireless transceiver module, which can receive the equipment information transmitted by the 4G network and the base station at the transport layer in real time, according to the operating parameters of the pump to analyze and process through the software system. Different production wells are equipped with different pump power, operating parameters are not the same, by controlling the man-machine interface of the application control layer, various device parameters can be set up, and the regular rule library instructions are downloaded into the control correspondence instrument of the ZigBee well group as the local backup[3]. Application control layer receives the network layer data generally go through check, unpacking, reverse the encryption transformation , It can dynamically display oil well temperature, pressure and flow of data through intelligent computer graphics software system of powerful, it can predict the abnormal running of the equipment, and make the corresponding output actions quickly according to the equipment process, mobile terminals, such as mobile phones and handheld PDA, can be allowed to access the Web interface of the control system through the public 4G network, operating curves, data, etc. that can be accessed by the device under permission; in addition, each branch of the oilfield enterprise can also access the operation of the browsing system or remote control through the Internet. It is convenient for Oilfield Enterprises to manage oil pumps efficiently.

## III. MEASUREMENT & CONTROL NODE HARDWARE OF PUMPS' INTERNET TO THING

### A. *Sensor instrument node*

The main function of sensor instrument node is collecting current and voltage data, convert data to A/D, and process 1 times digital filtering, these sensors are equipped with wireless ZigBee correspondence module, they can

upload data to the aggregation instrument node, and accept the instructions of the aggregation instrument node to make the necessary adjustment output. Typical pump sensor instrument node consists of a sensor module, analog filter module, A/D conversion module, D/A output module, I/O control module, CPU processor, RFID wireless node module, storage module and power management module etc, the schematic diagram of the hardware is shown in Figure 2.

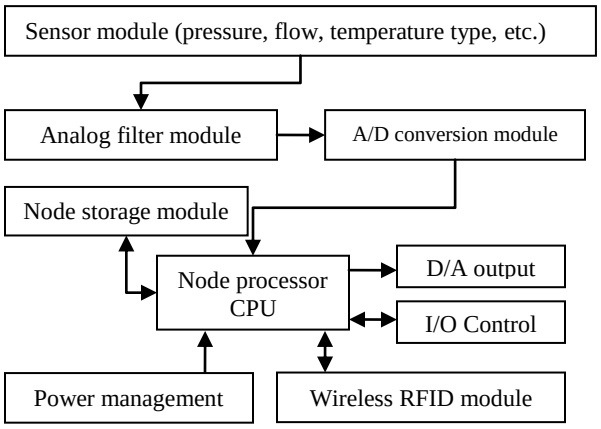


Figure 2. Hardware components theory block diagram of the fuel pump sensor instrument node

The pressure sensor of this system adopts Rosemount measuring accuracy 0.1% sensors, and the measuring range is 0~10 Mpa, the direct-current supply voltage is DC24V, the output sensing signal is 4 ~ 20mA, and the medium temperature is -20 ~ 90 ℃. The flow sensor adopts FD-M100AT sensor, the detection distance is 4~150 mm, the switching frequency is 1000Hz, the output mode is NPN, the response time is less than 0.5 ms, it can realize the detection of liquid flow in a severe environment, and is suitable for the field arrangement of an oil pipeline in an oil field enterprise. The temperature sensor uses the model DS18B20, its range is -55 ~ 125℃, can carry on the sampling to the temperature data, the quantification coding, the resolution generally may reach 0.0625, the work voltage is 3 ~ 5.5V, the sensor transforms the temperature into a digital format with only a maximum of 740ms, which is suitable for the low power consumption of sensor nodes.

