Intelligence Earthquake Safety Control System

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ABSTRACT :

The energy source supply system is both the power source of economic development and the lifeline of keeping the society stable. But it has much vulnerability under earthquake. Not only the earthquake can damage of the system itself, but the induced disasters can make a lot of loss of the society. The intellectualized system is based on analytical results of the earthquake-resistant capacity of the energy source supply systems. The paper presents the composing and the principles of the system. Also, the process of designing and exploring the simple strong motion seismograph, wireless control and transmission, and valves control is introduced in detail.

KEYWORDS: energy source supply, earthquake damage, earthquake safety, intellectualized control

1. SUMMARY

With the rapid development of our national economy, the infrastructure construction and safe operation of energy supply system have been receiving increasing attention from the government and society. Energy supply system usually includes power supply system, gas supply system and liquid fuel supply system, which are the drive force for social economic development and the lifeline for social stability. However, those energy systems have a great vulnerability towards earthquake. The historical earthquake survey shows that the earthquake damage on energy system not only brought material loss and shutout loss for themselves, but also resulted in the relevant losses for the relative industries, whose operation relied on the energy products (electricity, gas and oil). What's more severe is it sometimes would cause or aggravate earthquake-induced disasters (fire disaster and the spreading, poisonous gas leakage, and explosions, etc), meanwhile posed a big obstacle for emergency rescue and disaster relief and post-quake construction.

Earthquake alarm system was a new technology appeared in the international world in recent years, which can be adopted as a significant means for efficient emergency response. Supported by the intensive strong motion network constituted by strong motion seismographs, and adopted high efficient earthquake collection technology, it can provide early warning information for the would-be-impacted energy supply systems before the arriving of seismic wave so as for them to take emergency response measures in advance, therefore, furthest reducing the losses brought by the earthquake. Relying on the national digital strong motion network and observation technology, earthquake alarm system has set strong quake early warning system and emergency control system, which can sent out alarming a few seconds or dozens of seconds earlier before the arriving of strong earthquake and automatically dispose the key equipment as well as take emergency measures in time. Besides the national station network of strong quake pre-warning system, there is another real-time monitoring alarm system, targeting at lifeline projects with various functions and major projects. Quite a few of strong motion seismographs are installed in the key project parts for searching quake information; Automatic equipments are set in the cruel nodes, which can have a rapid response at the coming of big earthquake, to equip the system with automatic controlling emergency response capability.

Based on the seismic capacity analysis result of energy system, intelligent earthquake safety control system installs intelligent automatic turnoff or startup quake monitoring system. Once observes abnormal or earthquake information, it will send pre-warning signal to the upper computer and adopt systematic emergency measures according to the commandment of the upper computer so as to realize the goal of intelligent safety control through controlling mechanical structure actions.

2. SYSTEM DESIGN

Intelligent earthquake safety system is setting simple strong motion seismographs in the major stations or pipeline decks, form a monitoring network. It can get analyses and make judgment of the quake signals. Based on the pre-warning quake information and the abnormal detected messages, the monitoring center can take systematic emergency control and send dictation to the long-distance controlled nodes, which will be influenced by the coming earthquake so as for them to take measures in advance. Therefore, the system has the self-control emergency capability, under the influence of earthquake and can enter into the normal state through rapid system restart.

The system includes quite a few earthquake-monitoring nodes, monitoring centers and valves controlling nodes with the same mechanism. The earthquake signal and parameter got by the monitoring node will be sent to the monitoring center through wireless transmission. And the valve-controlling node will control the pipeline valves' mechanical action (turn on or shut off) according to the commandment of the controlling signal, and achieve the automatic control. The system is illustrated by figure 1.

