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Design of the Fuel Consumption Monitoring System for the Diesel Generator

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Abstract: The real-time monitoring system for the diesel generator's fuel consumption will be designed based on Zigbee technology. The system consists of the principal and subordinate computer and communication program. The subordinate computer is a PLC-centered fuel consumption meter which function as the indicator and storage of turbine flowmeter data. Zigbee module realizes data acquisition and wireless transmission while Zigbee coordinator receives data transmitted by the subordinate computer and then sends those data to the Principal Computer (PC) with data analysis software. The verified experiment shows that the system can realize the real-time and accurate measurement and effective transmission of flow data in the environment blocked by buildings and within the 30 m distance.

Key words: Diesel generator, fuel consumption meter; PLC; zigbee

INTRODUCTION

China's oil resource amount only accounts for 3.5% of the world oil whereas, its population takes up 22% of the world population which make the conflict between energy supply and demand increasingly prominent (Roberts and Rush, 2011). In course of the high-speed economic development, China confronts increasingly severe energy shortage. Therefore, it is of vital importance to reduce energy consumption and save energy (Leung, 2010). The diesel generator has the characteristic of high thermal efficiency, low running charge, high reliability and stable electricity output. Due to those advantages, it usually severs as the main power source or reserve power supply on the some important occasions, like communication, military and hospitals, particularly suitable for oil fields, mining area, forest region, pasturing area and national defense construction where power grid cannot reach (Zubair and Zhijian, 2013).Fuel consumption is a key index to evaluate economic performance of the diesel generator as well as one of the important measuring parameters. The accurate measurement of the diesel generator's fuel consumption not merely can evaluate its performance but also help to reduce man-made oil loss and oil consumption. At present, a variety of fuel consumption metering devices have been developed, but most of them have problems of low measurement precision, weak subsequent handling ability of measuring data, complex measurement methods and high cost. At abroad, developed countries, such as the US and Japan which attach importance to environment protection and energy conservation, possess advanced measurement technology and widely use micro-electrical (Lu, 2011) and sensor technology (Cumming, 2011).However, they are too expensive to promote.

Innovation points: In oil fields where electric power is insufficient and even power grid cannot reach, the diesel generator, as the widely-used main power source, consumes a huge amount of fuel, whereas, its corresponding fuel consumption metering devices are out of date and means of fuel consumption management are extensive. For these reasons, it is of great significance to realize the precise measurement of fuel consumption data.

The study proposes a data acquisition device with a turbine flow transducer (Zhen and Tao, 2008), takes PLC as the center of the system and employs the management system of Zigbee data wireless transmission (Erdogan and Bilgin, 2012) to monitor and manage the fuel consumption information of the diesel generating set. In contrast with traditional fuel consumption metering methods, the system possesses higher precision, more reliable performance and more brief and economic mode of data transmission.

SYSTEM OVERALL DESIGN SCHEME

According to functional requirements of the fuel consumption management system of the diesel generating set, the design system structure is shown in Fig. 1.

To start with, the subordinate computer takes advantage of the flow transducer to in real time collect the oil tank input and output and fuel information in the work process of the diesel generating set and then uses PLC system to calculate and process the required data; next,

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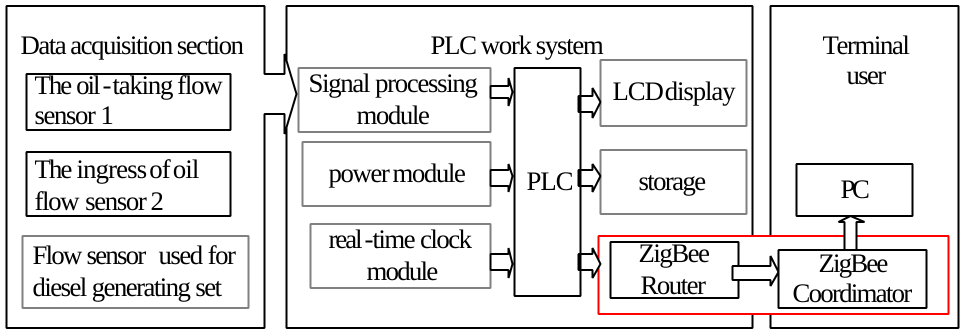

Fig. 1: System block diagram of the overall

fuel data are displayed on LCD which employ SD card memorizer to store data of oil filling and discharge and oil consumption of the diesel generating set for easy second storage; meanwhile, Zigbee wireless communication equipment transmits the corresponding data to the Principal Computer (PC) whose fuel management software realizes the monitoring of fuel usage and receives, analyzes and manages fuel consumption data per minute and the total consumption on various working conditions of the diesel generating set.

