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Fault diagnosis and analysis of analog module in a nuclear power plant

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Abstract*—The model of analog input module of a nuclear power plant is sm336; f-ai 6 × 0 / 4-20mA Hart. The module is a standardized fault safety product of Siemens company. It is passivated in the application of T2000 control system. Through fault information diagnosis and analysis, the fault cause of the analog input module is determined to be communication failure, and then the root cause of the fault is found through microscopic observation.

Keywords- Analog input module; T2000 control system; Fault diagnosis; Communication failure

I. INTRODUCTION

A large number of abnormal alarms occurred in the main control room of unit 2 in a nuclear power plant. The TCS platform alarm showed that six channels, 2CEX1002/2002MP, 2GSE011MC, 2GPV1101/2101MP and 2VVP0001MP[1], triggered channel fault alarms, the red fault indicator (SF) of an AI module in 2GSE001AR cabinet is on, and the safety mode green light (SAFE) is off, indicating that the AI module is working in error, the module is faulty. After hot restarting, all channels display normal and abnormal alarm disappears.

DEVICE INFORMATION

Fault module is used to receive analog input data transmission and processing in industrial field, as shown in the figure 1.

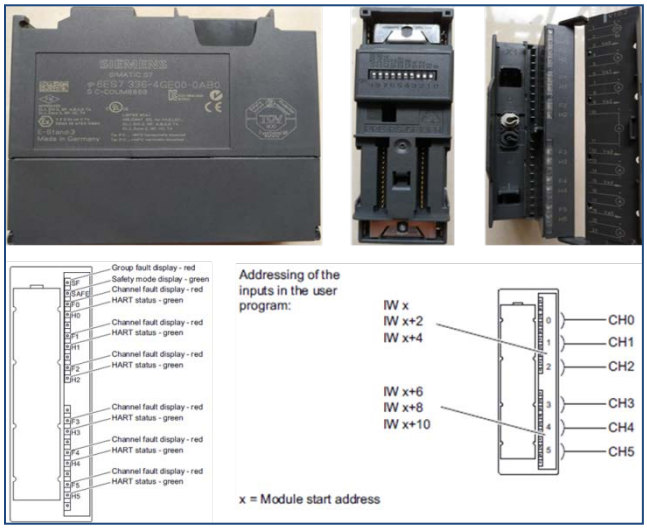

Fig.1 SM336;F-AI 6×0/4-20mA HART module

Call the fault diagnosis information of the Siemens module when the event occurs. The diagnosis information indicates that the module has communication fault, which leads to the module passivation, as shown in figure 2.

```
Event 332 of 1000:  Event ID 16# 79E5
F-I/O passivated
- Monitoring time exceeded at the safety frame detected in the F-CPU
Logical base address:     56
F-I/O database number:   4332
External error, Incoming event
03:50:31.974 AM  08/04/2018


Event 333 of 1000:  Event ID 16# 3942
Module problem or maintenance necessary
Module type: FM
Input address:    56
```

Fig2 Module fault diagnosis information

Regarding to the EOMM manual of the module, there are three failure modes of module passivation[2], as shown in figure 3.

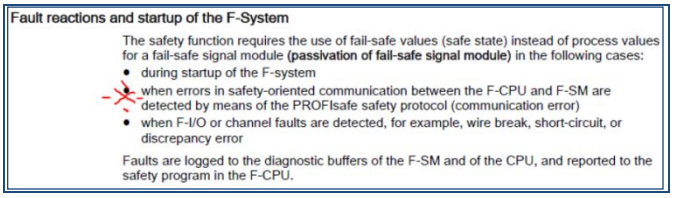

Fig.3 Fault response and startup of fail-safe system

According to the actual situation and the module fault diagnosis information, the module passivation is caused by communication failure, which is the second failure mode in the figure 3.

The communication function of the module is shown in figure 4. The red wireframe includes CPU chip, chip software configuration, module backplane pin interface and address dial switch.

