Establishment of Petrochemical Process Security Simulation and Emergency Drill Platform

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Abstract: The petrochemical process is universally featured in large production scale, long process and multiple procedures, which lead to high difficulty in security simulation system establishment for petrochemical process and formulation of emergency plan. This paper puts forward a construction method for security simulation system modeling platform for petrochemical process, and the platform could provide the function of emergency drill. The platform could rapidly build simulation model through mechanism modeling and data modeling, and apply knowledge graph technology and semantic feature matching method to automatically analyze different emergency plans to acquire formal definition of plan and realize automatic plan selection. Compared to traditional method, the platform proposed in this paper could simulate different accident scenes and acquire effective emergency plans, providing effective assistance for emergency disposal decision making.

1. Introduction

The petrochemical engineering industry is a pillar industry closely related to daily life of people, which creates massive material wealth for the society, promotes social and economic development and improves people's living standard. However, the petrochemical engineering industry is also a high risky industry. With continuous expansion of the scale, the “Nov. 22 pipeline explosion accident” in Qingdao in 2013, “Aug. 12 Massive explosion accident” in Tianjin in 2015, and “Mar. 21 Massive explosion accident” in Xiangshui, Jiangsu this year took place. Without doubt, those safety accidents not only threaten life safety, national property and environmental protection to people seriously, but also expose problems such as lack of on-site emergency personnel training and drill, lack of effective emergency plan and decision making after accidents.

The traditional emergency drill approaches are mainly paper or electronic learning and actual drills in the plant. Those methods are restricted by limited drill effect, single drill site and complex drill organization process. In the meantime, the training on production site is restricted and dangerous. Those objective conditions also restrict safety officers to enter the plant, leading to less understanding of production process and safety situations. A set of petrochemical process security simulation and emergency drill system makes safety officers understand the entire petrochemical process and specific process data through computer. Meanwhile, according to authenticity and availability of simulation modeling technology, the safety officers could realize process simulation of production process and safety drill simulation of accident scenes. Therefore, domestic and overseas petrochemical
engineering industry has started applying security simulation platform and corresponding emergency drill system to pre-simulation drill and emergency plan simulation of the accident scenes.

However, the production process of petrochemical engineering industry is featured in large production scale, long process and multiple procedures. It is difficult to make prediction, early warning, security monitoring, failure diagnosis and tracing. It requires highly for establishment of security simulation and emergency drill system. The petrochemical process security simulation and emergency drill platform in this paper is divided to two parts: intelligent simulation platform and emergency drill system. The intelligent simulation platform simulates the petrochemical process according to the basic idea of “equipment modeling and organic combination”. Through modeling of designated accident scenes and applying knowledge graph and semantic matching technology, the emergency drill system combines corresponding production process simulation model to inspect implementation results of emergency plans aiming at different accident sites so as to support on-site commander to make effective decision making and help safety officers know accident site and practice the solutions. The design ideas, some details and specific functions of the platform are introduced in this paper.

2. Platform structure

2.1 Platform design

The petrochemical process security simulation and emergency drill platform is mainly comprised of modeling and simulation. The modeling part provides technical support of the simulation part, while the simulation part provides information feedback for management and correction of modeling part. The two parts are linked through relevant drive engine.

![Platform frame diagram](image)

Fig. 1 Platform frame diagram

The modeling part contains visualization, graphic modeling, module management and bottom layer support. With support of aforesaid four sections, the modeling part could realize visualized modeling of production equipment; equipment model and accident phenomenon model are modeled separately and managed uniformly, and combined organically according to demands to form risk equipment model; the data of bottom layer support is used for model calculation and calibration.

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The simulation part contains emergency drill service, semi-physical simulation and 3D scene services; meanwhile, the simulation data could be used to correct modeling process.

2.2 Modeling method

(1) Mechanism modeling

The mechanism modeling is an accurate mathematical model established based on transfer mechanism of material flow in equipment or the correlation mechanism between modeling object and production process. It is known as the “white-box model” due to extensive applicability and powerful adjustability. In the modeling mechanism, corresponding physical and chemical formula and
mathematical formulation are referred to, involving: material property equation, chemical reaction law, basic circuit law and common mass balance equation, energy balance equation, momentum balance equation, and phase equilibrium equation; the common form of mechanism model is a equation set. By solving the equation set, the dynamic information of the object can be acquired.

