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Reliability Assessment of a Steam Power Generating Plant: A Case Study of Sapele Power Station

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Abstract
This study presents a comprehensive reliability assessment of a steam power generating plant using operational data from Sapele Power Station over a ten-year period (2004–2013). Key reliability indices including failure rate, Mean Time Between Failures (MTBF), and system reliability were evaluated for turbine, boiler, and electrical subsystems. Reliability is defined as the probability of a system performing without failure over a specified period under stated conditions [4]. Results indicate high reliability performance of turbine and generator subsystems, while boiler components exhibited relatively lower reliability due to operational constraints. The findings provide a basis for improved maintenance strategies and enhanced power system availability [3].

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I. Introduction

Reliable power generation is essential for economic growth and industrial development. Power system reliability has been identified as a key performance indicator alongside efficiency and cost [9]. However, many power systems experience outages due to component failures and poor maintenance strategies [8].
Reliability engineering provides tools for evaluating system performance and predicting failures [4]. In power systems, reliability assessment helps ensure continuous electricity supply and supports effective planning [3].

II. Methodology

Data spanning 2004–2013 were obtained from maintenance records of turbine, boiler, and electrical subsystems. Reliability evaluation was conducted using standard indices such as failure rate, MTBF, and reliability function [4].
The exponential distribution was used due to its suitability for constant failure rate systems [14]. This approach is widely applied in power system reliability studies [5].

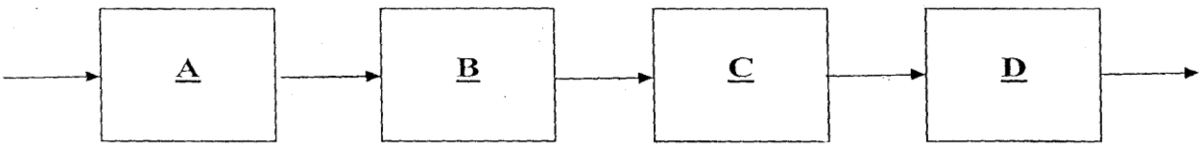

Figure 1: Series System Reliability

Usually, the reliability of the series system would be given by:

$$R_{sys=} R_a \times R_b \times R_c \times R_d \qquad (9)$$

where, R_{sys} =Reliability of the system
R_a= Reliability of component A
R_b = Reliability of component B
R_c= Reliability of component C
R_d = Reliability of component D
Parallel System Reliability
Consider two units A and B connected in parallel as shown in Figure 2. The system fails only when both A and B have failed. If the probabilities of failure are independent, then the reliability of the system in parallel is:
The Reliability of a Series System is given by:

$$R_{system\,=} 1 - [(1 - R_a) \times (1 - R_b)] \qquad (10)$$

where,R_{system} =Reliability of the system

R_a= Reliability of component A
R_b = Reliability of component B

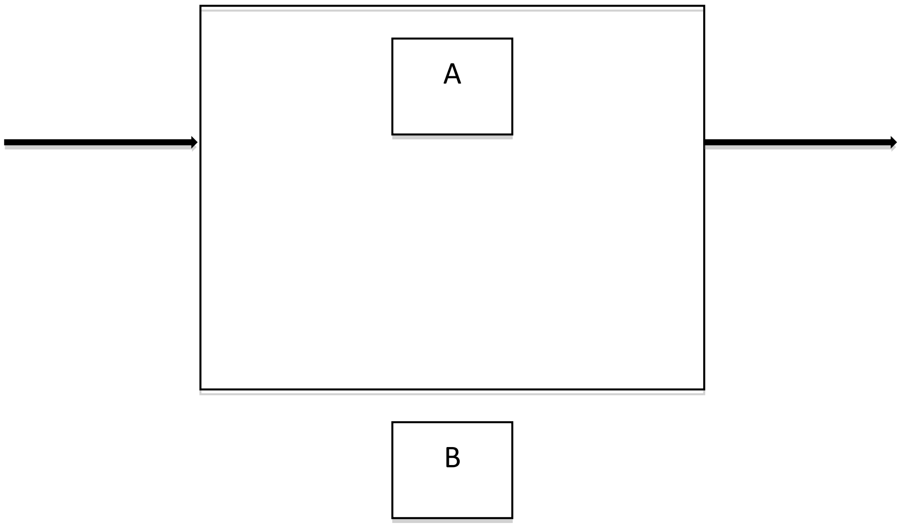

Figure 2: Parallel System

III. Results and Discussion

The analysis shows that turbine subsystems exhibited high reliability, with MTBF values exceeding 8700 hours in most years, indicating stable performance. High MTBF values correspond to improved system reliability and reduced failure frequency [4].

The generator transformer also demonstrated high reliability (approaching 0.999), consistent with findings in power system reliability literature [3]. However, the boiler subsystem showed lower reliability due to frequent failures in gas burner filters, which aligns with studies highlighting maintenance challenges in thermal plants [8].

Figure 5: Reliability block diagram of steam turbine plant

IV. Conclusion

The study demonstrates that overall system reliability is strongly dependent on individual component performance. Improving weak subsystems can significantly enhance plant availability and efficiency [9].

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