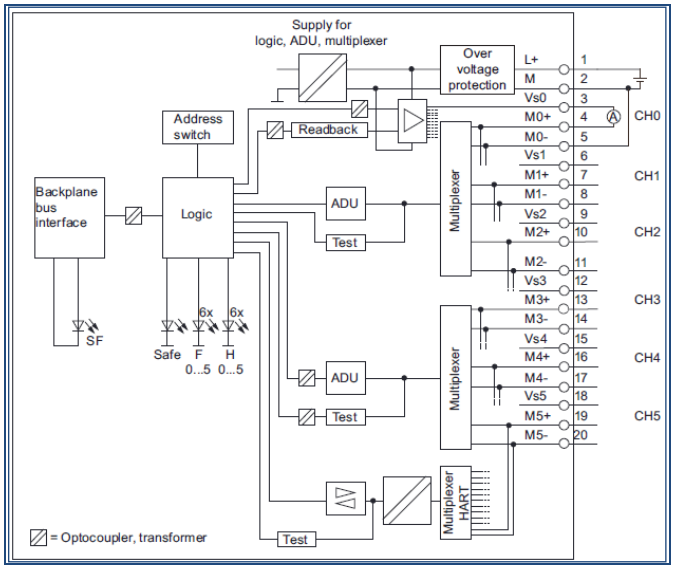

Fig.4 Schematic diagram of module circuit

The function of the address dial switch circuit board is set the address of on the rack, which is connected with the main circuit board of the module through the plug. The chip on the main circuit board can identify the module address by detecting the high and low level at the plug. As shown in figures 5.

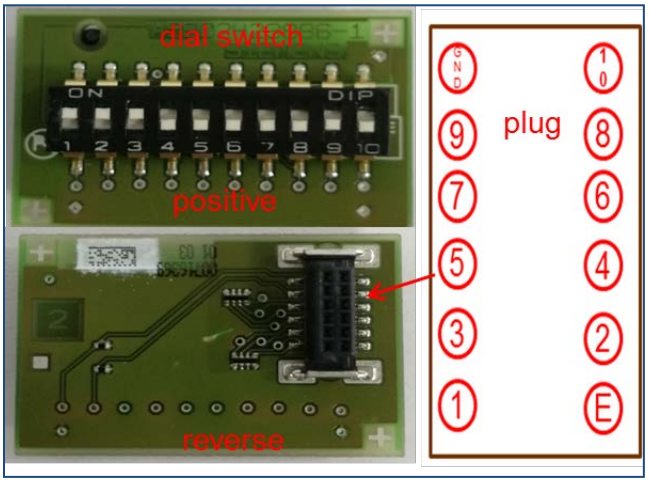

Fig.5 Address dial switch circuit board

CAUSE ANALYSIS

The processor of the module is 70F3235M1GC, which mainly provides communication and data operation functions, and is widely used in the industry with stable performance. If the module CPU is abnormal, it will cause the module communication failure. However, the function of the module will return to normal through hot restarting, so the possibility of CPU hardware failure of this module is low.

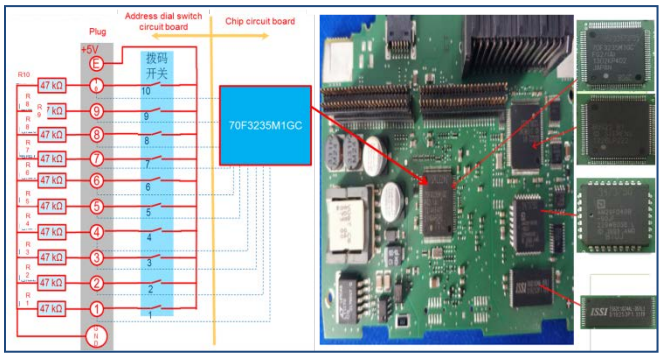

Fig.6 Schematic diagram of module address recognition

The module address dial switch has a total of 10 bits of address. The position of the module is 56 in the cabinet, which is inserted into the PCBA through the plug. Observe the morphology of switch pin and solder under scanning electron microscope (SEM) and metallographic microscope[3], as shown in figure 7.