DESIGN OF THE SYSTEM HARDWARE

According to the characteristics of flow measurement and design requirements, the hardware design employs PLC (Liang and Li, 2011) as the system process core. The programming software of PC is compatible to FXGP-WIN-C or GX Developer 8.5.2 while its command function is to support all basic instructions and frequently-used applied instructions of FX2N-series PLC and add a RS485 interface on 422 programming port to connect human-computer interface and other equipments. The output of two high-speed pulses and analog input and output are added to receive pulse signals collected by the turbine flow transducer. Ten-digital resolution (0-1000) and 0-10V industrial standard voltage output can set the principal/subordinate computer mode by MODBUS communication protocol to realize networking communication.

Data wireless transmission is through Zigbee communication mode. The system uses XBEE-PRO wireless transceiver chips produced by American DIGI Company. The chip meets IEEE802.15.4 standard and works at the frequency range of 2.4GHz which is a relatively mature wireless communication module with small size, low power dissipation and long transmission distance, suitable for building wireless sensor network with low-power dissipation. Collected data by the sensor is processed by the Fuel Consumption Meter (FCM) before sent to Zigbee router by RS485 communication that will send those data to the receiving end, i.e., Zigbee coordinator, by IEEE802.15.4. The coordinator transmits to the PC via RS232 and finally the PC software will deal with correlative data.

DESIGN OF THE SYETEM SOFTWARE

PLC programming of the fuel consumption meter: GX-Developer is a general Mitsubishi programming software, with noticeable features of easy operation, various connection types with CPU of the programmable logic controller (PLC) and rich debug function which is able to fulfill the compilation of FX-series PLC ladder diagram, instruction lists, SFC, Q series and A series (including motion control CPU). According to functional requirements achieved by the system, the study determines the software overall ideas of the PC's FCM in the oil management system of the diesel generator which is mainly used to process the received flow signals and realize signal measurement, data calculation and data transmission and display.

The main program flow chart is seen in Fig. 2, among which fuel flow data consist of five kinds, fuel filling per minute, fuel discharge per minute, the total flow, instantaneous fuel consumption and the total consumption of three diesel generators. In the process, timely cycle T is set as 1 min.

Fuel consumption management software in the principal computer: Visual Basic is a language for event-driven programming developed by Microsoft to assist development environment, stemming from BASIC programming language. VB has Graphical User Interface (GUI) and the Rapid Application Development system

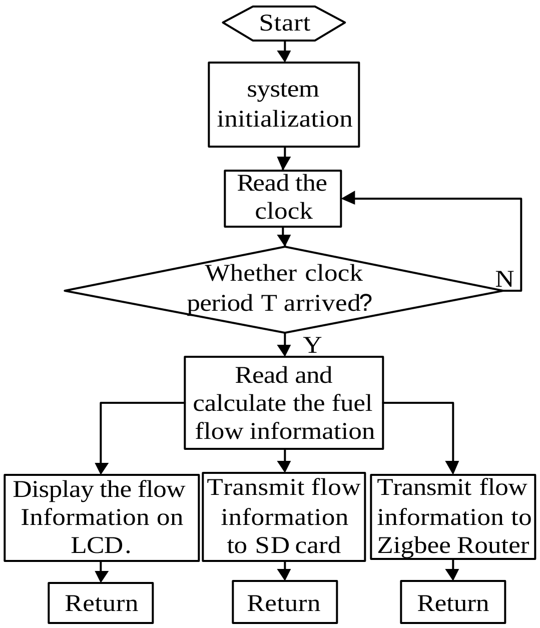

Fig. 2: Main program flow chart

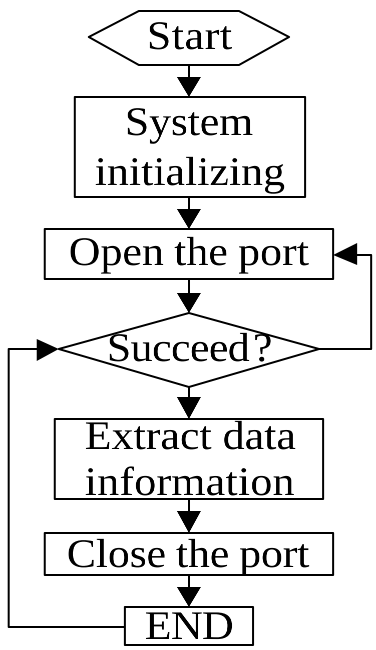

Fig. 3: VB data acquisition flow chart

(RAD) which enables it to easily connect with database by DAO, RDO and ADO or create Active X controls. The study employs VB to develop fuel consumption management software in the PC, seen in Fig. 3.

