# Applying and Deploying Cyber Physical System in Monitoring and Managing Operations Under Mines and Underground Works

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**Abstract.** This paper presents results of a study on the current situation of monitoring underground gases in Vietnam, on the basis of which a model of cyber physical system will then be proposed in order to monitor and manage operations under mines and underground works. This system composes of: devices that measure Methane (CH4) [1] and Carbon monoxide (CO) [2] that are set up under mines in order to track these gases 24/7. The information received from these devices will be sent to on-ground stations and stored in the system database for collecting and managing information about gas detectors, warnings of fire and explosion, so timely warnings can be sent to workers under mines through the alarming system that is integrated in the detectors in case of unexpected incidents.

**Keywords:** Managing system of operations under mines and underground works
Methane detector · Carbon monoxide detector · Under-mine gas warning system

## 1 Introduction

In recent years, together with the general development of the whole country, the mine exploitation [3, 4] industry has gained an increasingly important role in Vietnam's economy. Over the past years, mineral exploitation has been accounted for up to 5.6% of Vietnam's GDP, largely contributing to the nation's renovation cause. However, mineral exploitation has also caused many bad effects on the environment including serious under-mine air pollution, health problems and even fatal accidents that underground workers are prone to. Therefore, enhancing work safety and productivity, preventing fire and explosion, and minimizing the waste of resources and energy are urgent requirements for the current mineral exploiting operation. That is why automatic devices that measure, monitor and alarm warning are more and more important both in reducing potential hazards and in timely rescue when an unexpected incident occurs. Moreover, they also support effective management and reduce the number of technical workers whose duties are simply to do measurements, keep records, do calculation and make reports.

At present in Vietnam, these conditions need to be improved in thousands of mines and underground works of all sizes.


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### 1.1 Developing a Cyber Physical System for Monitoring and Managing Operations Under Mines and Underground Works

This system comprises fixed and portable measuring devices, monitoring stations that receive data from wire and wireless connections, circuit switch that transmits data to monitoring software, and a database that stores the received information. These are made according to regulations on fire and explosion prevention under mines. The software installed in the central computer is highly practical, easy to access and use with such functions as collecting and displaying data on mine-route maps and updating current data of the map. It also allows setting up and adjusting the alarming levels, controlling, sending automatic commands to switch off and on the electric equipment under mines, making statistical calculations, storing information and making reports on the status of gases daily, weekly and monthly, supporting remote supervision via the internet.

The whole system including hardwares and softwares is designed with openness, and is adaptable to the adding or removing measuring devices and functions when needed.

Measuring devices are installed under mines to measure and give on the spot alarming signals so that workers can quickly move out of the dangerous areas. Other devices play an immediate role that transmit information, distribute and process data so that the system can be operated synchronously and continuously on a 24/7 basis without interrupt or mistakes.

The software installed at the server: manage and monitor the measured data, set up alarming levels and power supply cut levels, set up power supply cut. Displaying measured data on the mine map, send commands to cut power to devices under mines when the concentration of gases exceeds dangerous levels. The database located at server can store and manage all information received from detectors chronically.

### 1.2 New Technologies Applied in the Project

Figure 1 shows the system structure and the diagram of connections of a centrally and automatically methane monitoring system. The system consists of 2 parts: on-ground and underground.

On-ground part: via the software of the system, the server can set up arguments for the system such as system configuration, manage the detectors, set alarming levels, set power supply cut levels, collect data from fixed and portable detectors underground, display the data of mine route map, send automatic alarming signals when the concentration of gases exceeds the set levels, send partial or interchannel power supply cut command, make statistic reports, store and search for data, update the map according to current status of exploitation under mines, allowing remote supervising via the internet. Moreover, on the ground there are data storing devices and a backup computer that automatically switches on backup mode when the server encounters an incident to ensure the continuity of the system. The circuit-switcher on the ground has the functions of transmitting and distributing data to intranet devices and devices in other systems.