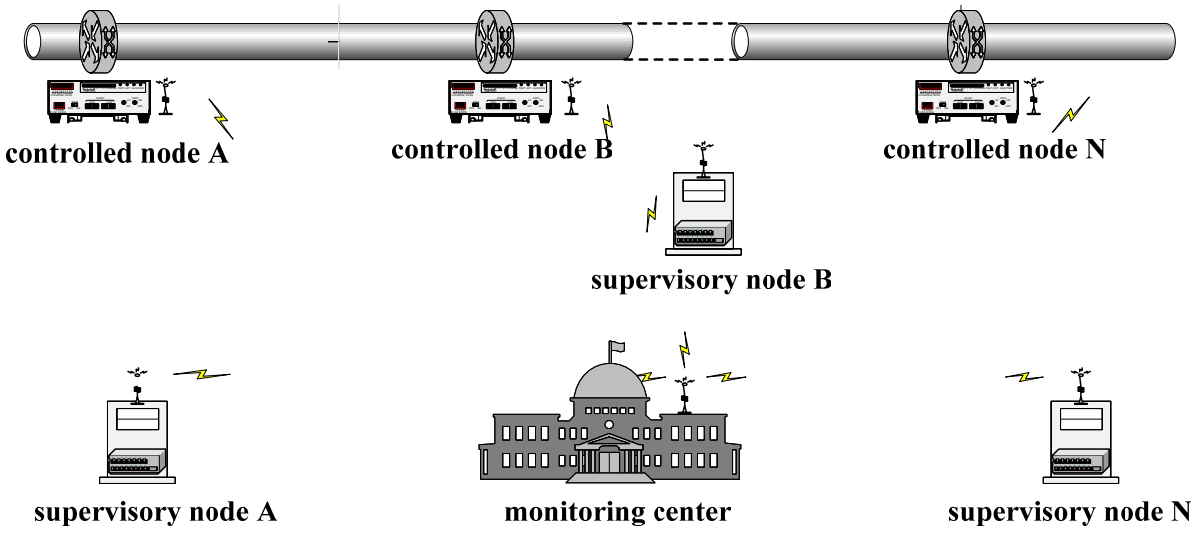
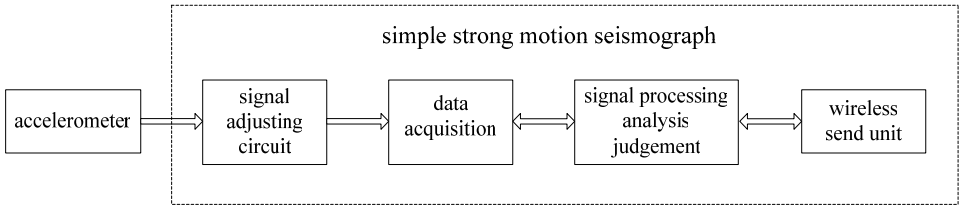


Figure 1 the system sketch map

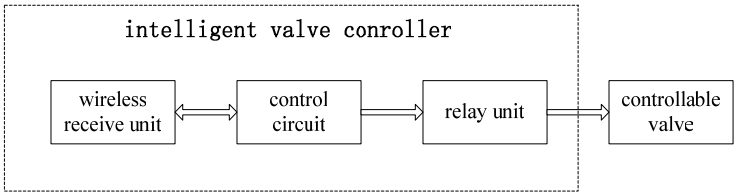
The earthquake-monitoring node is composed of three-component earthquake accelerometer, signal-adjusting circuit, data acquisition circuit, signal disposal, analysis and judgment as well as the wireless emission unit. The integration of signal-adjusting circuit, data acquisition circuit, signal disposal, analysis and judgment as well as the wireless emission unit is called simple strong motion seismograph**.** Monitoring center is the organic integration of the earthquake pre-warning system in lifeline and transmission pipeline projects, quake disaster rapid evaluation and emergency response system, which consists of wireless receiving unit, monitoring host computer and wireless emission unit. The controlling node is composed of wireless receiving unit, controlling circuit, relay unit and controllable valve. The intelligent valve-controlling meter is an integration of wireless receiving unit, controlling circuit and relay unit. Figure 2 is the system composition structure.

