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PREVENTIVE MAINTENANCE ANALYSIS ON THE KELVIN HUGHES MKVII X-BAND NAVIGATION RADAR IN WARSHIP TYPE-Z

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ABSTRACT

Navigation Radar has a very vital role for the readiness of KRI operations. However, with the age of the KH MKVII X-Band radar on the KRI Type-Z class which has reached eleven years and is faced with high operational tasks, making the radar has a high risk of damage. While the repair process takes quite a long time, especially if it requires replacement of spare parts. Therefore, preventive maintenance is needed to maintain radar readiness. In this study using FMECA to determine critical components and reliability to determine the replacement time of critical components with a minimum reliability of 0.65. The results of FMECA,analysis Risk Matrix, data distribution and reliability of 17 components obtained 5 components withcategory risk rating a high, namely Modulator RPN value of 365.25 with a proposed replacement of 3482 hours, Tx Microcontroller value of RPN 302.62 with a proposed replacement of 5803 hours, LNFE RPN value of 261.75 with proposed replacement of 5887 hours, Power Supply Trx value of RPN 260,05 with proposed replacement of 5498 hours and Magnetron with RPN value of 256.12 with proposed replacement of 5148 hours. By following the proposed component replacement before the component is damaged, it can save a budget of 12.87% or Rp. 27,612,000.00.

Keywords: *FMECA, Risk Priority Number, Reliability, Risk Rating.*

1. INTRODUCTION

Readiness of the KRI in carrying out operational tasks is largely determined by its main equipment. One of the components of KRI readiness is a good navigation system, in which the navigation system plays a vital role and has a high operating time, including RADAR (Radio Detection and Ranging). With the various capabilities possessed by the Type-Z Class KRI and high operating tasks, the direct operation of the KH MKVII Navigation Radar will also be high. Seeing this and the age of the radar which is no longer young, the possibility of components being damaged is high. Therefore, more maintenance measures are needed so that the radar function is maintained.

The current repair system implemented is based on the occurrence of equipment damage in the KRI, then the KRI makes a Damage Report (LK) to the Ship Unit. Then the LK is forwarded to the Ship Maintenance Service (Disharkap). Disharkap will coordinate with Fasharkan to carry out Shipcheck to KRI. Shipcheck result then sent to the Ship Maintenance Service (Disharkap). If Fasharkan is able to repair the damage, it will be carried out directly by Fasharkan with the support of component materials from the Department of Materials and Supplies (Dismatbek). However, if Fasharkan cannot carry out repairs, Disharkap will use a third party through the process of procuring goods and services. This repair system is good but has not accommodated emergency failure and requires immediate action. KRI had to wait for repairs, which of course took a relatively long time because spare parts were not necessarily available at the Materials Service and enough time was needed to order spare parts. In addition to spare parts, budget availability for repairs is also a consideration because budget availability is determined by budget planning in the previous time period.

With these conditions, using other KRI radar components that are not operating is an option to support KRIs that have operational assignments but have radar damage. However, this option is not effective because by using other KRI radar components that are not operating, it will be a problem if at any time the KRI also gets operational assignments. Component damage that occurs in urgent situations when the KRI has to carry out operational duties, while the unavailability of spare parts and budget will cause problems in the KRI's operational tasks. To maintain conditions so that the radar is always in high readiness, a planned maintenance system is needed. The treatment program is related to the cost of treatment, because the maintenance is too frequent, causing the maintenance cost to be large. Meanwhile, if the maintenance is infrequent then the damage often occurs, causing the cost of damage is also large.

In this research plan, proposed Failure Mode Effects and Criticality Analysis (FMECA) because it can be used to identify and analyze the potential failure mode of parts of the radar system, the effects of failure and how to avoid failure and or reduce the failure severity of the radar. Components that have rating of risk “high” is a result of the combination of the severity/impact and the probability of failure will receive maintenance priority.

2. LITERATURE REVIEW

2.1 Radio Detection and Ranging

Radio Detection and Ranging (Radar) is equipment that has a function to detect and determine the distance of an object by using radio waves. Meanwhile, according to Skolnik (1962), radar is an electronic device that functions to detect objects using electromagnetic waves where the target reflects back the emitted electromagnetic waves. Objects can be ships, airplanes, spacecraft, buildings, motor vehicles, humans or the surrounding environment. Judging from the type of emission, radar is divided into two types, namely active and passive radar. Active radar emits microwaves in all directions which then if it hits an object, it will be reflected back to the transmitting radar. While the passive radar only receives radio waves from objects.