Under-mine part: consisting of input/output devices which are fixed and portable (wireless) detectors.

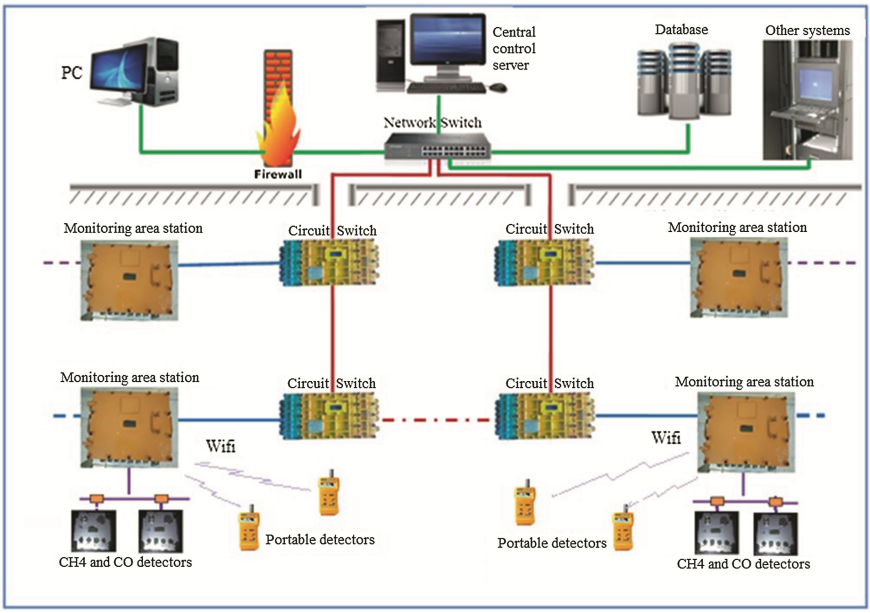



**Fig. 1.** The system diagram

+CH4 and CO detectors are fixed and have the functions of measuring the concentration of gases, displaying and send alarming signals when the concentration of gas goes beyond the set levels, automatically send power supply cut command to prevent risk of fire and explosion caused by high gas concentration under mines. Gas detectors transmit information/data to the centre through area control stations via RS485 line [5].

## 2 The Building of Database Structure

By practical investigation on the operating procedure, especially the storing and managing the information of gas detectors used in some underground gas tracking and monitoring systems, the researchers suggest model of storing information that needs monitoring in a system, including:

– Monitoring data information from gas detectors:

Data from gas detectors need to be stored in the database of the system including: The ordinal number of the name of detectors set by a person in charge, the ordinal number of data record from the main detector, the status of detector, alarming level 1, alarming level 2, the time of report, date of report submission, detailed description of the number of times of report and the standby mode.

This part provides detailed information about undermine gas detections at different times and continuously transmit to the system's central computerized controller.

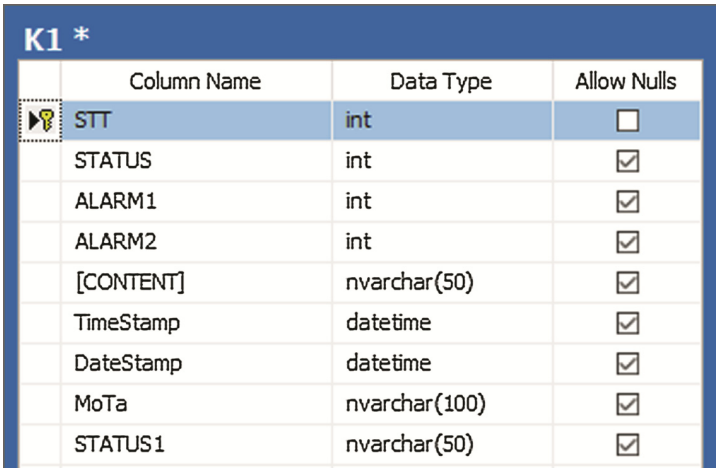
Function-related assumptions: each detector has it own storing table, with each detecting time is attached a unique code and automatically ascending in the database system.

