Application of Fault Model of Gun Control System Based on Petri Net

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Abstract. By analyzing the structural composition and fault characteristics of a certain type of tank gun control system, the method of establishing the fault tree model is introduced. In order to solve the problem of the low-level repetitive events and incapable of dynamic diagnosis of fault tree in complex systems, the Petri net modeling method was applied to the fault diagnosis model. On the one hand, the diagnosis is performed using the incident matrix and the state equations, which improves the speed and efficiency of fault diagnosis. On the other hand, through the assignment and transfer of token, we can dynamically show the specific propagation process of the fault of gun control system. Combining with a certain type of test system in the project group, the application of petri net in fault diagnosis of gun control subsystem was realized.

Introduction

The tank working environment is complex and varied, and the work intensity is high. These factors can easily lead to various types of faults such as component damage and equipment operating parameters. Tank gun control system plays a role in stabilizing and controlling artillery, and its failure will affect the performance of the tank's firepower\[1\]. Therefore, the rapid diagnosis of the gun control system is of great significance. Figure 5 shows the structure of the gun control system.

In the 1960s, various types of fault diagnosis methods were gradually applied in military equipment and currently mainly include knowledge-based methods, analytical model-based methods and signal processing-based methods. Knowledge-based methods do not require precise mathematical models and have good diagnostic results.\[2,3\] At present, the fault tree analysis method has been widely used in tank fault repair, but there are still difficulties in building trees. The minimum cut set calculation is easy to produce combined explosion, neglecting the timing relationship of fault occurrence, and cannot dynamically express the fault propagation process. The petri net model tool has both an intuitive graphical representation and a rigorous mathematical definition, and is increasingly applied to various fault reasoning models. Ling-xun D et al. use the hybrid Petri net to represent the interaction between the continuous system and the discrete system and the evolution and operation of the system, and realize the autonomous decision of the tank fire control system.\[4\] Basile F et al. proposed a state estimation and fault diagnosis program for a labeled time Petri net system, which solved a certain number of linear programming problems in fault diagnosis tasks.\[5\] Jiang Z et al. proposed a method of simulating TPTS and its control system structure using a petri net to construct a controlled system with a battery energy storage system to avoid output interruption during fault detection and recovery of some important ES.\[6\] In this paper, the fault tree model is compared with the petri net. The petri net model is established by taking the common faults of the gun control system as an example. The fault is diagnosed by linear algebraic analysis method. The validity of the fault is verified by an example.
Fault Mode Analysis and Fault Tree Mode of Gun Control System

Gun Control System Composition and Working Principle

A certain type of gun control system is mainly composed of a control box, gun control box, motor amplifier, gyroscope group, power cylinder etc. The gun control system mainly has the following characteristics. First, the component relationship is complex. The gun control box is the core of the gun control system. It is associated with many components such as the console, angular velocity limiter, hydraulic amplifier, etc. and there are also links between the components. Second, the signal relationship is complex, involving various types of digital and analog electrical signals, hydraulic signals, torque signals. At the same time, according to the signal function, it can also be divided into an excitation signal and a response signal. The excitation signal includes a power-on signal and various types of driving signals, and the response signal includes various types of electrical signal output and operation states such as switching, lighting, and pitching horizontal motion; Third, the fault condition is complex. A single fault may cause one or more faults, and the fault of a certain component may also be divided into an indirect fault and a direct fault. The direct fault is caused by the component itself, and the indirect fault is caused by the propagation of other faults.

Gun Control System Fault Tree Model

The fault control tree of the gun control system is built down with the final fault as the top event, and the events are related by logical symbols until the bottom event. After analyzing the structural composition of the gun control system, combined with the record statistics of common fault phenomena, the fault tree model of the gun control system was established. Take the common fault phenomenon of the gun control system, "the gunner and the commander can't turn the turret" as an example. The fault tree is shown in Figure 1:

![Fault Tree Model](image)
After calculation, there are 10 minimum cut sets in the fault tree, and 210 items need to be calculated to solve the top event probability. As the tree capacity increases, the repetitive events increase, and the calculation amount will show an exponential growth trend. In order to improve the diagnostic efficiency, the model structure needs to be optimized.

**Establishment and Diagnosis of Petri Net Model**

**Construction of Faulty Petri net**

Define the Petri net model as a four-element array:

\[ \Sigma = \{S, T, F, M\} \]

\[ S = \{s_1, s_2, ..., s_m\} \] is a collection of places, indicates the fault status. \[ T = \{t_1, t_2, ..., t_n\} \] is a collection of transition. \[ F \subseteq (S \times T) \cup (T \times S) \] is a set of directed arcs connecting place and transition. \[ M: S \rightarrow \{s_1, s_2, ..., s_m\} \] is the model network identifier.

The establishment of the petri net model is shown in Figure 2:
See table 1 for the corresponding place information:

| place | Fault phenomenon          |
|-------|---------------------------|
| S₁    | The turret cannot rotate  |
| S₂    | Turret motor does not turn|
| S₄    | Motor amplifier does not turn|
| S₇    | G8-2 has no signal        |
| S₈    | G11-1 has no signal       |
| S₁₁   | Power distribution box failure |
| S₁₂   | G8-2 cable failure        |
| S₁₃   | G11-1 cable failure       |

The model structure can be described by the n×m-order correlation matrix A, and the state of the system is described by the state equation to dynamically display the fault propagation path. Normally, satisfying the state equation is only a necessary condition for fault accessibility, and the accuracy of the inference result cannot be guaranteed. However, the gun control system model can satisfy the acyclic condition, so it satisfies the conditional equation as a necessary and sufficient condition for the state to reach.

Some faults can cause multiple faults, and repeated events in the fault tree model account for a large proportion. In Figure 4, the petri net avoids the two repetitive events of S₁₁ "distribution box failure" and S₁₂ "motor amplifier failure", which reduces the underlying fault state by 11.7%, effectively simplifying the model structure.

**Diagnostic Steps based on Petri Net Model**

The model structure of the Petri net can be fully represented by the correlation matrix A, and the fault diagnosis process is shown in Figure 3:

![Fault diagnosis process](image-url)
System Simulation Experiment

The petri net model is applied to the project development system. The hardware part is based on the PXI bus computer and the high-speed capture card, including the test host, the gun control adapter, and the aerial cable. The software part uses LabWindows CVI for test program programming.

After entering the main interface, select the corresponding fault phenomenon, determine the diagnosis process according to the fault model, and enter the fault test interface, as shown in Figure 4:

![Figure 4. Gun control system](image)

In the test interface, the virtual instrument displays the pre-processed acquisition signal, and the tester combines the collected information and the fault phenomenon to make a step-by-step judgment. After the completion, the diagnosis result is printed in the form of a report. The experimental results show that the test system can quickly diagnose according to the fault phenomenon of the gun control system.

Conclusion

In this paper, the structural composition and failure mode of the tank gun control system are deeply analyzed. Using the petri net modeling, the library, transition and directed arc are used to replace the expression of events and logical symbols in the fault tree, which avoids the model. Repeated events appear, simplifying the model structure and improving the speed of understanding. Finally, according to the actual needs of the project, the fault diagnosis of the gun control system based on petri net modeling is realized. The feasibility and effectiveness of the method are verified, and the diagnostic efficiency of the gun control system is improved.

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