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Research on Dynamic Monitoring and Risk Assessment Technology of Liquid Tank Area

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Keywords: Liquid Tank; Dynamic Monitoring; Risk Assessment;
Abstract: Dynamic monitoring and risk assessment of liquid storage tank is an important technical part of enterprise safety guarantee. A general framework of safety monitoring system for tank area was brought up in this paper. It established a parameters monitoring and precaution system on the base of configuration software, including storage tank level, temperature, pressure, and concentration of combustible gas. By using fuzzy comprehensive evaluation model and Analytic Hierarchy Process (AHP), the risk evaluation index system for tank was optimized by introducing the safety-related facilities and safety management elements. Regional risk assessment model was presented for the overall risk assessment of tank area.

Introduction

Storage tank is one of the important storage facilities for storing liquid dangerous chemicals in petroleum chemical industry, the chemicals mostly have dangerous and harmful properties such as flammable, explosive, volatile and toxic. Once leakage, fire or explosion accident happens in chemical Tank Area, it will cause major property damage and casualties, especially in the major hazards storage tank area, which accident consequence is disastrous [1].

The experiences of major accidents prevention show that in order to prevent effectively accidents and reduce the damage, it is necessary for us to build up dynamic monitoring and risk assessment system [2].

This study started by improving the safety management of liquid storage tank area，made an integrated application of risk assessment, dynamic monitoring and warning, intelligent video analysis, safety management, emergency rescue decision support system, form a safety supervision platform integrating with data collection, analysis and expression to provide services and support for company safety management.

System Framework

The dynamic monitoring and risk assessment system of storage tank area was building on the control and management information network, including management information system and data access system, the system structure was shown in Fig.1.

Management information system was B/S mode system based on J2EE tri-level structure. Base on the real-time monitoring data by configuring system，enterprise safety management accounts and GIS platform，the system can well indicate the safety status of the chemical enterprise. The system provides services of risk assessment, intelligent video monitoring and analysis, monitoring and early warning, emergency rescue decision support and security management.

Configuration system was in the industrial control layer, mainly be responsible for the integration of the underlying distributed data access. The monitoring data was collected from industrial control layer and stored in relational data base. It will be presented to the user after processing, and provide the basic data source for each module in the application layer.

