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Optimization of Equipment Maintenance of a Power Plant Based on TRIZ Theory

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Abstract: At present, China's electricity production mainly relies on thermal power plants, and thermal power generation is also the most commonly applied power generation method. The operation of thermal power plants requires the use of many mechanical devices, each of which has a different role and is a very important component of thermal power plants. Maintenance is an important part of the production management of power plants, which has a significant impact on the safety and economy of power plants. Thermal power plant equipment works under high temperature and high pressure as well as severe environmental conditions such as wear, corrosion and vibration. After a period of operation, the safety and economy of equipment operation will be affected by the wear and deformation of parts, the reduction of tightness, the shortening of material service life, and the appearance of scaling, slagging, ash plugging, corrosion and other phenomena on the heating surface. Therefore, improve the health level of equipment, prolong the service life of equipment, and ensure the safety and economy of unit operation. In this paper, we use TRIZ theory to optimize the equipment overhaul of thermal power plants, with the ideal final result as the goal, and use technical contradictions to develop relevant programs, thus solving the tediousness of daily equipment overhaul, improving overhaul efficiency and ensuring overhaul quality.

1. Introduction

With China's carbon peak and carbon neutral targets, the pace of clean and low-carbon transformation of the power system will be further accelerated [1], but with the large-scale development and high proportion of new energy sources connected to the grid, its volatility and randomness characteristics pose new challenges to the power balance and shock resistance of the power system, and the grid dispatching is also under pressure.

At present, the current situation of equipment maintenance in thermal power plants:

1) Negligence of technical management responsibilities, not conducive to development. In the traditional planned maintenance system, it is required to repair on due, strictly according to plan, which go round and begin again. Repeated disassembly and assembly, it has no any flexibility, to a large extent, leading to technical management personnel do not think about pioneering [2]. The technical management work keeps circle around in the same place, rigidifying the way of thinking of the technical staff. From the current situation, the production technology management cannot keep

up with the development of the situation, which is naturally related to the management system. In the planned maintenance system, because they do not have the right to make the arrangements for maintenance work, equipment cannot be timely maintenance. Dislocation of maintenance weakens the responsibility of equipment management personnel, when equipment problems occur, just blaming to "equipment accidents".

2) It is not conducive to prolonging the service life of the equipment. Under the planned maintenance system, it often leads to the following phenomena: First, the overhaul project cannot catch the keys, cannot distinguish between priorities [3], either is overhaul or underhaul. The second is the planned maintenance schedule generally have plenty of time, so there are phenomena that the defects or no defects was repaired at the same time. Originally, the state of the equipment is still relatively good, has potential to exploit. But due to the time schedule, it was disassembled and repaired for the good, to avoid future responsibility problems with the equipment. Third, due to excessive maintenance and disassembly, accelerating the wear and tear of the equipment. A good condition equipment become worse and worse, artificially shorten the service life of the equipment, unfavorable to the safe operation of equipment.

3) It is not conducive to improving the economic efficiency of the enterprise. Because the planned maintenance is not targeted, too much blind maintenance, reducing the utilization rate of equipment, wasting a lot of manpower [4], but also increased a lot of maintenance costs of ineffective expenditure, affecting the overall economic benefits of the enterprise.

2. The Application of TRIZ Theory in the Optimization of Equipment Maintenance

TRIZ theory successfully reveals the inner laws and principles of creation and invention, focusing on clarifying and emphasizing the contradictions in the system, with the goal of completely solving the contradictions and obtaining the final ideal result [5]. In this paper, the application of TRIZ theory to equipment overhaul management breaks the original equipment overhaul management idea and enables the formulation of relevant overhaul strategies in a clear and concise manner to ensure the quality of equipment overhaul.

2.1. Ideal Final Result

The final ideal resultis the key to solve the problem. The idealization is used to define the final ideal result (IFR) of the problem to clarify the direction and location of the ideal result, and to ensure the progress along this goal and obtain the ideal final result in the process of problem solving [6], thus avoiding the drawback of lack of goal in the traditional innovation involving methods and improving the efficiency of problem solving.

Its four characteristics are: 1) eliminates the defects of the original system 2) retains the advantages of the original system 3) does not make the system more complex 4) does not create new defects [7]. This paper is oriented to optimize the equipment overhaul process by sorting out the existing equipment overhaul obstacles and influencing factors by designing the final goal as a result, and IFR is specially formulated (as shown in Table 1).