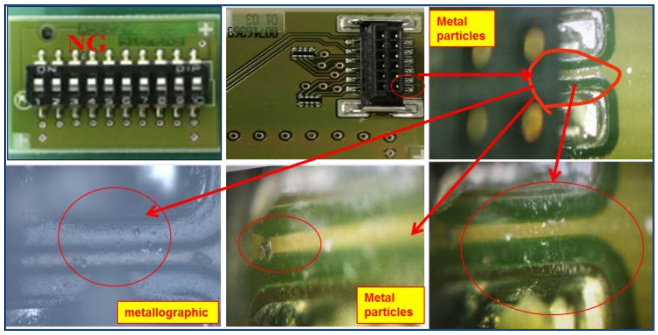

Fig.7 Morphology of address dial switch

The address dial switch PCBA was placed under the SEM. It was found that there were abnormal phenomena at E position and pin2 of power supply terminal, as shown in figures 8.

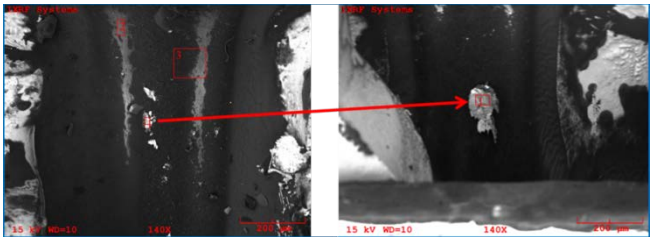

Fig. 8 SEM observation of pin of module address dial switch

The results of energy spectrum analysis are shown in figures 9 and table 1.

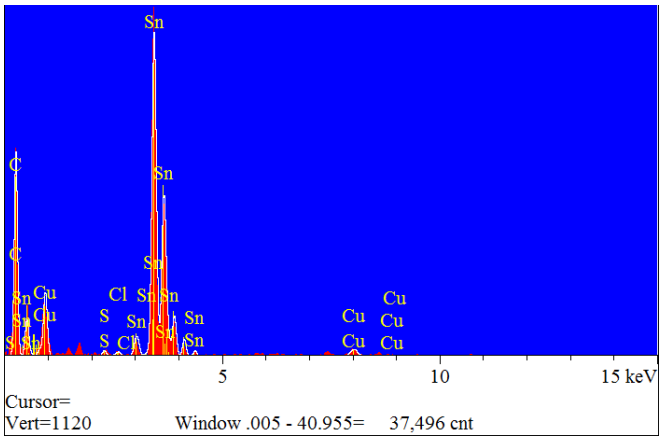

Fig.9 EDS analysis spectrum of module address dip switch pin

TABLE 1 EDS ANALYSIS DATA OF MODULE ADDRESS DIP SWITCH PIN

Elt.	Line	Atomic %	Conc	Units	MDL 3-sig	
C	*Ka*	*57.44*	*18.0*	*wt.%*	*.141*	
O	*Ka*	*14.83*	*6.2*	*wt.%*	*.256*	
S	*Ka*	*.45*	*.4*	*wt.%*	*.155*	
Cl	*Ka*	*.43*	*.4*	*wt.%*	*.175*	
Cu	*Ka*	*5.60*	*9.3*	*wt.%*	*1.136*	
Sn	*La*	*21.24*	*65.8*	*wt.%*	*.587*	
		100.00	*100.0*	*wt.%*		*Total*

The metal particles between the plug pins of the address dial switch circuit board are metal tin (Sn), which is the same as the material of the solder joint of the plug pin. It is the residual solder when the plug surface is mounted and welded.

Through the comparative analysis of the morphology observation and electrical performance measurement of the module, no abnormal phenomenon such as metal migration was found in the PCBA module[4], but there was solder residue at the plug pin of the address dip switch of the module.

Analysis of influence of solder residue

At present, SMT technology is widely used in PCB mounting, which has a high degree of automation. The E of the power supply of module, pin 2 and the GND position of copper foil in PCBA yellow area are all dispersed with solder. From the morphology analysis, it can be seen that the solder is residual when the plug is installed, as shown in figure 10.