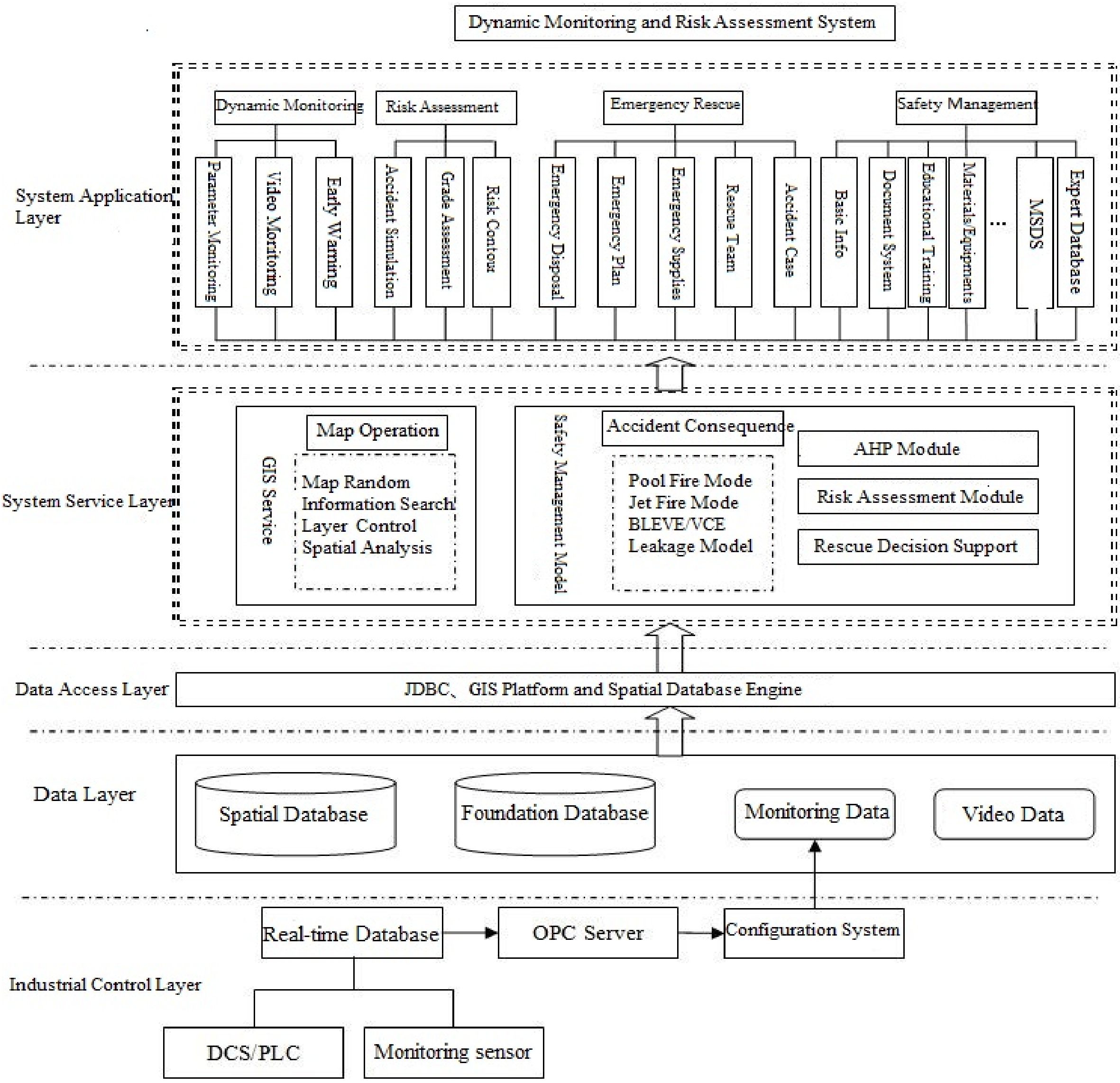

Fig.1 System structure frame

Dynamic Monitoring

The dynamic monitoring system was designed which was composed of management layer, network communication layer and field device layer, as shown in Fig.2.

In field equipment layer, physical quantity information is gathered by field instrument and output through RS485 serial port. All the instruments are fed by field power supply independently.

Network communication layer mainly realizes two functions. Firstly, the serial server centralized accesses field data collection near the monitoring instrument and converts it into digital signal output based on Ethernet protocol. Cable is RS485 serial port line. Secondly, an Ethernet switch is deployed in the industrial control room, to achieve the data connection between the serial port server and industrial control server. Serial port server output of local remote monitoring points, accesses to enterprise LAN, and realizes remote transmission with existing network cabling.

The monitoring management layer includes industrial computer hardware system and configuration monitoring software system, which supports all kinds of industrial control equipment and common communication protocols, and provides the distributed data management and network functions. Industrial computer exchange data with front-end acquisition equipment, through industrial Ethernet switches in the communication layer and serial server in the field.