2.2. Nine Screen Analysis Method

The nine screen analysis method can expand your thinking to include: System Axis: Subsystems, systems, supersystems [8]. Timeline: Past, Present, Future. Spatial Axis: Negative environment, neutral environment, and positive environment. The nine-screen thinking model can be applied to things and related things, in the form of different time stages and different environments. In this paper, we use the time process to segment the equipment overhaul by overhauling the equipment process (as shown in Figure 1).

Table 1: IFR

The ultimate goal of the design?	Prevention, autonomous maintenance
The end result of idealization?	The quality of inspection is improved, and the efficiency of maintenance personnel is increased
What are the obstacles to reaching the ideal result?	The inspection process is unclear, the maintenance plan is disorganized, the single equipment peripheral system equipment maintenance inspection is unclear
What is the result of the emergence of this disorder?	Cumbersome inspection process, untimely equipment elimination, short equipment normal operation cycle
What are the conditions under which this disorder does not occur?	Reasonable standardization of the overhaul process, the development of overhaul process cards, the blocking of the implicated system equipment, and the improvement of the overhaul process
What are the resources used to create these conditions?	Flowcharts, process cards, etc.

2.3. Cause and Effect Analysis Method

Cause and effect analysis method is the use of the development of things to predict the causal relationship [9]. It is based on the cause-and-effect relationship of the development and change of things, grasp the interrelationship between the main contradiction and the secondary contradiction of the development of things, according to the cause-and-effect relationship between things, know the cause and measure the effect or reverse fruit to check the cause. Cause and effect prediction analysis is the basis of the whole prediction analysis. Causal and effect analysis method (technique) applied to project management is a method to study and discuss the current problems of the project in depth step by step with the result as the characteristic and the cause as the factor. In accordance with the principle of sorting out the process, a cause-effect analysis diagram for equipment maintenance optimization is formed.

2.4. Technical Contradictions

A technical contradiction is an action that produces both useful and harmful effects, and the introduction of a useful effect or the elimination of a harmful effect that leads to the deterioration of one or several subsystems. Technical contradiction is often expressed as a contradiction between two subsystems in a system and always involves two basic parameters: When one of them is improved, the other one becomes worse. The technical contradictions of this problem are as follows:

(1) If the reliability of the overhaul quality is ensured, then the complexity of the overhaul operation control increases.

(2) If the increased power generation rate of thermal power plants is ensured, then the control complexity of maintenance operations increases.

(3) The control complexity of overhaul operations is increased if the improved efficiency of equipment operation is ensured.

(4) If improved equipment safety is ensured, then the control complexity of the overhaul operation is increased.

Therefore, improving the parameters: Operating efficiency (24), reliability (35), safety (37), productivity (44)

