تقدير مؤشرات الصيانة لمحطة الرميلة للطاقة الكهربائية

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المستخلص:

يهف البحث إلى توظيف توزيع سوجاثا المحول التكعيبي المعدل ((MCT- SUJATHA في تقدير مؤشرات الصيانة للتوربين الخامس في محطة الرميلة للطاقة الكهربائية التي تتمثل في(تقدير متوسط الوقت بين العطلات (MTBF)، ومتوسط وقت التصليح (MTTR)، ومعدل الفشل (F.R) ، والإتاحية ($Availability$))، وذلك لبيان الفترة الزمنية بين عطلات التوربين والفترة الزمنية لتصليح التوربين وإمكانية بقائه يعمل بشكل جيد. وقد تم التوصل إلى أن التوزيع الملائم للفترات الزمنية للفشل، هو توزيع سوجاثا المحول التكعيبي المعدل (MCT–SUJATHA)، وتبين من التطبيق العملي أن نسبة متوسط وقت التصليح إلى متوسط الوقت بين العطلات كانت مساوية إلى (0.390)، وهذا مؤشر جيد يشير إلى انخفاض أوقات الفشل أو التوقفات، وقد أدى بدوره إلى ارتفاع مؤشر الإتاحية للتوربين الخامس في محطة الرميلة للطاقة الكهربائية والذي بلغ (0.719) نسبة قدرته على العمل وتنفيذ وظيفته.

الكلمات المفتاحية: مؤشـــرات الصيانة، متوسط الوقت بين العطلات، متوسط وقت التصليح ، الاتاحية ، تقدير .

Estimation of maintenance indicators for Rumaila Power Station

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Abstract:

The research aims to employ the Modified Cubic Transmuted Sujatha distribution **(MCT-SUJATHA)** to estimate the maintenance indicators of the fifth turbine in Rumaila Power Station, which are represented in (Estimation of Mean Time Between Failures **(MTBF),** Mean Time to Repair **(MTTR)**, Failure Rate **(F.R)**, and **Availability**). This is due to the data of the time period between turbine malfunctions and the time period for repair and the probability of survival the turbine working well, and the appropriate distribution of maintenance indicators has been reached, which is the distribution of the modified cubic transmuted **(MCT-SUJATHA)**, The practical application showed that the ratio of the mean time to repair to the mean time between failures was equal to (0.39). This is a good indicator indicating a decrease in failures times or stoppages, which in turn led to an increase in the availability index of the fifth turbine in the Rumaila Power Station, which amounted to (0.719) the percentage of its ability to work and carry out its function.

Keywords: maintenance indicators, mean time between failures, mean time to repair, availability, estimation.

Introduction:

The process of maintenance of machinery and equipment is one of the basic operations that the owners of facilities, factories and production factories care about in order to sustain the work of these machines and prevent their cessation, which causes the production process to stop, which in turn leads to the loss of those facilities and factories, It is worth noting that the times of failure and repair times of machinery and equipment are random variables and follow probability distributions according to the behavior of these times, Which prompted researchers to pay attention to maintenance indicators and not clear in several ways to evaluate the performance of machines , the research aim to estimate maintenance indicators for the fifth turbine of the Rumaila Electric Power Station by employing the modified cubic transmuted **(MCT-SUJATHA)**.

There have been many studies and researches conducted on maintenance indicators.:

In **(2019) (ANGGRADEW et al.)** He identified the main performance indicators of the maintenance process to improve the quality of service management, and found the most important key indicators of the maintenance process are (Availability, Mean Time Failures, Mean Time to Repair, Overall Effectiveness Of Equipment, Maintainability, Mean Time Between Failures, Reliability, Performance Rate, quality rate, maintenance time). In**(2020) (Zughayr and Ghabban) ,** he was interested in studying comprehensive productive maintenance and its great importance in industrial facilities as one of the most important ways to preserve material and human resources in a productive manner on an ongoing basis, using comprehensive production maintenance indicators, which are (Availability Factor, Performance Efficiency Of Fuel Quality, Reliability Factor), In **(2022), (Abu Shaala)** presented a research paper on the application of one of the methods of operations research represented by Macrov chains to measure the total failure rate of industrial facility lines and the possibility of moving from one operational state to another.