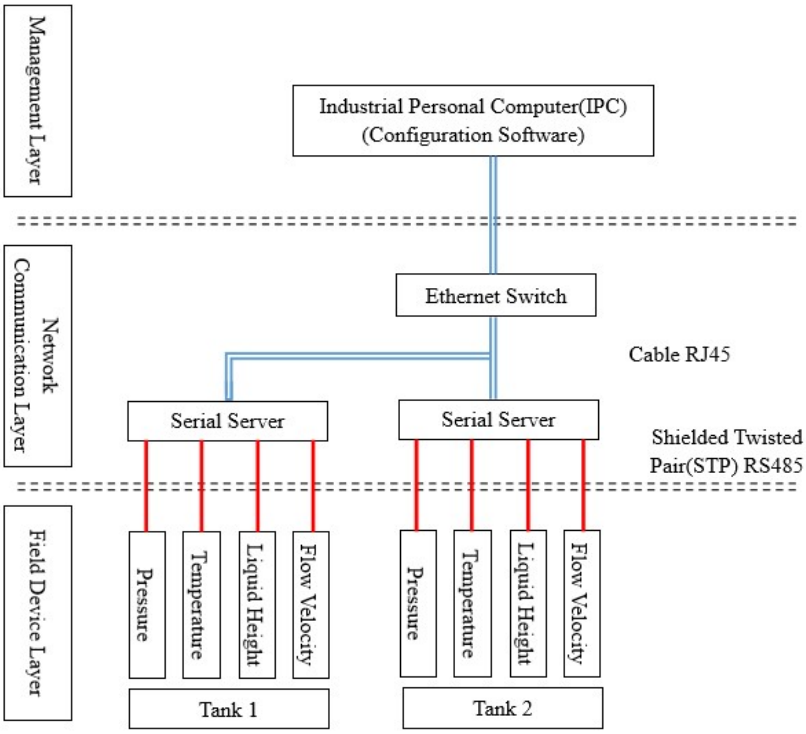

Fig.2 Architecture diagram of dynamic monitoring system

Risk Assessment

Risk Assessment for single tank

Safety influence factors of chemical storage tank are complicated, including personnel quality, safety management, monitoring parameters, equipment reliability, etc. But in a specific personnel quality and safety management conditions, monitoring parameters, equipment and electric safety states are key factors for risk assessment of single tank. Fig.3 shows the safety assessment index system for single tank.

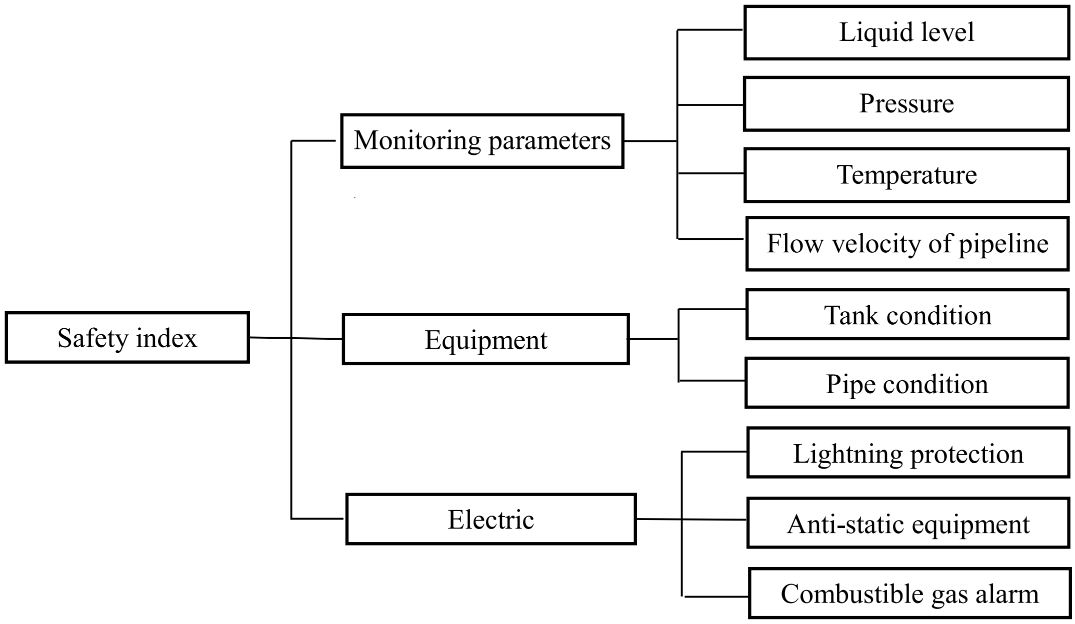

Fig.3 Safety index system for single tank

In order to achieve risk assessment for single tank, analytic hierarchy process (AHP) is used in determining weight coefficient of assessment index.

$U=\{U_1, U_2, U_3\}$

$U_1=\{u_{11}$(Liquid height)，u_{12}(pressure)，u_{13}(temperature)，u_{14}(Flow velocity of pipeline)$\}$

$U_2=\{u_{21}$(tank condition)，u_{22}(pipe condition)$\}$

$U_3=\{u_{31}$(Lightning protection equipment)，u_{32}(anti-static equipment)，u_{33}(combustible gas alarm) $\}$

Take real-time monitoring parameter factors for example, start by establishing the assessment factors set U_1, and then the weight coefficient calculation for real-time monitoring parameters, the judging matrix was established, as shown in table 1.