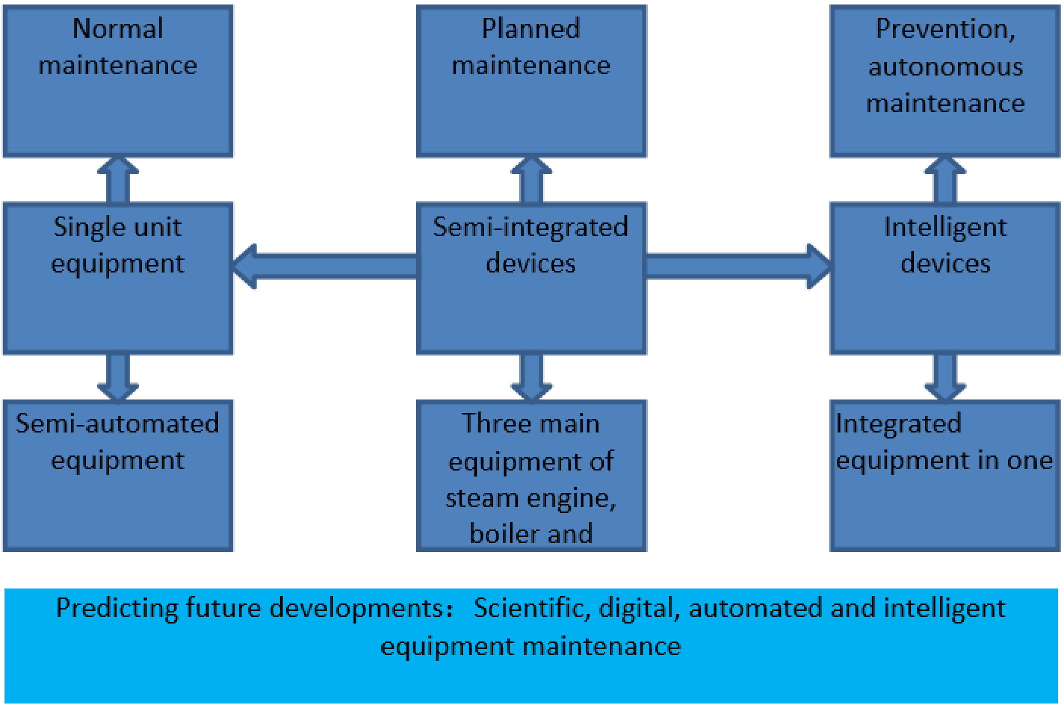

Figure 1: Nine screen

Deterioration parameters: Complexity of control (46) (as shown in Table 2)

Table 2: Technical contradiction matrix

Deterioration parameters / Improvement parameters	Complexity of control (46)
Operational efficiency (24)	25,1,37,4,10
Reliability (35)	1,19,25,37,10
Security (37)	25,37,9,26,4
Productivity (44)	25,1,19,7,24,16

3. Equipment Maintenance Optimization Solutions

Determine the principle of invention by comparing and filtering according to the TRIZ method: Separation principle (1); pre-action principle (10); periodic action principle (19); self-service principle (25).

The solution steps are as follows:

Step 1: By separation principle (1), the thermal power plant equipment maintenance is divided into: Boiler subsystem equipment maintenance; generator and transformer subsystem equipment maintenance, turbine subsystem equipment maintenance; auxiliary control and utility equipment subsystem equipment maintenance.

Step 2: Through the pre-action principle (10) and self-service principle (25), the equipment fault causation analysis diagram (shown in Table 3), the sub-system flow chart (shown in Fig. 2) for turbine sub-system equipment overhaul, the sub-system fault variation amount (shown in Fig. 3) for turbine sub-system equipment overhaul, and the single equipment overhaul process card (shown in Fig. 4) for turbine sub-system equipment overhaul are developed.

Table 3: The equipment fault causation analysis

Material	Machine	People				
Coal quality	Back-up, spare parts	Hydrogen, oil, water	Liquid ammonia, limestone and other raw materials	Measurement instrumentation issues	Measurement point failure	
Aging of equipment	Mechanical wear and tear	Mechanical Failure	Clogging or oil contamination	Media leakage	Environmental Factors	Equipment operating environment
Equipment corrosion	Lubrication system	Electrical Failure	Current and voltage jumps	Foreign sound, vibration	Operation and maintenance procedures	Equipment Management System
Test	Environment	Method				