The workings of radar starts from the magnetron as a generator of electromagnetic waves generating a microwave which is then followed by a modulation process, superimposing data onto the carrier by the modulator. After the modulation process, the wave goes to the antenna through a circulator which functions as asignal regulator transmitter and receiver. In antennas, microwaves emitted in different directions and if the object will be reflected back to the radar to antenna in the form of echo. Echo will be received by the antenna and forwarded to the receiver then to the display. Before the echo reaches the display, the limiter diode will protect the receiver from overvoltage that occurs. Furthermore, echo will be amplified and processed to detect the presence of the target and determine its location. The target distance is determined by measuring the time the radar signal to the target returns to the radar. The processing results will be displayed on the display radar. The working principle of radar is shown in Figure 1.

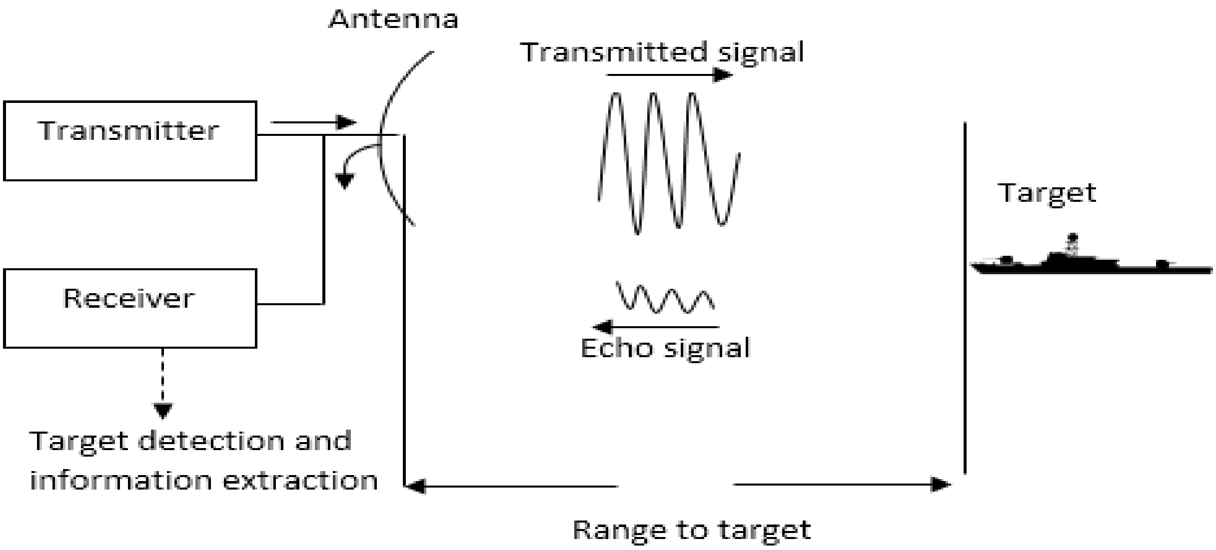

Figure 1. Radar Working Principle
(Source: Skolnik, 1962)

2.2 Failure Modes Effects and Criticality Analysis

In preventive maintenance, it is necessary to analyze the system to determine the function of components, types of failure modes, potential failures that arise, the effects of the failure and how to avoid or reduce the effects of the failure. For this reason, needed an analytical method that can help solve these problems, including Failure Modes Effect and Criticallity Analysis (FMECA). FMECA is a development of FMEA by considering the level of criticality associated with the impact of the failure mode component. This criticality level is analyzed based on a combination of the level of damage (severity) and the probability of its occurrence.

FMECA was originally developed by the United States Military. The first FMECA guide was Military Procedure MIL-P-1629 dated November 9, 1949. FMECA is the result of the method used to identify the criticality or priority associated with the severity of failure mode component, with an analysis of the failure mode evaluation so that each potential failure is ranked from the importance level. and its impact so that preventive measures can be taken to eliminate the risk of failure.

Severity or the impact of damage is a factor that shows how serious the impact of a damage on the next process. The scale is from (1) which means there is no impact to (10) which means the damage impact is very high. Occurance or frequency of occurrence is a factor that shows how often failures occur in a certain period.

The scale is from (1) which means it is very rare to (10) which means the frequency of occurrence is very high. Detection or the ease of detection of damage is a factor that shows how the working control system is able to detect failures in the system operating process. Scale (1) which means it is definitely detected up to (10) which means that the failure mode cannot be detected.