– Managing the information of alarming data:

The alarming data lets us know for details about the times of alarming when there are systematic incidents like errors in starting detectors, power supply cut, lost of connection, detectors switching on and off. This part consists of the following information: alarming code which is the main key, status of switching on and off, timestamp of alarm, date of alarm, type of alarm indicating what happens to the system.

– Results and discussion:

From investigating and building the model of database structure to manage information, the researchers used MS SQL Server 2008 R2 [6, 7] to design the system. This is the most commonly used database managing software at present, with full functions that meet all technical requirements in managing information of the system. The researchers have set up all information table for every main key. Following are the results received on the MS SQL Server R2 (Fig. 2):


K1 *

| | Column Name | Data Type | Allow Nulls |
|---|---|---|---|
| 🔑 | STT | int | ☐ |
| | STATUS | int | ☑ |
| | ALARM1 | int | ☑ |
| | ALARM2 | int | ☑ |
| | [CONTENT] | nvarchar(50) | ☑ |
| | TimeStamp | datetime | ☑ |
| | DateStamp | datetime | ☑ |
| | MoTa | nvarchar(100) | ☑ |
| | STATUS1 | nvarchar(50) | ☑ |

**Fig. 2.** Table of data about gas detector channels.

Building storing information table according to function-related assumptions above include: Alarm, Error, separate detectors K1, K2, K3, K4, K5, K6, K7, K8 and other information fields on each table are run on MS SQL Server 2008 R2. The product pilot run gave correct results, and meet the requirements of receiving and managing data information received from under mine gas detectors to the system database. The function-related assumptions are justified.

The researchers have built a general and unified structure model for managing information transmitted from fixed and portable detectors, contributing to the monitoring and managing the operation under mine and underground works at present (Fig. 3).

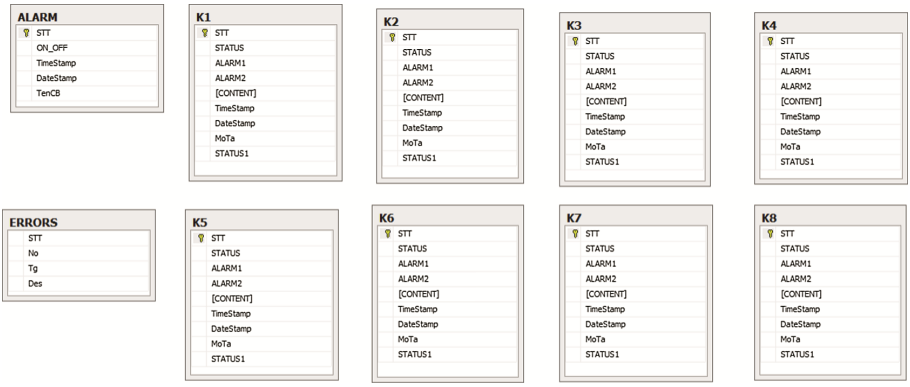



**Fig. 3.** Tables of data in the system

## 2.1 System Software

The environment tracking system used in mine exploitation is designed to measure and set alarm for gases such as CH4 and CO in the mines. The system will send an alarm signal when any one of the parameter exceeds the preset level of danger (sound and light), at the same time cut the power supply at the dangerous place. When the danger is resolved, the power supply can be turned on again from the centre or locally. This system can store, search and print out reports on environment parameters according to fixed templates.