Probability distributions used in reliability analysis

The time periods between failures and repair periods are characterized by continuity and thus will generate a continuous variable with a continuous probability distribution and we have used in reliability analysis as the following distribution:

Modified Cubic Transmuted Sujatha Distribution (MCT-SUJATHA)

The random variable X follows the modified cubic transmuted Sujatha distribution **(MCT-SUJATHA)**, and the probability density function is represented by the following equation:

$$f_{MCT-Suj}(x,\alpha,\theta,\lambda) = \Bigg\{1-\lambda(\theta-1) + \lambda\left[1-\left[1+\frac{\alpha x(\alpha x+\alpha+2)}{\alpha^2+\alpha+2}\right]e^{-\alpha x}\right]\left[(\theta-2) + 3\theta\left[1+\frac{\alpha x(\alpha x+\alpha+2)}{\alpha^2+\alpha+2}\right]e^{-\alpha x}\right]\Bigg\}\frac{\alpha^3}{\alpha^2+\alpha+2}(1+x+x^2)e^{-\alpha x}e^{-\alpha x} \quad ; \lambda\in[-1,1], \theta\in[0,2], \alpha>0\ x>0 \in R \qquad (9)$$

α : (scale parameter). **θ**: (shape parameter). **λ**: (shape parameter).
$MCT-Suj$: Represents the distribution of (MCT-SUJATHA)

Some terms in Reliability analysis

Maintenance concept

Maintenance of all kinds and different strategies is an essential pillar in any facility, regardless of the size and type of that facility, maintenance is not limited to large industrial facilities, but is a very important process, starting from the home facility through small industrial facilities and simple production lines to huge factories with complex production lines. **(Elias,2015: 17)**

The strategic importance of maintenance

Maintenance in service management is a concrete action from the service provider directly to the customer's possession. There is a need to have good maintenance of equipment. In addition, doing good quality maintenance for the purpose of keeping the equipment in effectiveness and safety that can achieve the production goal in the expected time and at the optimum cost. To improve the quality of service management
related to the maintenance process the service provider needs to do equipment management. **(ANGGRADEWI,et al. ,2009: 72)**

Maintenance objectives **(Sabti,2007: 15-16), (Al-Aib, 2018: 34-35)**

- Extend the life and optimum productivity of machinery and equipment.
- Maximizing the use of available equipment and devices.
- To ensure the constant readiness of all machines and equipment, especially for emergencies.
- Reducing costs by ensuring the continuous operation of all machines and equipment and increasing their productivity.2
- Ensure the safety of workers using this equipment.
- Increase the percentage of time that machinery and equipment are available for operation.
- Achieving the optimal balance between the operating cost of equipment and the outputs it achieves.
- Increase system reliability and facility performance (equipment or machine, site and factory buildings) by reducing lost time and production costs resulting from work bottlenecks and repeated maintenance work.

Maintainability indicators

Maintainability refers to the ability to return a product (machine) to service again if it fails. **(Maafi, et al,2016: 152)**
There are many maintenance indicators used by researchers, some maintenance results indicators (delayed indicators) use in this research as follows

Mean time between failures

It is the mean time between failures that occur in the system or one of the repairable and non-repairable parts, and the higher the value of this mean, the greater the availability, and this time is a measure of the efficiency of the machine or machine, and **(MTBF)** can be found as in the following equation: **(Abd,2012: 15-16),(Al-Baqir,2017: 21),(Youssef, et al,20116: 316)**

$$MTBF = \frac{Total\ time\ of\ all\ units}{Total\ failures} \qquad (1)$$

$$MTBF = E(T_1) = \int_0^{\infty} R_{MCT-Suj}(t_1)dt_1 \qquad (2)$$

t_1.: Represents failure times. $R(t_1)$: The reliability function is defined assuming that the failure times are distributed according to the modified cubic transmuted **(MCT-SUJATHA)** with the following equation

Reliability function

Reliability function is defined as the probability that the machine will not fail during the time period. **(Mohan, Qassem,2022:91), (Abd El-Rahman, Ashour,2022: 274)**

$$R_{MCT-Suj}(t_1) = 1 - F_{MCT-Suj}(t_1;\alpha,\theta,\lambda)$$

$$= 1 - \left\{\left[1 - \lambda(\theta - 1) + \lambda\left[1 - \left[1 + \frac{\alpha t_1(\alpha t_1 + \alpha + 2)}{\alpha^2 + \alpha + 2}\right]e^{-\alpha t_1}\right]\left[(\theta - 2) + 3\theta\left[1 + \frac{\alpha t_1(\alpha t_1 + \alpha + 2)}{\alpha^2 + \alpha + 2}\right]e^{-\alpha t_1}\right]\right]\frac{\alpha^3}{\alpha^2 + \alpha + 2}(1 + t_1 + t_1{}^2)e^{-\alpha t_1}\right\} \quad ; \quad 0 \le R(t_1) \le 1 \qquad (3)$$