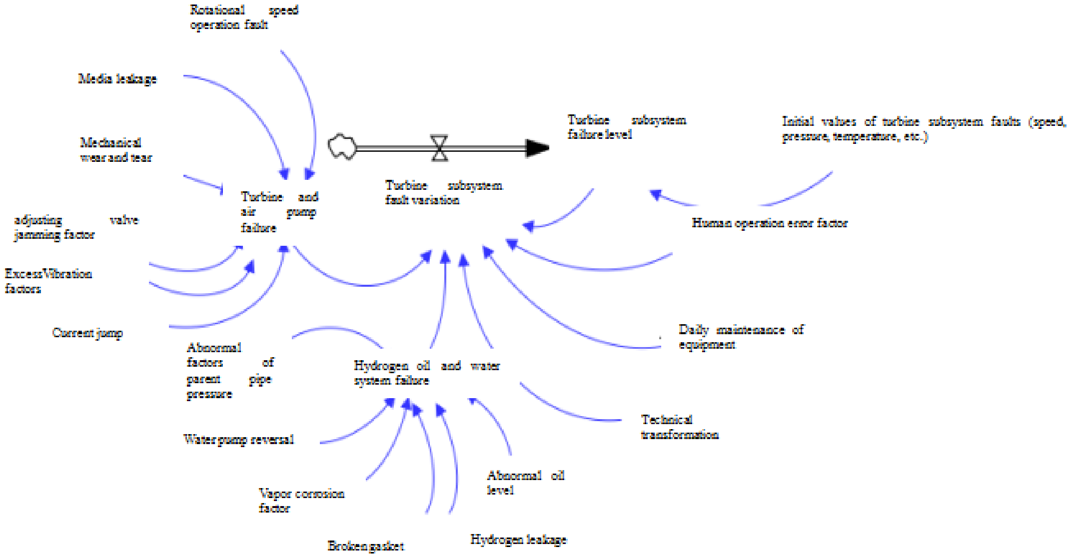

Figure 2: The sub-system flow chart

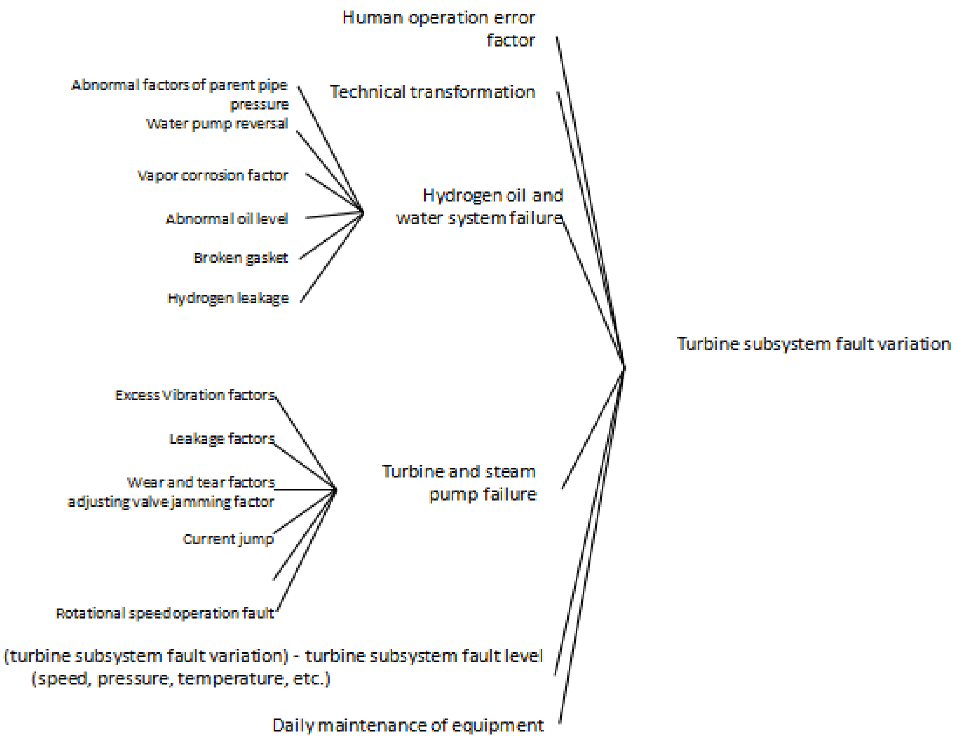

Figure 3: The sub-system fault variation amount

330MW generator XX overhaul quality process management card

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Figure 4: The single equipment overhaul process card

Step 3: Through the principle of cyclic action (19), regular maintenance of equipment (shown in Figure 5) work is developed, including lubrication, tightening, adjustment, and sanitary cleaning.

330MW Unit Maintenance Periodic Worksheet

330MW steam engine overhaul specialty Year Month

No.	Device or system name	Job Description	Time interval	Responsible team	Acceptance level	Receiver's signature
1	Steam turbine	Measurement, oil pressure, oil temperature recording				
2	#1 Turbine	Vibration measurement				
3	#2 Turbine	Vibration measurement				
4	#1 machine A/B small machine	Vibration measurement				
5	#2 machine A/B small machine	Vibration measurement				
6	#1 sealed oil vacuum pump	Go for it!				
7	#2 sealed oil vacuum pump	Go for it!				
8	#1 machine A\ B feed pump turbine bearing smoke exhaust hole	Sweeping				
9	#2 machine A\ B feed pump turbine bearing smoke exhaust hole	Sweeping				
10	#1 machine A/B circulating feed water pump	Vibration measurement				
11	#2 machine A/B circulating feed water pump	Vibration measurement				
12	#1 machine A/B steam-driven feed water pump	Vibration measurement				
13	#2 machine A/B steam-driven feed water pump	Vibration measurement				

Figure 5: Regular maintenance of equipment

4. Conclusion

This paper integrates TRIZ theory into equipment maintenance management for the first time, which improves equipment management and ensures the efficiency of maintenance personnel with remarkable results. It also divides the overall thermal power plant equipment maintenance into blocks and integrates systematic preventive maintenance, so that the defects can be inspected and overhauled in advance.

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