Technical features:

- The system consists of: server computer, central controller, methane gas detector, CO detector, power supply and switch; repeater (used for large distance).
- The system can manage hundreds (or more) detectors.
- Time to update data ranges from 8–30 s (depending on the number of places that need monitoring).
- Can transmit data to the centre via typical cable, optical cable, wifi lines for portable hand devices.
- The system can send alarming signals by sound and light and automatically send command to cut power supply when there are gas related risks.
- Server displays the mine map, store and search for data in forms of tables or charts.
- The uses of this system:
  This software directly receives data of gases like CH4 and CO present at places under mines and transmit to centrally controlled computers at realtime, whose interface is simple and friendly so that person in charge can easily set up and use. This program can track and measure at any position of any detector under mine, helping the remote monitoring and collecting of data on the status of observation system, tracking multi-meter of gases, heat, and wind inside the mine climate according to real time. This program is written in Visual Basic language.

- Features of the program:
  - Setup details for sensor detectors like locations, types of detectors, detailed descriptions of detector, high and low level of gas warning.
  - Able to send measuring command to CO and CH4 detectors separately or all together in order to collect data and display on the screen.
  - Able to re-assign the detectors under mines using maps of mine routes.
  - Display concurrent parameters of CO and CH4 from all gas detectors in the system.
  - Able to track the value of gases received in graphs daily or a certain duration and print out for reports.
  - Display and print out the list of system warnings.
- Setting up sensor detectors:
  At this interface, the person in charge can use the following features:
  - Setup name for each channel.
  - Set up warning value 1 (alarm 1), warning value 2 (Alarm 2). Warning 1 is to remind and have lower value of warning compared to warning value 2. Warning value 2 is the official warning.
  - Set up measuring range for different channels.
  - Set up CH4 and CO gas detectors.

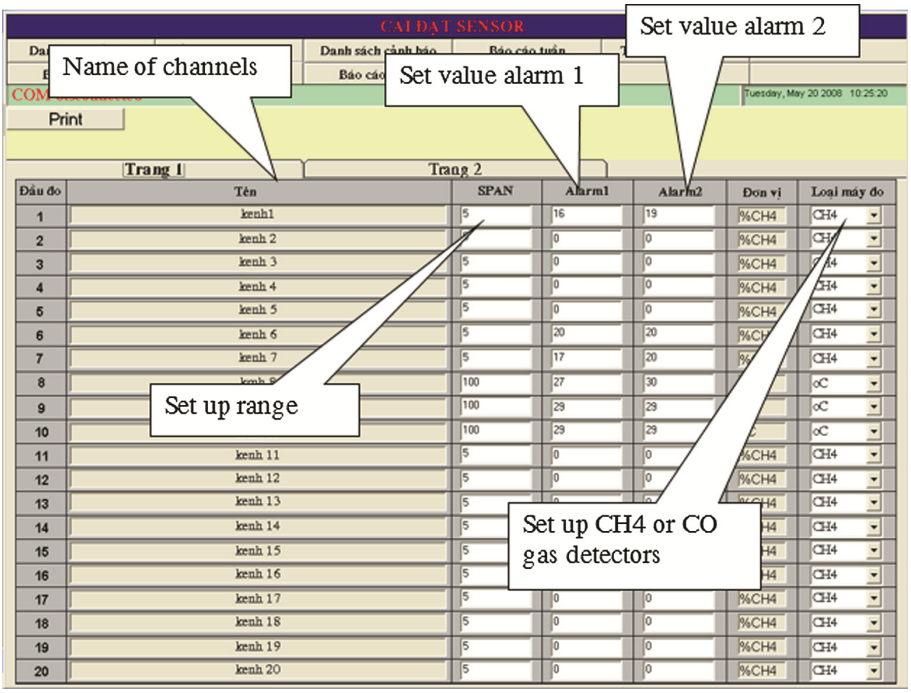



**Fig. 4.** Functions setup for sensor detectors

As shown in Fig. 4, we can set up names, range, alarming level 1, alarming level 2 and the types of detector. After that, during operation, if the value of received data exceeds the set up levels, the detectors will send alarming sound, on the server will send the same alarming sound.