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Mean Time To Repair

It is the mean time required to repair the system after a malfunction and is symbolized by **(MTTR)**, the higher the rate of this mean, the lower the availability **(Availability)**, which is a measure of the efficiency of workers in maintenance, the higher it is indicates a decrease in efficiency, and represents the mean time between the moment of failure (malfunction) to the moment when the machine becomes workable, and it is expressed by the following equation: **(Abd,2012: 17),(Al-Baqir,2017: 22)**

$$MTTR = \int_0^\infty t_2 \, f_{MCT-Suj}(t_2) dt_2 \qquad (4)$$

$f(t_2)$ The density function of the repair time t_2 that follows the Sujatha distribution modified cubic transmuted **(MCT-SUJATHA)**

Failure rate

It is defined as the reciprocal of the mean time between failures, and is the percentage of the probability of failure, as it determines the percentage of failure or probability of failure of equipment that has been in operation for a certain period at any future moment. **(Maafi, et al,2016: 153)**

The failure rate is calculated according to the following equation

$$F.R = \frac{1}{MTBF} \qquad (5)$$

Availability

It is the ability of the machine or system to carry out the function required of it within a specific period of time, and the top of the indicator must be as high as possible, and this depends on the preventive maintenance work carried out during the planned operating time. It represents the ratio between mean time between failures (MTBF) and mean time between failures plus mean time to repair. **(Abd,2012: 17-18),(Al-Baqir,2017: 25), (Maafi, et al,2016: 153),(Youssef, et al,20116: 316)**

and is expressed by the following equation:

$$Availability = \frac{MTBF}{MTBF + MTTR} \quad (6)$$

$$A = \frac{1}{1 + \frac{MTTR}{MTBF}} \quad (7)$$

$$B = \frac{MTTR}{MTBF} \quad (8)$$

Application

Rumaila Power Station

The Rumaila Power Station is the most important and largest project implemented by Rumaila Operating Authority since its establishment, Rumaila power station was opened on March 28, 2018 and put into full service, Supervised and implemented by China Petroleum Engineering & Construction Corporation in Iraq, a joint venture between Basra Oil Company, BP and PetroChina, and managed and operated by Rumaila gas field, Rumaila Power Station uses gas extracted from Rumaila Oil Field to operate units (turbines) that generate electricity, contributing to Rumaila Field’s self-sufficiency in electricity and enhancing the national electricity grid with electricity.

The station generates 235 megawatts per day during the winter when operating at maximum capacity, and 150 megawatts per day during the summer season at its lowest limits when temperatures rise. The station consists of five units (gas turbines). **(Rumaila Operating Authority website)**

Analysis

The CRAN method was adopted in estimating the modified (MCT-SUJATHA) distribution parameters shown in Table 3, for the time intervals between failures and repair intervals of the fifth turbine at Rumaila Power Station (Measured in hours) shown in Tables (1) and (4), The sample size **(n=102)** was limited.

Table 1: Time intervals between failures (TBF) for the fifth turbine of Rumaila Power Station (Measured in hours)

75.92	64.38	63.00	56.48	27.78	21.92	11.50	6.67
111.08	108.22	107.50	102.90	92.42	84.48	81.00	80.50
157.33	143.48	123.03	122.08	120.57	119.38	119.00	116.32
211.62	205.17	205.08	197.87	185.00	173.17	170.25	170.03
248.40	245.63	242.75	240.00	232.98	228.92	217.88	217.83
301.50	297.17	281.57	279.63	267.00	255.08	249.33	248.40
350.67	348.00	347.52	340.65	333.67	324.50	323.00	315.42
387.10	385.40	382.00	380.37	378.62	371.43	369.20	366.67
453.70	442.70	422.00	410.63	409.00	408.30	400.30	400.03
501.58	500.50	492.00	481.50	480.17	469.50	464.43	454.08
610.73	592.43	592.00	565.50	563.17	541.68	528.00	522.33
1051.32	899.00	829.37	768.00	688.10	666.05	631.98	611.07
		15.02	1763	1620.00	1342.6 2	1277.53	1088.5 8

Source: Prepared by the researcher

Table (2) below shows the estimated parameters of the modified cubic Transmuted Sujatha distribution **(MCT-SUJATHA)** for the data of the time periods between failures.

