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Method for Assessing the Overall Performance Level of a Production System Through A Reverse Probabilistic Study Considering Operational Reliability

Kenza Berrada[1]

Faculty of Sciences and Techniques, Sidi Mohamed Ben Abdellah University of Morocco, Kenza. berrada@usmba.ac.ma

Brahim Herrou[2]

Higher school of technology, Sidi Mohamed Ben Abdellah University of Morocco, brahimherrou@yahoo.fr

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***Abstract* – The performance level of a production system is not always easy to identify, and researchers often need this information to find out the overall state of the system before proceeding with a case study. This article proposes a probabilistic analysis linking a reverse study based on the collection of data in the shop floor, to exploit them in a theoretical study in the office to re-exploit them in the shop floor. The aim is to carry out a review on the shop floor, covering all the parameters of operational safety, by a multi-functional team whose mission is to ensure that all failure modes are verified. The result is a real performance level chosen from among three: low, moderate, and high. This rapid approach enables us to optimize downtimes by always having an idea of the system's performance level, which in turn enables us to act directly on the faulty parameter.**

***Index Terms* – Dependability, Performance level, Probabilistic analysis, Production system**

INTRODUCTION

Production system performance levels are a critical aspect of any manufacturing process. The ability to maintain high performance levels is essential to meet customer demands, reduce costs and increase profitability. Many factors influence production system performance levels, including equipment reliability, maintenance practices and workforce training. One of the most important factors influencing production system performance levels is equipment reliability. When machines break down or fail to operate at peak efficiency, this can lead to costly downtime and delays in achieving production targets.

To limit these risks, manufacturers need to invest in regular maintenance and repair of their equipment and implement strategies such as predictive maintenance to identify and resolve potential problems before they become major issues. In addition to equipment reliability, maintenance practices also play a crucial role in determining the performance levels of production systems. Effective maintenance programs must be designed to minimize downtime, reduce costs, and ensure compliance with regulatory requirements. To achieve these objectives, manufacturers need to implement a range of maintenance practices, including preventive, corrective and condition-based maintenance. They must also train their staff in appropriate maintenance techniques and provide them with the tools and resources they need to carry out these tasks. The performance levels of production systems are also strongly influenced by the skills and knowledge of the workforce. Manufacturers need to invest in comprehensive training programs that equip workers with the technical expertise and operational know-how needed to operate machines safely and efficiently. Effective training programs need to cover a wide range of topics, including equipment operation, maintenance procedures, safety protocols and quality control standards. To monitor and measure production system performance levels, manufacturers need to establish a set of key performance indicators (KPIs) that reflect their specific goals and objectives.

These indicators should be regularly monitored and analyzed to identify areas for improvement and optimize overall system performance.

By tracking these indicators, manufacturers can better understand the factors that determine performance levels and make data-driven decisions to improve efficiency and profitability. Since dependability refers to a system's ability to operate reliably and safely, without causing damage or harm to users or the environment, engineers need to consider many factors to ensure a system's dependability, including component reliability, preventive maintenance, and safety protocols. It is in this sense that performance level and dependability are two closely related concepts, as an unsafe system can also have poor performance. The aim of this article is to propose a risk analysis method based on a probabilistic approach and on operational safety parameters (Reliability-Maintenance-Availability-Safety) to assess the overall performance level of a production system through the performance level of each of the operational safety parameters, which is carried out based on analogous risk parameters (Severity-Frequency- Probability). The aim is to answer the following question:

-What is the current performance level of a given production system?

We did not find enough research in the literature on the performance levels of a production system throughout its life cycle. Existing operational safety studies are concerned with monitoring the performance of a system under development, to ensure that the announced performance levels are maintained throughout the system's operational life, and to detect any ageing phenomena likely to degrade them. However, the performance announced during the development phase is not necessarily the one perceived throughout the production system's life cycle. The aim is to propose a method for defining the overall level of performance of a production system, based on the four parameters of operational reliability, so as to be better able to assess the state of the system at any given time, and take action in good time.

DEPENDABILITY

In order to market their products, the Dodge Brothers (car dealers of a company called REED BROTHERS DODGE) first used the term dependability around 1914 in their advertising, making it synonymous with the robust construction, quality and power of their vehicles. The term appeared in the dictionary in 1930 [1]. Dependability is based on several key concepts: reliability, availability, maintainability and safety. Reliability refers to a system's ability to operate without failure for a given period of time. Availability measures a system's ability to be operational when required.

Maintainability refers to the ease with which a system can be maintained or repaired in the event of failure. And security refers to protection against internal and external threats that could compromise a system's dependability.