- Tracking sensor detectors:
  Display the current status of measuring devices, set up for each channel. This interface is displayed on 2 pages. The first page displays channel 1 to channel 20, the second page displays channel 21 to channel 40. Features include:

– Display the current status of CO and CH4 measuring devices: whether it is on or off, the current measured value, alarming status, open-circuit, alarming level, status of sending measurement command of each devices.
– Display alarming levels for detectors: there are 2 alarming levels: alarming level 1 (alarm 1) and alarming level 2 (alarm 2).
– Display types of detector and measurement units.

The following Figure explains the current status of a channel in detail (Fig. 5).

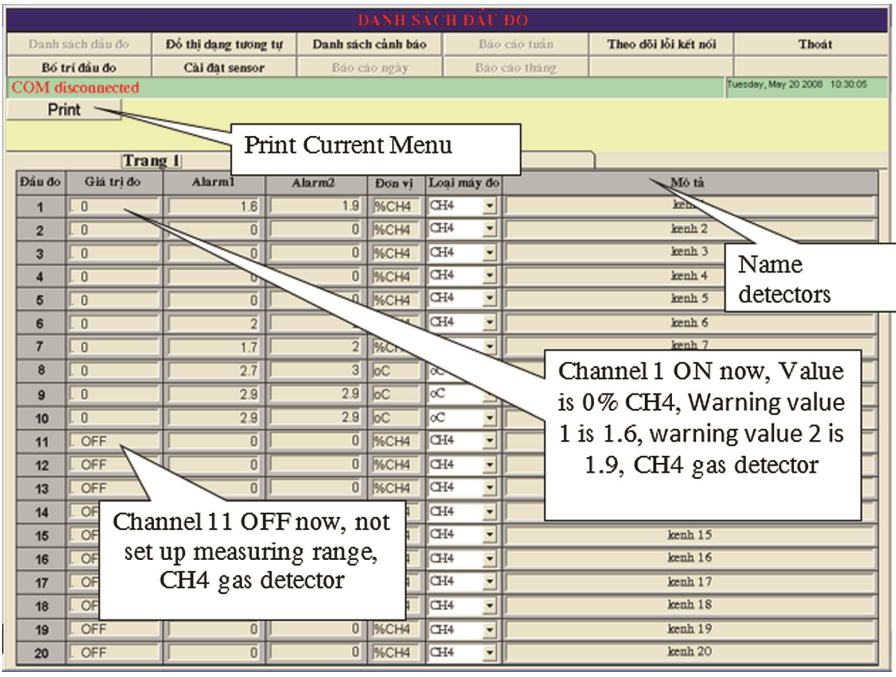



**Fig. 5.** Tracking all sensor detectors in the system

- Assigning gas detectors using map of mine routes:
  This part of the system helps the person in charge track measuring devices put in the map of mine route visually. The interface includes 10 pages, which users can add or remove channels of measuring displayed on each page. (there are 40 channels

maximum). Moreover, map of mine routes and the positions of CO and CH4 detectors can also be changed.

– Select the interface page: directly click the mouse on the page menu or click on previous/next page.
– Add or remove channel: Use mouse to tick the equivalent channel in the box "Add/remove channel" to add or remove the corresponding channels. The selected channel will hide from the map or reappear on the map accordingly. After that, symbols of channel of measuring can be altered on the maps (Fig. 6).