Table 2: Estimation of Modified Cubic Transmuted Sujatha Distribution Parameters (MCT-SUJATHA)

Model	Parameter Estimation		
	α	θ	λ
MCT-SUJATHA	0.00819999	2	-0.49999

Source: Prepared by the researcher

While Table (3) below shows the results of goodness-of-fit tests (KS, CVM, AD) to demonstrate the suitability of the study sample data to the (MCT-SUJATHA) distribution and (SUJATHA) distribution for the time periods between failures.

Table 3: Goodness of fit tests for the distribution of (MCT-SUJATHA) and (SUJATHA)

Dist.	TEST	Statistic	P-Value
MCT-SUJATHA	Anderson-Darling	2.35044	0.059537
	Cramér-von Mises	0.161628	0.35601
	Kolmogorov-Smirnov	0.104579	0.20002
SUJATHA	Anderson-Darling	4.6147	0.0054
	Cramér-von Mises	0.3682	0.0878
	Kolmogorov-Smirnov	0.148	0.0605

Source: Prepared by the researcher

The results of the goodness-of-fit tests indicate that the study sample data fit the (MCT-SUJATHA) distribution. This is because the value of the significance level (P-Value) for these tests is greater than (α=0.05).

Figure (1) also shows the fit of the study sample data to the histogram of the probability density function curve of the (MCT-

SUJATHA) distribution for the data of the time periods between failure (BTF).

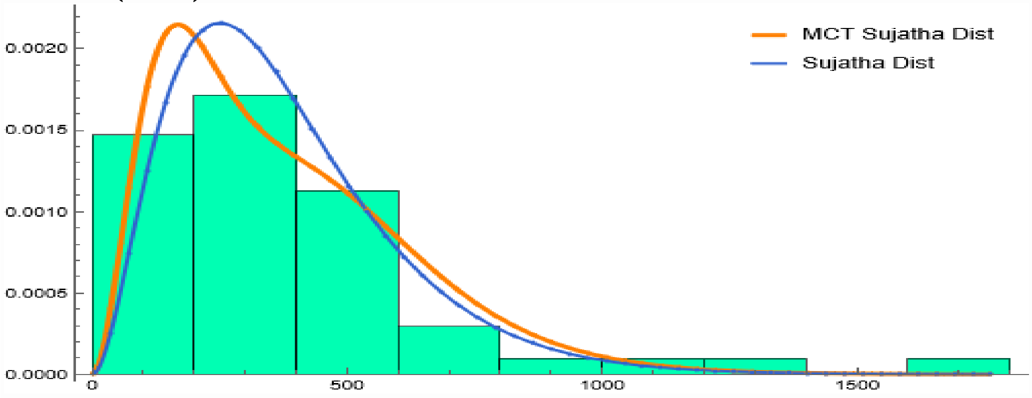

Figure 1: Histogram of the real data, the probability density function curve of the MCT-SUJATHA distribution, and the probability density function curve of the SUJATHA distribution.

Source: Prepared by the researcher

Table 4: Repair Time Intervals (TTR) for the fifth turbine of Rumaila Power Station (Measured in hours)

3.89	1.91	1.90	1.40	1.02	1.00	0.81	0.58
4.67	4.50	4.46	4.08	4.00	4.00	3.92	3.92
7.00	6.90	6.07	5.08	5.00	5.00	5.00	4.70
10.02	10.00	10.00	9.37	9.22	9.00	7.79	7.10
20.92	17.52	17.17	15.95	14.12	12.00	11.00	10.98
38.02	36.17	34.00	32.45	29.00	26.75	25.00	23.00
72.00	55.75	55.40	49.80	47.68	44.78	43.00	40.58
108.00	105.00	99.10	88.34	82.90	78.88	78.00	77.57
168.80	165.20	157.00	140.40	132.50	128.60	117.00	114.80
217.90	205.20	204.40	199.30	197.30	192.80	183.50	181.30
347.50	320.80	311.20	309.70	264.80	264.40	245.90	232.20
490.10	479.50	471.00	462.50	461.50	426.40	422.00	351.00
		1449	764.8	731.50	642.90	592.40	562.00

Source: Prepared by the researcher

As for Table (5) below, the estimated parameters of the modified cubic transmuted Sujatha distribution **(MCT-SUJATHA)** for data on repair time periods

Table (5): Estimation of Sujatha distribution parameters modified cubic transmuted (MCT-SUJATHA) for repair time periods

Model	Parameter Estimation		
	α	θ	$\boldsymbol{\lambda}$
MCT-SUJATHA	0.0231	2	-0.99998
SUJATHA	0.023786	-	-

Source: Prepared by the researcher

While Table (6) shows the results of the goodness of fit tests (KS, CVM, AD) to demonstrate the suitability of the study sample data to the (MCT-SUJATHA) distribution.