Mohamed et al. have developed models for assessing the performance of a production system through the parameters of operational reliability, while Reena and Basotia have also developed performance models enabling them to assess the strength of their cement plant. Kumar and Tawari have synthesized a number of approaches for evaluating system performance via these same parameters. Monika and Ashish were able to analyze the performance of a production unit in an industrial plant, while Sanusi and Yusuf also used dependability parameters to assess the performance of a computerized system. Choudhary et al. analyzed the reliability, availability and maintainability parameters of a cement plant, while Jagtap et al. analyzed the optimization of reliability and availability in a thermal power plant. All these studies were carried out with the aim of analyzing system performance, but none of them included a definition of the performance levels of a production system based on the four parameters of dependability. The proposed approach will serve as a basis for identifying these performance levels.

METHOD FOR EVALUATING THE PERFORMANCE LEVEL OF PRODUCTION SYSTEM

On the basis of a given production period and after calculating the key performance indicators of the production system, i.e. reliability, availability and maintainability, a risk analysis is carried out to assess the level of performance of each of these parameters, in addition to that of safety, using a probabilistic approach based on analogous risk parameters (Severity-Frequency-Probability).

I. Assessing the security performance level

The evaluation of the security performance level considers the following parameters [2]:

S: Severity of the hazardous situation, where:

- S1 = slight injury (normally reversible)
- S2 = serious injury (normally irreversible, including death)

F: Frequency of occurrence of the hazardous situation, where:

- F1 = rare to fairly frequent and/or short duration of exposure
- F2 = frequent to continuous and/or long exposure duration

P: Possibility of avoiding the hazardous situation, where :

- P1 = possible under certain conditions
- P2 = rarely possible

As shown on Figure 1, Performance levels A, B, C, D, E are respectively from highest to lowest.

The production system with a safety performance level SPL_A (SPL_A =S1+F1+P1) is considered to be a system with a high safety performance and whose function is established with the least risk to the machine operator, in contrast to a production system with a safety performance level of SPL_E (SPL_E =S2+F2+P2), which is considered a system with very low safety performance and whose function is established with the least risk to the machine user.

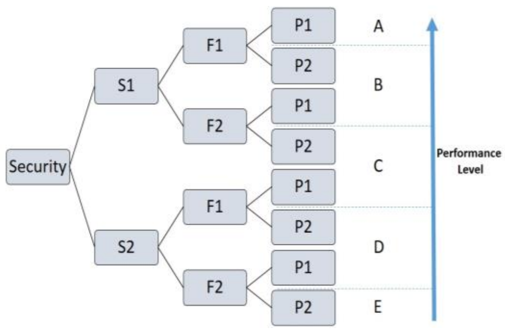

Figure 1 Security Risk Analysis By Tree Structure

II. Assessing the reliability performance level

The assessment of the reliability performance level considers the following parameters:

S: Severity of machine malfunction, where:

- S1 = Safe operation for a time greater than 80% of opening time
- S2= Operation disturbed for more than 20% of opening time

F: Frequency of occurrence of the malfunction, where:

- F1 = rare to fairly frequent and/or short duration of exposure
- F2 = frequent to continuous and/or long exposure duration

P: Possibility of avoiding the malfunction, where :

- P1 = possible under certain conditions
- P2 = rarely possible

As shown on Figure 2, the production system with a reliability performance level RPL_A (RPL_A =S1+F1+P1) is considered to be a system with high reliability performance and whose function is established with safe operation, in contrast to a production system with a reliability performance level RPL_E (RPL_E =S2+F2+P2), which is considered to be a system with very low reliability performance and whose function is established with disturbed operation.

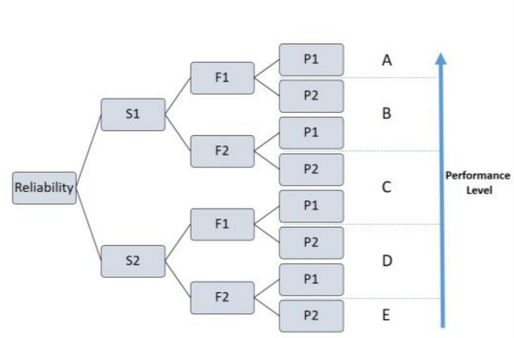

Figure 2 Reliability Risk Analysis By Tree Structure

III. Assessing the maintainability performance level

The assessment of the maintainability performance level considers the following parameters:

S: Severity of machine repair, where:

- S1 = Controlled repair
- S2 = Complex repair / New failure

F: Repair frequency, where :

- F1 = rare to fairly frequent and/or short duration of exposure
- F2 = frequent to continuous and/or long exposure duration

P: Possibility of avoiding repair, where :

- P1 = possible under certain conditions
- P2 = rarely possible

As shown on Figure 3, the production system with a maintainability performance level MPL_A (MPL_A =S1+F1+P1) is considered to be a system with a high maintainability performance and whose repair function is mastered in terms of simplicity and speed, in contrast to a production system with a maintainability performance level MPL_E (MPL_E =S2+F2+P2), which is considered to be a system with a very low maintainability performance and whose repair function is complex and much slower.