SYSTEM TESTING EXPERIMENT

In order to verify the system's reliability and measuring accuracy, the testing experiment will be conducted after the system is developed. The experiment includes three parts: The first part is to make error measurement and analysis of fuel flow data collected by the FCM; the second part is to measure the effective transmission distance of Zigbee module wireless communication; and the last part will test and evaluate the whole performance of the system.

FCM test analysis: The measuring accuracy of the system will be verified by weight method and the experiment system is seen in Fig. 4. Running water is pumped to bucket 1 by the pump and by regulating water flow of the faucet controls water flow to flow sensor (under the stable 220 v alternating current, the water volume flowing from the pump is certain in unit time). A flow sensor installed in the pipe of the bucket 2 measures the water volume in the bucket 2 and water quality change of the two buckets in the corresponding time will be measured on the electronic scale. Then by comparing the minute flow with the total flow calculated by the metering device verifies its accuracy and reliability. For avoiding temperature affecting experimental data, it'd better to conduct experiment in the room temperature of nearly 20 degrees Celsius.

The test result is seen in Table 1, in which M_0 (true value) stands for water quality in bucket2 measured by the electronic scale, Q_0 is its corresponding volume, Q(measured value) is the total water flow in bucket 2 measured by the FCM, $Q-Q_0$ is the absolute error and $(Q-Q_0)/Q_0$ is the relative error.

We can seen from Table 1 that at the measuring range the absolute error of the total measurement is between 0.01L and 0.11L while the relative error is between 0.13 and 0.21% with an average 0.162%, almost ranging with ±0.20% which is quite stable. The experimental result shows that water flow measured by the FCM is consistent with actual water flow.

Now we plot actual flow as the horizontal axis and measured flow as the vertical and draw scatter diagram and fitted curve, seen in Fig. 5.

The picture displays that measured consumption by the FCM and actual consumption by the experiment appear a clear linear relation and have the same change trend, proving that the result has good repeatability and reliable data and could be the basis of measuring system modeling.

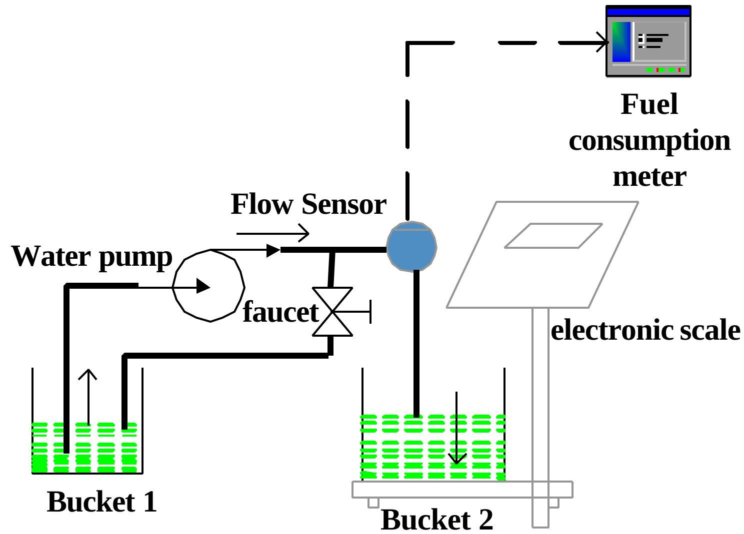

Fig. 4: Oil consumption meter test-bed

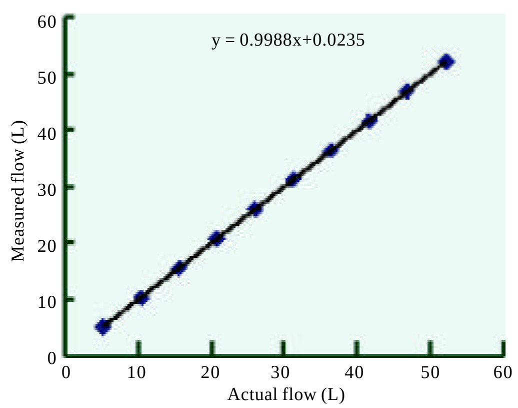

Fig. 5: A corresponding experimental data fitting curve

Table 1: Comparison of system measurements and the actual value

Sequence number	M_0(kg)	Q_0(L)	Q(L)	Q-Q_0(L)	(Q-Q_0)/Q_0(%)
1	05.20	5.20	05.21	0.01	0.19
2	10.43	10.43	10.41	-0.02	-0.19
3	15.62	15.62	15.64	0.02	0.13
4	20.80	20.80	20.83	0.03	0.14
5	26.01	26.01	25.98	-0.03	-0.15
6	31.20	31.20	31.24	0.04	0.13
7	36.45	36.45	36.40	-0.05	-0.14
8	41.65	41.65	41.58	0.03	-0.17
9	46.81	46.81	46.89	0.07	0.17
10	52.19	52.19	52.08	-0.11	-0.21