Table 1 Tank real-time parameter judgment matrix

Assessment factor	u_{11}	u_{12}	u_{13}	u_{14}
u_{11}	1	1	1/2	2
u_{12}	1	1	1/2	2
u_{13}	2	2	1	4
u_{14}	1/2	1/2	1/4	1

$M_{u11}=1$ $\overline{W}_{u11}=1$ $W_{u11}=0.22$ $M_{u12}=1$ $\overline{W}_{u12}=1$ $W_{u12}=0.22$

$M_{u13}=16$ $\overline{W}_{u13}=2$ $W_{u13}=0.45$ $M_{u14}=0.0625$ $\overline{W}_{u14}=0.5$ $W_{u14}=0.11$

$\lambda_{max}=4.02$ $\quad CI=\frac{\lambda_{max}-n}{n-1}=0.007$

According to table 3.2 to determine the random consistency index, calculate the consistency ratio:

$$C_R=CI/RI=0.008$$

Because $C_R=0.008<0.1$, the judgment matrix assignment is reasonable. So each index weight is as follows:

$$W_{u1}=\{0.22，0.22，0.45，0.11\}$$

In the same way，W_{u2} , W_{u3} *and* W_u can be calculated. The risk rating value of each indexes can be determined by real-time monitoring value, and then the risk of tank can be calculated by weighted calculation of each risk rating value and index weight.

Overall risk assessment of tank area

Overall risk assessment of tank area is mainly based on the regional risk assessment method and described by personal risk contour.

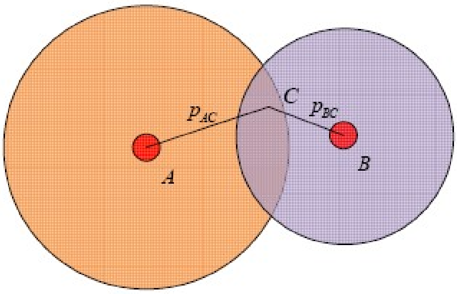

Fig.4 Schematic diagram of risk calculation

As shown in Fig.4, take pool fire as an example, the failure of tank A could lead to thermal radiation value r of C, according to the relationship between thermal radiation and the probability of casualties, the probability of death caused by tank A at point C can be calculated as P_{AC}. In a similar way, the failure explosion of tank B could lead to intensity of shock waves ΔP in C, according to the relationship between shock wave and probability damage to human body, the probability of death from tank B at point C can be calculated as P_{BC}.

If the failure probability of tank A and tank B were respectively D_A and D_B, the individual risk at point C can be approximated as:

$$R_C = D_A P_{AC} + D_B P_{BC}$$

Fig.5 shows an application case of overall risk assessment for an oil tank area.

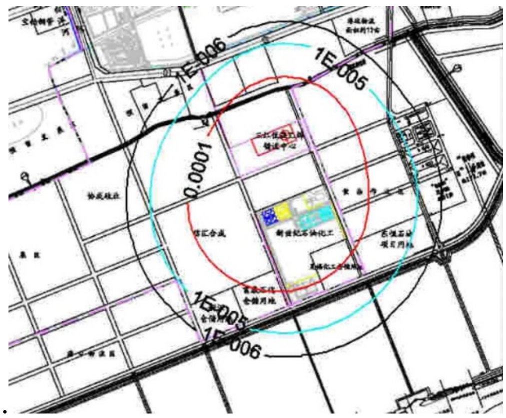

Fig.5 Personal risk contour map for an oil tank area

Conclusions

（1）Dynamic monitoring and risk assessment for storage tank area is a very important work，this study made an integrated application of risk assessment, monitoring and warning, intelligent video analysis, safety management, emergency rescue decision support system.

（2）By front-end data access system based on configuration software, this study achieved the on-line monitoring and data acquisition of storage tank temperature, pressure, level with different brands sensor.

（3）By using fuzzy comprehensive evaluation model and Analytic Hierarchy Process (AHP), the risk evaluation index system for single tank was optimized. Regional risk assessment model was presented for the overall risk assessment of tank area.

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References

[1] Wu Zongzhi, Zhou Yonghong. Study on the grave dangerous headspring surveillance and urgent rescue construction. China Public Security, 2005, (4):36-39. (In Chinese)
[2] Wei Lijun, Guan Lei, WU Zongzhi. Probe into and analysis of running mode for major hazard installations safety monitoring system. Journal of Safety Science and Technology, 2006, 2(5):37-40. (In Chinese)