### *B. Aggregation instrument node (Sink node)*

Aggregation instrument node (ZigBee well control correspondence device, also known as gateway node or sink node, or Coordinator node), it is responsible for collecting local sensor signals, and interacting with data through the network layer and the central machine of Internet of things . When the central machine of the Internet of things sends a control instruction through data operation, after aggregation instrument node receiving, then send to the sensor node immediately through the wireless correspondence, the sensor node unpack according to the correspondence command information, carry out D/A output or I/O control. The aggregation instrument node is mainly composed of the upper layer wireless correspondence module, lower layer wireless correspondence module, node processor CPU, node LCD display module, node Key button control module, node storage module and power management module etc, its schematic diagram of the hardware is shown in Figure 3. The aggregation instrument node itself is a relatively independent local oil pump control instrument, and it has two patterns: Remote and Local, the normal situation is in the remote pattern. Once the correspondence delay or correspondence failure, the aggregation instrument node automatically transfers to the local pattern, and automatically regulates the oil pump according to the standby rule library of the instrument.

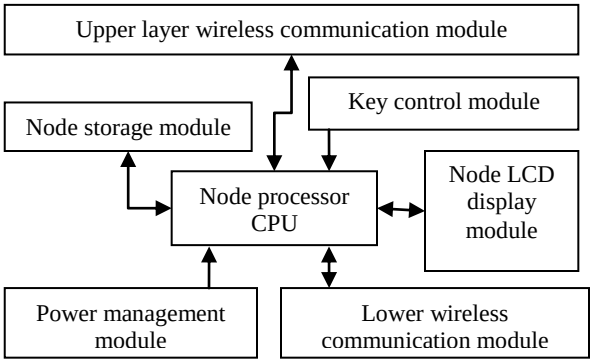


Figure 3. Hardware components theory block diagram of the IOT aggregation instrument node

The lower layer wireless correspondence module uses the CC1100 correspondence module, which can directly receive acquire information of the perception layer. The upper layer wireless correspondence module uses the SRWF508A wireless module, and the distance between the node and the network layer base station is 3.5km, by building wireless network, it is easy to realize long-distance transmission of information. The node storage module uses the AT 24C256 chip, which can extend the storage capacity through the interconnection of multiple chips. The node LCD display module can display the operation information and equipment status of the oil pump which is transmitted by the current sensor instrument node. It is convenient for user to view directly. Key button control module is convenient to operate the regulation rule library with the direct local manual input, set the working mode of the node, or directly issue a control command to start and stop the oil pump equipment, etc, it works in a matrix scan mode.

## IV. SYSTEM SOFTWARE DESIGN

The software design of the intelligent wireless monitoring system for oil well pump is fundamental principle on reliability, safety and control robustness, design with modular, scalable upgrades as the guide. The software design mainly includes the program design of sensor instrument node, the programming of the aggregation

instrument node and the software design of the intelligent monitoring system of the Internet of things[4].

### *A. Node program design*

The node program is mainly based on the design of microcontroller program. In this system, there are many similar working principle between the sensor instrument nodes and the aggregation instrument nodes, and their programming methods are similar, workflow of aggregation instrument node, the node program uses modular subroutine design patterns, it consists of a number of relatively independent subroutines called by the master loop program, each loop through these subroutines mainly completes the lower layer sensor data acquisition, correspondence layer, data storage and processing Key processing, wireless correspondence, data submitted to the upper node data display task, the maximum cycle time is set for each subroutine during the main loop operation, if occurs abnormity during the running the loop subroutine of the node, the system uses the stack to record the exception number in sequence, unify to the last step, carry out running exception handling subroutine by centralized stack mode. this can improve the efficiency of the program and peripheral wireless correspondence timely response[5].