The modeling parameters of mechanism modeling method have distinct physical significance, and are easy to adjust. They could not only express external characteristics of the object, but also keep internal characteristics of object and actual system consistent. Particularly in petrochemical production process, the mechanism model is usually used to realize repeated model utilization through parameter adjustment, and is greatly applicable. The mechanism modeling method usually needs accurate expression formula since the object is not known sufficiently or mathematical expression formula is too complex. It is not easy to realize in actual application. In the meantime, the parameters of known expression formula and parameters during the process shall be corrected for multiple times to get accurate results. Under the background of multiple mechanism model parameters, the correction workload is large and also affects modeling efficiency.

(2) Data modeling

Data modeling is a modeling method based on data-drive ideas. It acquires model after mathematical processing according to historical data of input and output. Different from mechanism modeling, the data modeling process only uses input and output data, and many specific parameters are unnecessary; therefore, it is known as the “black-box model”. Since the model fitness is favorable based on data modeling method, and modeling process is simple, and meanwhile the modeling process could be combined with many efficient computer algorithms, it is a hot spot of research in process industry modeling field.

The common data modeling methods are as follows: basic modeling method, including unsupervised independent principal component analysis and principal component analysis method, and supervised partial least squares (PLS); multi-modal and nonlinear process data modeling method, such as fuzzy-grey cognition network modeling method; dynamic process modeling method such as large-scale modeling based on canonical variate analysis method. The advantage of the data modeling method is small parameter number and simple realization process. When model precision is approaching, the data modeling method is usually selected to replace the mechanism modeling method.

3. Platform function

3.1 Simulation modeling

(1) Process simulation

The petrochemical production process is a dynamic process of materials in each kind of equipment (heat exchanger, tank, tower and reactor) such as feeding, charging and stacking. The process parameter calculation of equipment is based on mechanism model according to the rigorous chemical engineering theory or based on the simplified model according to reliable numerical analysis.
Accidents are the changes in equipment operating status due to changes of equipment risks or external conditions. Such change may damage equipment or other peripheral devices, or change product quality, leading to nonconforming products. The accident model of the device describes the changes of each process parameter of each set of equipment under accident status.

(3) 3D modeling

3D modeling mainly adopts 3D MAX and Unity program to establish 3D scenario, which may either be displayed on common display or on VR head-mounted display. Data exchanges between 3D scenario and simulation model. The process data shown on 3D scenario is from simulation model. In 3D scenario, the manual valve and switch could be operated, and the operation results will be sent back to simulation model for model calculation. Different roles are present in 3D scenario, and different roles shall finish designated operation as per operation specifications or emergency plan.

3.2 Emergency drill

(1) Semantic matching and emergency plan recommendation based on knowledge graph

With development of information and industrialization in the petrochemical field, the traditional deduction method is unable to meet demands for on-site information of emergency treatment and massive petrochemical process and emergency rescue knowledge capture and understanding; while the knowledge graph technology is superior in solving complete knowledge expression, accurate knowledge inquiry and expandability. Thus, it becomes a hot topic in current study.
When applying semantic understanding technology, the knowledge graph could be used to apply automatic digital processing to writing emergency plan so as to acquire formal definition of emergency plan, acquire semantic feature description, carry out intelligent plan matching and select the optimal emergency plan for the accident.

(2) Emergency drill system
The emergency drill system uses 3D modeling technology to apply visualized operation processing to emergency plan for the convenience of safety officers to operate and understand. During operation, safety officers will select corresponding scenario for training. In addition, the platform will recommend a corresponding emergency plan according to the knowledge graph and corresponding semantic feature matching function described aforesaid. Safety officers shall drill in accordance with operating procedures regulated in the emergency plan.

4. Conclusion
This platform establishes a simulation model corresponding to actual device with simulation modeling technology, and combines with knowledge graph technology to improve availability and usability of security simulation and emergency drill system. Meanwhile, the graph module setting technology is used to make simulation modeling easier. The 1:1 3D simulation scenario modeling technology is adopted to further improve visualization degree of emergency disposal process, and also provide technical support for decision making of emergency disposal process. The platform adopts mechanism modeling technology internally in combination with data modeling technology to respectively set model of equipment module and accident phenomenon module. The digitalization and deduction of the emergency plan can get implementation results of different emergency plans. The analysis results may provide feasible and effective plan and corresponding operation. Aforesaid technical support could display complex petrochemical process by various forms to deepen cognition of staff about on-site environment and accident so as to improve security prevention and accident treatment ability, further deepen the concept of security management, reduce accidents and lower losses brought about by accidents.

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