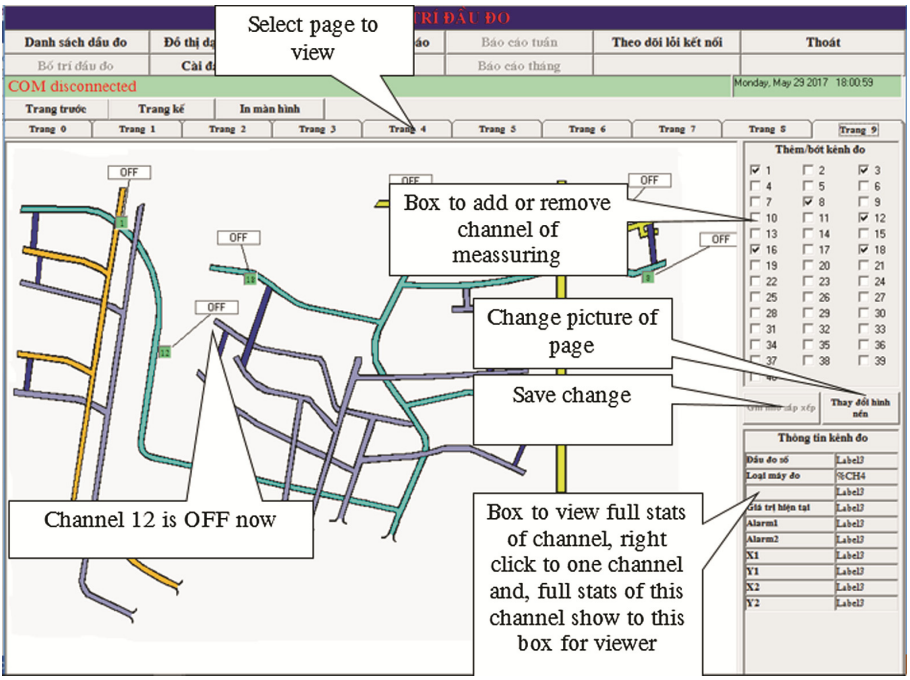



**Fig. 6.** Assigning multi-sensor gas detectors in the mine map

- Tracking graphic data (Fig. 7):
  – The concentration of CO and CH4 present in the air is shown in the form of continuous graph: digital value of measurements of each channel is connecting in the system help the person in charge easily monitor the parameters visually.
  – With the vertical axis showing the concentration of gases that need tracking and the horizontal line show values after every 3 h, 6 h, 12 h and 24 h.
  – Let users to track 6 different sensor detectors at the same time, with each detector assigned one color to distinguish between them.
  – Let users select dates to track data.
  – Send commands to selected detectors to continuously collect and display data of gases according to real time (Figs. 8 and 9).