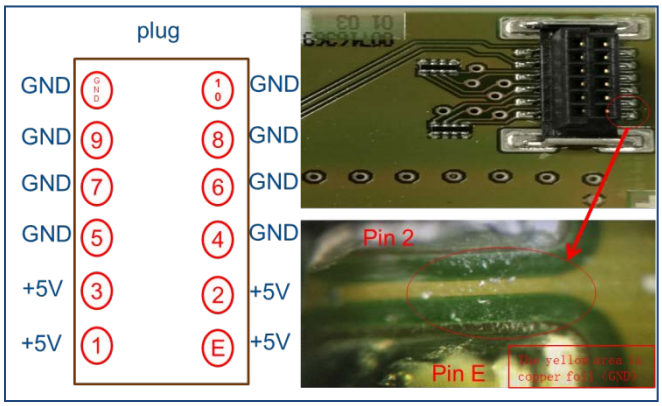

Fig.10 Potential distribution of plug pin

The address of the fault card is 56, and the dial switches 1, 2 and 3 are all closed, so the plug power supply, 1, 2 and 3 are at high level, and the rest are grounded. There is copper foil ground between pin E and pin 2, and metal particles are distributed between pin E of plug, copper foil ground and pin 2, pin E and pin 2 are high level. During the normal operation of the module, dust or moisture will cause the insulation resistance between pin E or pin 2 and the copper foil ground to be reduced or even short circuited, resulting in the voltage reduction at pin 2, pin 3 and pin 1, the high level at pin 1, pin 2 and pin 3 will become low level, and the module address will change, resulting in communication failure.

address change test of analog dial switch

As it is impossible to simulate the working condition of the change of the dial switch address, the welding method is adopted to draw out the dial switch pin, and the artificial disconnection or short connection is used to simulate the working condition changed of the dial switch address for the test, as shown in figure 11.

Fig.11 Analog module dial switch address change

Adjust the address of the module backplane dial switch, install the module into the cabinet, the SF indicator light of the module is always on in red, the reset fails, and the module passivation is not shown in the fault diagnosis information, as shown in figure 12.

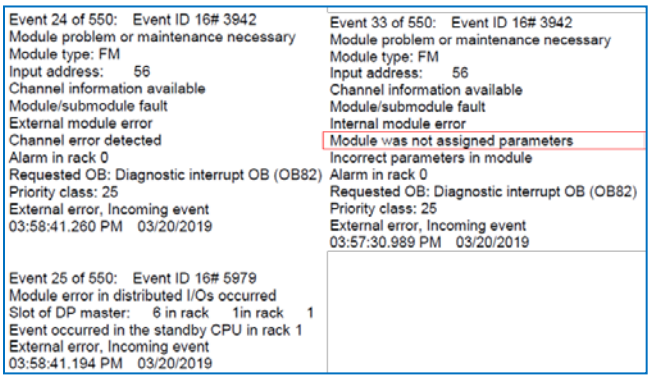

Fig.12 Module diagnostic information

As can be seen from the diagnostic information, the module is not passivated, and the CPU does not recognize the module.

Online adjustment address change test

Through many tests, when the module is installed in the cabinet according to the correct address, and the dial switch address is adjusted according to the above method, the module address is changed artificially for about 20 minutes, the whole module is passivated, the SF indicator light is always on, and the reset fails, as shown in figure 13.