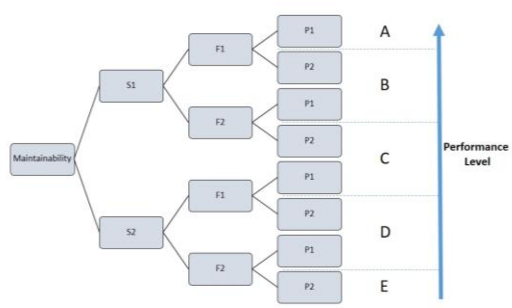

Figure 3 Maintainability Risk Analysis By Tree Structure

IV. Assessing the availability performance level

The evaluation of the availability performance level considers the following parameters:

S: Severity of machine stoppages, where:

- S1= Short stops: the total number of stops over the opening time is less than 96min (equivalent to 20% of the T.O of an 8h shift).
- S2 = Long stops: the total number of stops over the opening time exceeds 96min.

F: Stopping frequency, where :

- F1 = rare to fairly frequent and/or short duration of exposure
- F2 = frequent to continuous and/or long exposure duration

P: Possibility of avoiding stops, where :

- P1 = possible under certain conditions
- P2 = rarely possible

As shown on figure 4, the production system with an availability performance level APL_A (APL_A =S1+F1+P1) is considered tobe a system with high availability performance, whose downtime has no impact on the production system's output, unlike a production system with an availability performance level of APL_E (APL_E=S2+F2+P2), which is considered to be a system with very low availability performance, and whose downtimes are long and repetitive, or continuous, and have a negative impact on the production system's yield.

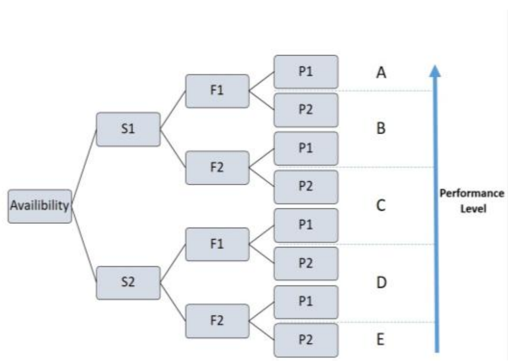

Figure 4 Availability Risk Analysis By Tree Structure

V. Gathering the risk assessment of the four parameters

A grid is composed by all the performance levels of each of the four parameters as shown in figure 5, each level is rated according to a weight ranging from 0 to 1, from the lowest to the highest where PLA =1; PLB =0.75; PLC =0.5; PLD =0.25 and PLE =0. Once the weights have been assigned to the corresponding level, the method consists of circling the performance level obtained by each parameter, to derive the average of their weights in order to classify the overall performance level of the production system according to the following criteria as on Figure 5:

- Between 0.75 and 1: The system is said to be "high-performance".
- Between 0.5 and 0.74: The system is said to be of "moderate performance".
- Between 0 and 0.49: The system is said to be "low performance".

Figure 5 Evaluation Grid For Overall Production System Performance Level

For example, as on Figure 6, at a reliability performance level of RPLB and a maintainability performance level of MPLC and an availability performance level of APLD and a security performance level of SPLC , we would assign the following weights:

RPLB=0.75, MPLC=0.5, APLD=0.25 and SPLC=0.5

Figure 6 Example Of How To Fill In The Global Performance Level Evaluation Grid

The average of all the performance levels for each parameter gives a value of 0.5 ((0.75+0.5+0.25+0.5)/4) , which means that this production system has a moderate performance level. Now that we've been able to situate the performance level of our production system, we can compare it with the performance level of the previous study, or possibly, the initial study, in order to trace the deviations from the latter and act firstly on the last perceived causes, review their effectiveness or, if not, look for new root causes through a diagnosis of the critical FMDS parameters.

CONCLUSION

Before embarking on any research into a given production system, it is essential to know how to situate it in terms of a suitable level of performance, hence the usefulness of this proposed approach, which, through an inverted study, enables us to project a level of performance for each of the parameters of operational safety (FMDS) based on a probabilistic analysis, and which finally gives us a clear idea of the overall level of performance of the production system, classified into 3 parts: low level with a weighting of 0 to 0.49; moderate from 0.5 to 0.74 and high from 0.75 to 1.

Once the overall performance level has been identified, we can act immediately on the most critical FMDS parameter, using the previous performance level as a basis for comparison between the initial performance level and the current one, and act first on the latest causes already identified in the previous study if the same parameter is failing, and then focus on the new root cause of the problem.

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AUTHOR INFORMATION

Kenza Berrada, PhD student, Industrial techniques laboratory, Faculty of science and technology, Sidi Mohammed Ben Abdellah university, Fez Morocco.

Brahim Herrou, Professor, Department of ndustrial and mechanical engineering, Sidi Mohammed Ben Abdellah university, Fez Morocco.