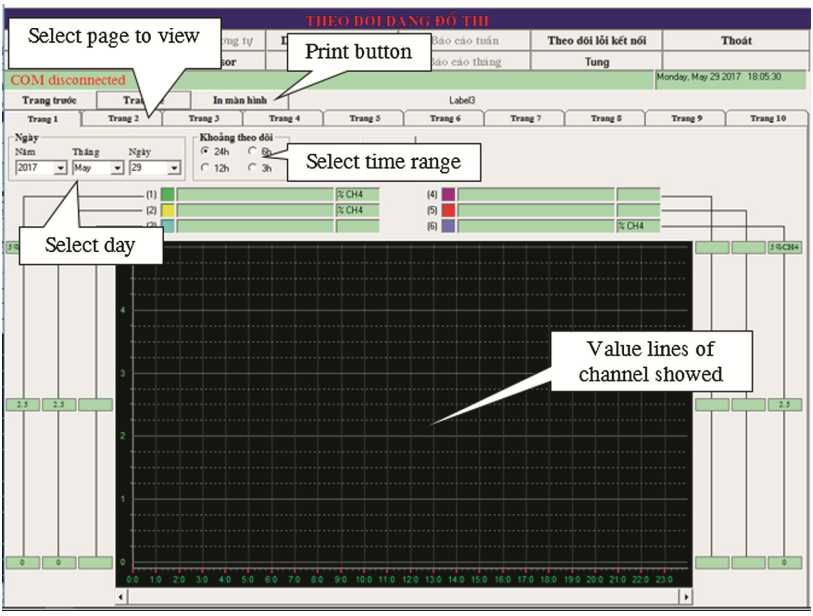



**Fig. 7.** Tracking data from sensor detectors in graphs. (Color figure online)

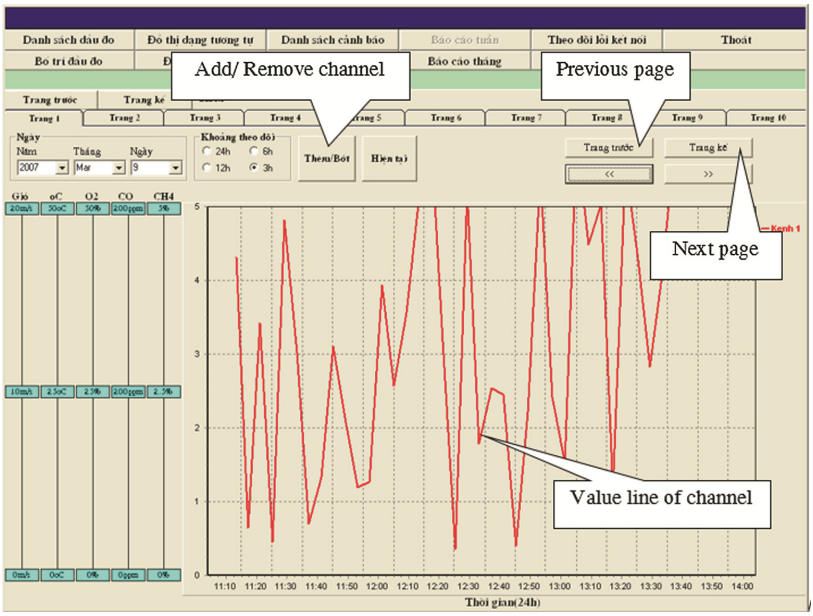



**Fig. 8.** Data of channel 1 in graph displayed in the program

| STT | ON_OFF | TimeStamp | DateStamp | TenCB | Address |
|---|---|---|---|---|---|
| 1 | ☑ | 10:49:41 AM | 9/11/2008 | HMI started | 192.168.6.14 |
| 2 | ☑ | 10:50:07 AM | 9/11/2008 | COM disconne | 192.168.6.3 |
| 3 | ☑ | 10:54:32 AM | 9/11/2008 | COM serial err | 192.168.6.7 |
| 4 | ☐ | 10:54:32 AM | 9/11/2008 | COM disconne | 192.168.6.1 |
| 5 | ☑ | 10:54:52 AM | 9/11/2008 | COM disconne | 192.168.1.3 |
| 6 | ☐ | 10:55:48 AM | 9/11/2008 | COM disconne | 192.168.1.16 |
| 7 | ☑ | 10:56:08 AM | 9/11/2008 | COM disconne | 192.168.1.27 |
| 8 | ☐ | 10:56:12 AM | 9/11/2008 | COM disconne | 192.168.6.2 |
| 9 | ☑ | 10:56:41 AM | 9/11/2008 | COM disconne | 192.168.6.5 |
| 10 | ☐ | 10:58:06 AM | 9/11/2008 | COM disconne | 192.168.1.1 |
| 11 | ☑ | 10:58:30 AM | 9/11/2008 | COM disconne | 192.168.1.1 |
| 12 | ☑ | 1:16:46 PM | 9/11/2008 | HMI started | 192.168.1.1 |
| 13 | ☑ | 5:09:53 PM | 9/24/2008 | HMI started | 192.168.1.2 |
| 14 | ☑ | 5:10:14 PM | 9/24/2008 | COM disconne | 192.168.1.2 |
| 15 | ☑ | 9:51:29 PM | 9/24/2008 | HMI started | 192.168.3.8 |

**Fig. 9.** The data of ALARM table in the central database

## 3 Conclusion

The above research results suggest a model of database structure used in receiving and managing information and operation under mines and underground works automatically by applying information technology and data transmission. With this model of database structure, the received data from gas detectors will be sent to the central server to be stored and processed easily and conveniently, especially when the number of times receiving results are numerous and increasing in time.

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