Data communication test: Given that obstacles like houses will have certain impact on Zigbee data communication when the diesel generator works, it is necessary to conduct experimental test for Zigbee data communication (Huang *et al*., 2011). The test environment is around buildings and the test site is indoor office area and laboratory area at the same floor within the room temperature of 20°C, ensuring all doors and windows closed in the test process. Zigbee router and IPC (industrial personal computer) are regarded as sending codes while Zigbee coordinator and the notebook computer as receiving codes. Data are manually sent by IPC serial debugging assistant and each sending unit is 50 30 byte data packages while the computer's serial debugging assistant receives and displays the number of data packages and the exact receiving data packages are deemed as the evaluating results of data communication. Within the communication distance between 20 and 90 m, five groups of repeated experiment are conducted and the test result is shown in Table 2.

Table 2: Wireless data transmission test results

Communication distance (m)	20	30	40	50	60	70	80	90
First set	50	50	50	49	48	42	39	35
Second set	50	50	50	49	49	43	42	26
Third set	50	50	50	50	50	46	41	29
Forth set	50	50	50	50	48	46	37	34
Fifth set	50	50	49	50	47	45	36	32

The Table 2 displays that as for the average number of the exact receiving data packages in different transmission distances, all data packages are correctly received in the distance of 20 and 30 m, almost all data packages are received at 40 and 50 m with less than 1% package loss rate (Abbasov and Korukoglu, 2009), the package loss rate becomes rising when the distance is more than 50 m and the package loss rate is close to 40% and the completeness of transmission data cannot be ensured at the 90 m distance. Therefore, in the dense buildings, the reliable communication distance of the system should be within 50 m, otherwise communication data will be affected significantly.

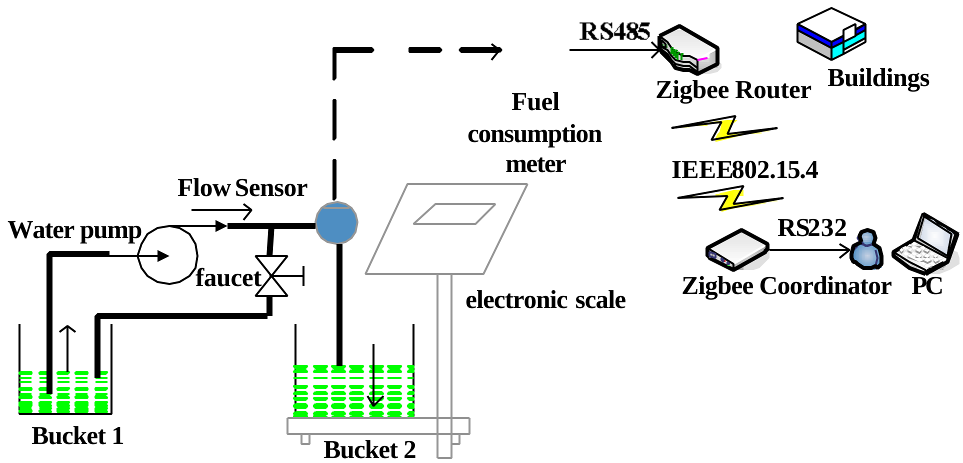

Fig. 6: System test experiment

Table 3: System error analysis

	Maximum	Minimum	Average	Standard deviation
Absolute error (L)	0.38	-0.53	-0.01	0.25
Relative error (%)	1.10	0.00	0.70	0.30

System test experiment: Reliability and stability of data acquisition and transmission will be tested plus the former tests of the FCM and wireless communication to study the system's overall performance. The system test experiment is made in the emulated environment, the measurement of data acquisition and testing precision is by the above weight method and the test site still is indoor office area and laboratory area at the same floor within the room temperature of 20°C at the test distance of 30 m, seen in Fig. 6.

After the test begins, the FCM nodes collect flow data from the flow sensor at interval of one minute and the collected data are transmitted by Zigbee router to PC terminal via coordinator nodes. The test lasts 0 min and acquires 50 sets of data including minute flow and the total flow. The experimental data received by the system terminal are compared with the actual measuring value and then the absolute error and relative error are calculated by the statistic method, seen in Table 3.

We can see from Table 3 that the smaller absolute error is, the higher the accuracy is. Less than 1% relative error and small standard deviation prove that the error distribution is comparatively centralized and the stability and repeatability of the system are quite good.

CONCLUSION

The study employs the turbine flow sensor with high accuracy, suitable for the spot, optimizes the PLC type and program and chooses an appropriate data communication mode for the diesel generator on the oil field. Combining the above three factors, the study designs a Zigbee-based fuel consumption monitoring and management system with high precision for the diesel generator which have certain reference value to fuel consumption measurement.

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