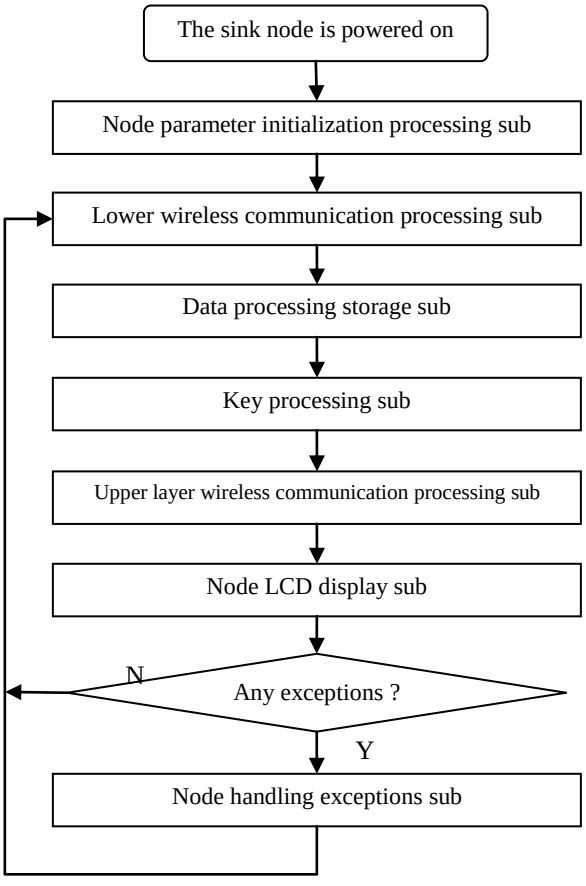


Figure 4. MCU control program flow chart of the IOT aggregation instrument node

The aggregation instrument node microcontroller program, using the C language syntax, MCU development environment to prepare, the code for its main loop program is as follows:

```
void main()     /* Main loop function definition */
{ GatherGaugeLoad();/*Aggregate node initialization */
  while (1)  /* Infinite loop until the node is powered down */
  { DownWirelessComm();/*Lower communication, collecting oil pump data */
    DataProcessSave();/*Data is normalized and saved */
    KeyInService();/*User Key processing */
    UpWirelessComm();/*Upper layer communication, execution of remote instructions */
    KeyInService();/*The node meter LCD displays the required data */
    if (RunError()!=0)    /* This round of abnormal */
      Exceptionhand();/*Handling exceptions that occur in the loop program */  }
}
```

The wireless correspondence networks of the sensor instrument nodes and the aggregation instrument nodes is based on the traditional MAC protocol in this system, it mainly realizes the establishment and maintenance of wireless data link between correspondence equipments, MAC data frame adopts time slot CSMA/CA mechanism, during running, it uses 3 parameters, namely the back index NB, the collision window CW and the back index BE to achieve reliable data transmission.

### *B. Software design of center monitoring system*

According to the actual demand of the remote monitoring well group oil pump in oilfield enterprise, the central control system software of the Internet of things mainly consists of 7 modules, as shown in figure 5. It includes the system user management module, the network correspondence processing module, the data recording processing module, the process picture display module, the dynamic curve display module, the sensor node parameter module and the aggregation instrument node parameter module[6].

The system user management module is used to control the privileges of the user using the software, including remote desktop terminals and mobile end users, it can display or maintain the basic information record of the logged in user. Network communication processing module is the key module of the system, on the one hand, it performs exchange with the system's data in real-time through a dedicated network of network layer and the system's multiple aggregation instrument node, on the other hand, it provides data services for enterprise remote mobile terminals and desktop terminals through the public 4G network and Internet. The system control center adopts C/S design mode and adopts TCP/IP asynchronous correspondence mode, it handles network related work through proxy callback functions, it does not need to block or suspend threads when performing network operations. The system provides interfaces based on standard Modbus TCP RTU for Web based page access to remote desktops or mobile terminals. The main function of the data processing module is to normalize the data of all the oil station pump data monitored by the system, and then record the data in the database server

periodically (time can be set, usually 5min). Process picture display module is the man-machine interface system's main components, it uses virtual instrument technology to display the position of the corresponding position of each part of the oil pump and the sensing parameters in real time, and can prompt whether the system alarm or not, picture refresh time generally is 5S.

The function of the dynamic curve display module is showing the sensing parameters of each oil well in the form of curves, the dynamic curve shows the historical data curve, and also has a short running trend graph, system is built in fault diagnosis algorithm, can predict whether the future will be possible failure according to the trend of the curve, this make users prepare in advance and nip in the bud. The parameter module of sensor instrument node can set a series of parameters, such as the type of sensor, the mode of sensor operation and the communication mode of sensor network. The parameters module of the aggregation instrument node can set up a series of parameters, such as the working mode of each node of the oil station, the standby logic rule base and the correspondence mode of the node network[7].