Table (6): Goodness-of-fit tests for the (MCT-SUJATHA) distribution and the (SUJATHA) distribution for the repair time periods

Dist.	TEST	Statistic	P-Value
MCT-SUJATHA	Anderson-Darling	82.5764	0.057112
	Cramér-von Mises	3.26904	0.30243
	Kolmogorov-Smirnov	0.305844	0.155922
SUJATHA	Anderson-Darling	107.457	0.051457
	Cramér-von Mises	5.80996	0.224543
	Kolmogorov-Smirnov	0.434558	0.114322

Source: Prepared by the researcher

The results of the goodness-of-fit tests indicate that the study sample data fit the (MCT-SUJATHA) distribution. This is because the value of the significance level (P-Value) for all of these tests is greater than (α=0.05).

Figure (2) also shows the fit of the study sample data to the histogram of the probability density function curve of the (MCT-SUJATHA) distribution for data on repair time periods.

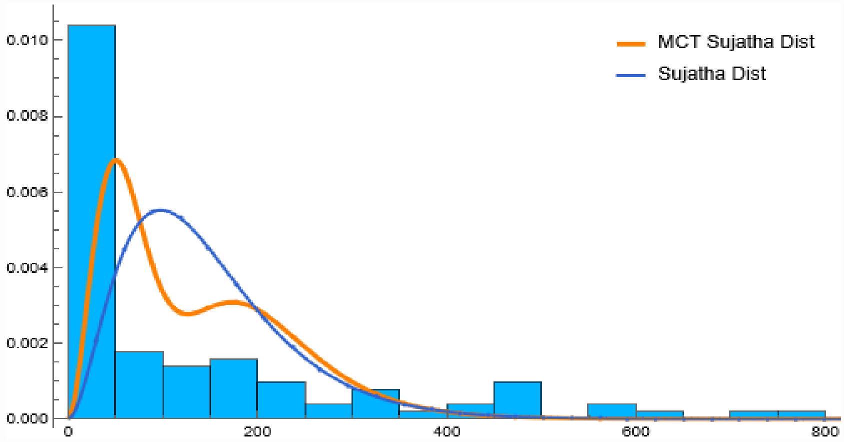

Figure (2): Histogram of real data and probability density function curve for (MCT-SUJATHA) distribution and (SUJATHA) distribution.
Source: Prepared by the researcher

Analysis of maintainability indicators

Based on the results of the analysis of the (TBF) and (TTR) repair time data using Mathematica program, Table (4) summarizes the maintenance indicators for the fifth turbine in Rumaila Power Station, which are represented in (mean time between failures (MTBF), mean time to repair (MTTR), failure rate (F.R), ratio of mean time to repair to mean time between failures (B), availability as follows:

Table 4: Maintenance Indicators Values

Maintainability indicators	MTBF	MTTR	F. R	B	Availability
Value	374.408	150.882	0.0026596452	0.3904093194	0.7192539455

Source: Prepared by the researcher

We can see from Table (4) the following

1- The mean time between **MTBF** failures was (374.408 hours), which is approximately (15 days), which represents (the time period of operation + the time period of repair).
2- The mean repair time **(MTTR)** was (150.882 hours), which is approximately (6 days), and the mean time for the fifth turbine to operate at Rumaila Power Station is (223.526 hours), i.e. (9 days).
3- The failure rate was (0.00265), which indicates a low incidence of fifth turbine failures at Rumaila Power Station.

The ratio of mean repair time to mean time between failures was equal to (0.390), which is a good indicator indicating a decrease in failure times or stops, which in turn led to a rise in the availability index of the fifth turbine at Rumaila Power Station, which amounted to (0.719) the ratio of its ability to work and carry out its function.

conclusions

1- suiting the data of the study sample to the distribution of **(MCT-SUJATHA)** of the two study samples (data for the time periods between failures, and data Repair time periods).
2- Maintenance indicators for the **MCT-SUJATHA** distribution reached (374,408 hours), which is approximately (15 days), **MTTR** reached (150,882 hours), which is approximately (6 days), and the average period of time for the operation of the fifth turbine at Rumaila Power Station. Electricity is (223,526 hours), or approximately (9 days). The failure rate of the fifth turbine in Rumaila Power Station is low, as the failure rate reached (0.003), and the availability reached (0.719), the percentage of its ability to work and carry out its function.

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