The data, information, and commandment of the three components of the pipeline valve earthquake safety automatic controlling system in the whole lifeline project are sent through wireless transmission. And all the wireless communication modules work in the same frequency, which realize the signal transmission of multi-points to one point and the control of one point towards multi-points.



supervisory node structure diagram

monititoring center structure diagram



controlled node structure diagram

Figure 2 System composition diagram

3. PRINCIPLE of ACCELEROMETER and SIMPLE STRONG MOTION SEISMOGRAPH

3.1. Three-component Accelerometer

Three-component accelerometer is shown in Figure 3

Main technical specifications:

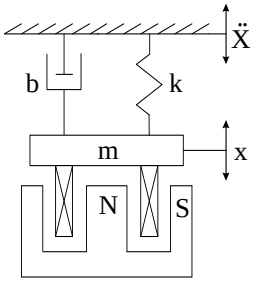
Maximum measurement range（p-p）： 40 m/s^2

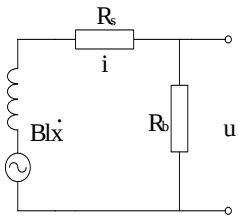
Sensitivity ： 0.1 V/m/s^2

Pass band ： 0.5～80 Hz

Basic principle

Accelerometer is the type of the moving coil reciprocating velocity-pendulum. Its mathematical model and circuit principle:





Mathematical Model of Accelerometer Circuit Principle of Accelerometer

Figure 3 Mathematical Model and Circuit Principle of Accelerometer

In Figure 3, b is air damper, k is spring stiffness, m is partial mass of movement, Rs is coil resistance, Rb is damping adjusting resistance, B is magnetic induction intensity, l is total length of coil winding, i is loop current, $\ddot{X}$ is acceleration of base movement, x is relative displacement between partial mass of movement m and base.

The motion equation:

$$\left.\begin{aligned} m\ddot{x} + b\dot{x} + kx &= -m\ddot{X} - Bli \\ i &= \frac{Bl\dot{x}}{R_s + R_b} \end{aligned}\right\} \quad (3\text{-}1)$$

$$m\ddot{x} + \left(b + \frac{(Bl)^2}{R_s + R_b} \right)\dot{x} + kx = -m\ddot{X} \quad (3\text{-}2)$$

Transfer function after Laplace transforms:

$$\frac{x(s)}{X(s)} = -A\frac{s^2}{s^2 + 2Dns + n^2} \quad (3\text{-}3)$$

3.2. Simple Strong Motion Seismograph

The working principle of Simple strong motion seismograph is: Through some adjustment of the sensor analog signals to achieve level conversion and 0-25Hz low-pass filter, to get the perfect seismic signal. Data acquisition part implements the digital process of seismic signal by using 32-bit digital signal processing DSP chip and A/D conversion with conversion precision of 16-bit. Signal processing and analysis judgment are the core part. Utilize the advantage of fast algorithm of DSP MCU, to continuously acquire ground vibration signals collected by accelerometer. When the earthquake reached the trigger conditions, it can timely send early warning information to monitoring center.

Main technical specifications:

1. Channel : channel 3
2. A/D Conversion:16 bit
3. Full-scale range: ±2.5V; ±2.0g
4. Dynamic range: 70dB
5. Sampling rate: 50SPS, 100SPS, 200SPS
6. Trigger mode: threshold trigger
7. Communication mode: RS－232 wireless control

Systematic principle diagram:

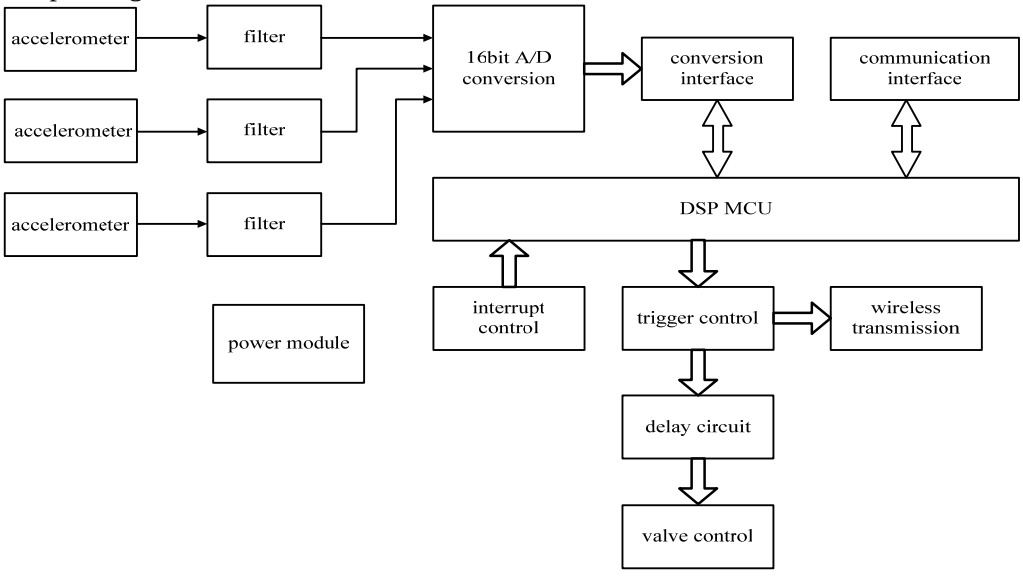


Figure 4 Systematic block diagram

4.CONTROL UNIT and WIRELESS TRANSMISSION PRINCIPLE

4.1 Control Unit

Control unit is constituted by control circuit、relay unit and controllable valve. To accomplish control by driving control circuit, transition of two excitation signals, positive and negative of valve by relay unit, controllable valve use positive and negative excitation signals to open or close the valve. Furthermore, after power down, it can maintain existing status.

Main technical parameters:

Principle structure : type of pilot tablet

Liquid scope : air、fuel gas、water、light oil and other liquid and gas

Temperature range : －20～＋60℃

Stamper material : NBR、(specially made VITON、EPDM)

Pulse voltage : DC6-24V，pulse width 60～80ms

4.2 Wireless Transmission

Adoption of wireless transmission controlling signals method is to achieve the control of remote terminal. It is mainly because the dispersed monitoring node positions of energy supply system will cover a few kilometers or even the scope of a dozen or so km. It is an important component of the system, with the responsibility for signal wireless transmission. The system uses a pair of wireless data-transmission module to complete the wireless transmission task of controlling signals. It can also use module to address coding, thus achieve point-to-multipoint wireless monitoring network.

Main technical specifications of wireless transmission are as the follows:

Working frequency band : 227MHz~233MHz

Wireless code rate : 9600bps

Working mode : half-duplex

Modulation mode : FSK

Transmit power: 10W

Wireless transmission radius: 5-10 km

Power supply: 12VDC

Control process:

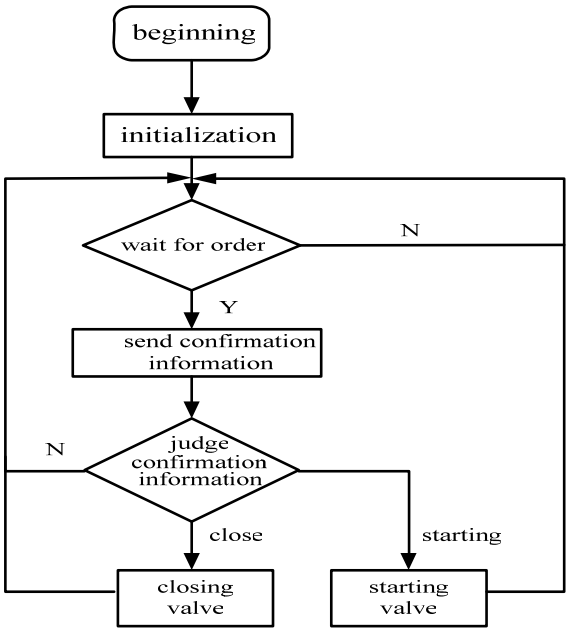


Figure 5 Control process

5. CONCLUDING REMSRKS

In recent years by related work, intelligent earthquake safety control system as mentioned above has completed accelerometer development、prototype development of simple strong motion seismograph、debugging of wireless transmission system、development of controlling circuit and assembly, etc. It actualizes the laboratory test and initial field test, also puts forward related patent applications for inventions. With the further study of the project, intelligent earthquake safety control system will be practical and apply to actual lifeline earthquake safety controlling engineering.

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