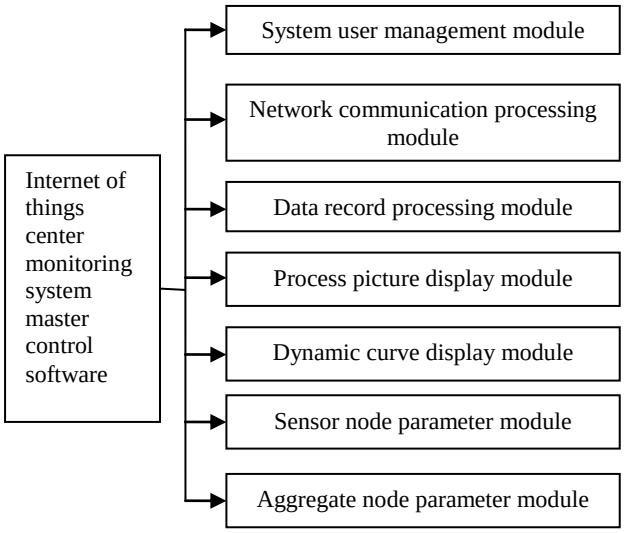


Figure 5. Module structure diagram of the IOT center computer monitor system software

## V. PRACTICAL DEVELOPMENT AND EXPERIMENT OF THE SYSTEM

The author puts forward to the Internet of things theory framework in this paper, successful development and experiment have been made in the project of remote monitoring of oil well digital oil field in a subordinate oilfield enterprise of china. The key frame for the monitoring of the well pump operated by the system is shown in figure 6. The system can switch and control the 4 groups of petroleum well fuel pumps in different areas of the enterprise. The central software of the Internet of things is developed by using object oriented integrated programming tool Embarcadero, RAD, Studio and XE, the database system uses SQL Server 2008, remote desktop and mobile terminals use Visual Studio 2012 to develop B/S architectures for Web systems. Considering the safety of the special equipment controlled by the system, the mobile terminal only realizes the operation parameters and data of each oil pump and can not be remotely controlled. The system has been running for more than half a year. Compared with the traditional way of artificial inspection and management, the system is easy to operate, intelligent, equipment operation early warning, accurate and timely, it provides a powerful guarantee for the petroleum fuel production safety of the well group.

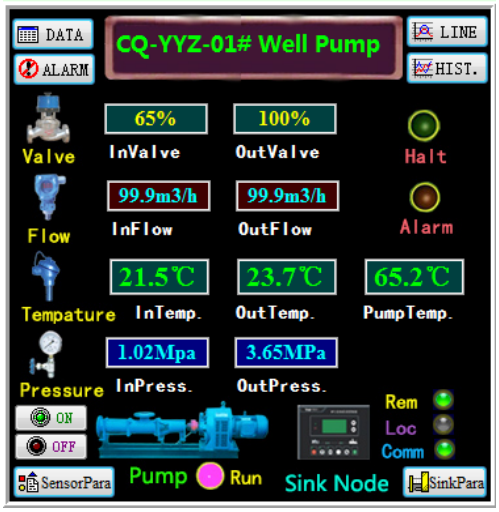


Figure 6. Remote monitoring main screen of the petroleum well based on IOT technology

## VI. CONCLUSION

Design of petroleum well fuel pump measurement & control system based on Internet of things technology is an important part of digital oilfield construction, it can collect, transform and transfer information about the operation and monitoring of the petroleum fuel pumps in different areas, so as to realize remote real-time control, reducing the labor intensity of workers, improving the reliability of pump equipment operation. In addition it can realize trans regional cooperative work of oil well through internet to things, and closely connects to other parts of crude oil production, such as transportation, storage, and sales. It has realized the efficient integration of oilfield production and management technology.

## ACKNOWLEDGMENT

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