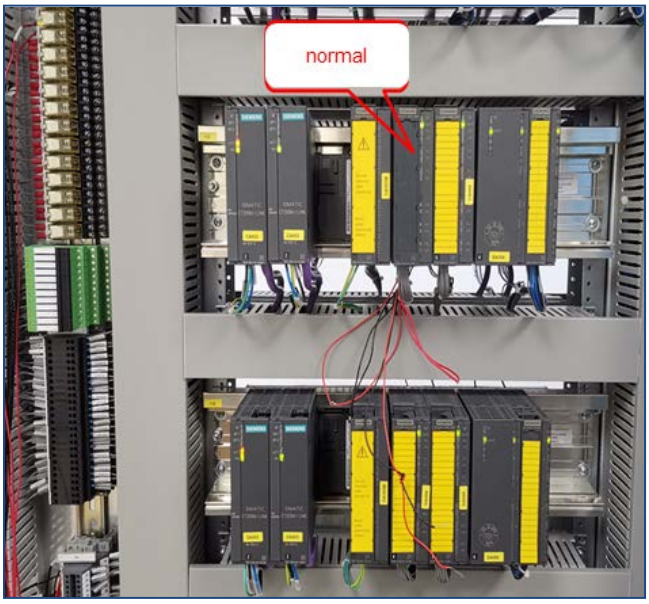

Fig.13 The experiment racks

When the address dial switch is adjusted to the correct address, the module can return to normal through hot restart and reset operation. The phenomenon is consistent with the field fault, and the fault diagnosis code is also the same, as shown in figure 14.

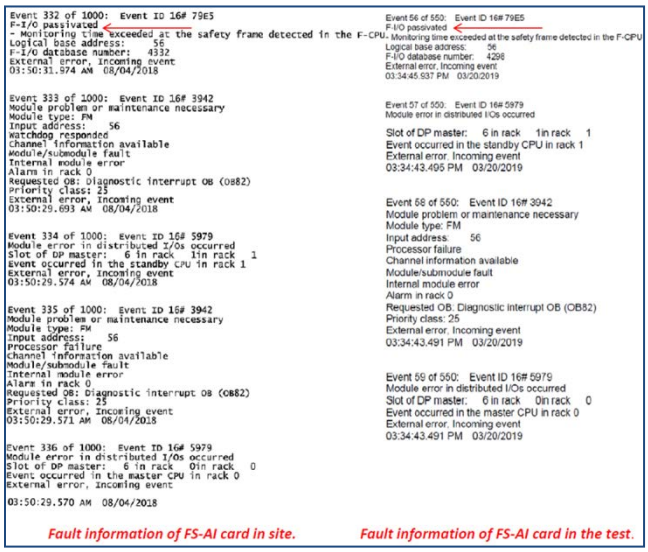

Fig.14 Comparison diagnostic information

When the module is installed in the cabinet according to the correct address, the dial switch address is changed artificially during the normal operation of the module, and the results are as follows:.

- After several short-term address changes and recovery, the module is normal;
- If the address is not recovered after changing the address, the module will be abnormal and the module will be passivated.

After many tests, it is found that the cycle of CPU scanning and detecting module is about 20 minutes, and there are two possibilities for the CPU not to detect the module

The module dial address changes for more than 20 minutes;

When the CPU detects the module, the module dial switch address just changes.

If the module address changes for a short time, such as the abnormal change of the resistance value between the pins of the module dial switch (no more than 20 minutes), and the CPU scanning time point happens, the module will have a fault, otherwise the module will not report a fault.

The test results show that the change of module address will lead to module passivation and communication failure.

CONCLUSION

According to the diagnosis information of module, and the failure mode of module passivation, it is determined that the module failure is caused by communication fault; there is copper foil ground wire between plug pin E and 2 of module address dip switch circuit board, and metal particles are distributed between plug pin E, copper foil ground and pin 2, pin E and pin 2 are high level. During the normal operation of the module, dust or moisture will cause the insulation

resistance to be reduced or even short circuited between pin E or pin 2 and the copper foil ground, resulting in the voltage reduction at pin 2, pin 3 and pin 1, the high level at pin 1, pin 2 and pin 3 will become low level, the module address will change, resulting in communication failure.

The solder residue in the plug pin of address dial switch circuit board is the most likely to cause module abnormality.

REFERENCES

[1] D521 Frequency based Speed Monitor Series with optional Analog Output8

[2] SIMATIC automation system S7-300 et 200m distributed IO station fault safety signal module

[3] Gjb-548b-2005 test methods and procedures for microelectronic devices

[4] Ipc-a-610 acceptability standard for electronic assembly

AUTHORS' BACKGROUND

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