2.3 Reliability

According to Kapur and Pecht (2014), reliability is the ability of a product or system to carry out its duties properly as expected without failure over a certain period of time in life cycle conditions. There is no general definition of reliability, but several definitions of reliability used are:

a. Reduction of something that causes errors/damages.
b. The ability of the product to meet consumer expectations over time.
c. The probability of an equipment/product/system that it will not fail over a certain period of time under certain operating conditions.

The reliability function states the relationship between reliability and time, namely the length of time the system can carry out tasks and in the time interval (0, t), the components will not be damaged. The reliability function is expressed by:

$$R(t) = 1 - F(t) = P(T > t) = \int_t^{\infty} f(t)dt$$

R(t) represents the reliability of the system for t units of time. The properties of R(t) are as follows:

a. monotony does not go up
b. $0 \leq R(t) \leq 1$
c. $R(\infty) = 0$; $R(0) = 1$

F(t) is a cumulative distribution function/ lifetime of the system. So the reliability function is the complement of the cumulative distribution function / lifetime of the system.
F(t) has the following characteristics:

a. $0 \leq F(t) \leq 1$
b. monotony does not decrease
c. $F(t)(\infty) = 1$, $F(t)(-\infty) = 0$, but because t is never negative then $F(0) = 0$.

2.4 Failure Rate

Failure Rate states the amount of damage that occurs per unit time. According to Kapur and Pecht (2014), failure rate h(t) is the number of failures for each number of non-failed products remaining in the unit time t. The failure rate can be expressed as the ratio between the number of failures per unit time per the number of non-failure products remaining at time t. Failure rate of components according to the time period, can be divided into Decreasing Failure Rate, Constant Failure Rate and Increasing Failure Rate are shown in Figure 2.

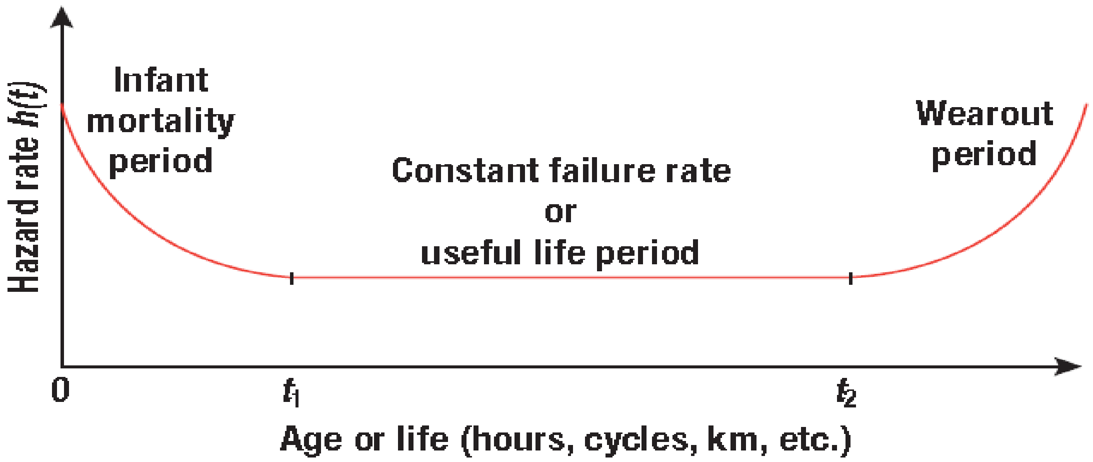

Figure 2. Bathtub hazard rate curve
(Source: Kapur and Pecht, 2014)

a. DFR (Decreasing Failure Rate) Component

DFR component is a component where damage function decreases with the longer the component is used. The use of components will cause components to become better because they are more tested and trained. In this period, the curve shows that as time increases, the rate of damage decreases. Damage that occurred during this period was generally caused by errors in manufacturing. So if an equipment that is operated has passed this period, it means that the design and manufacture of the equipment at the factory is correct. This period is also known as burn-in period or infant mortality period.

b. CFR (Constant Failure Rate) Component

CFR component is a component where the damage function is constant. In this period the rate of damage is constant. The period of normal equipment use is included in this period and is characterized by a constant amount of breakdown each unit time. Environmental conditions affect equipment damage and damage is random. This period is known as the useful life period.

c. The IFR (Increasing Failure Rate) Component

IFR component is a component where damage function increases with the age of the component. In this period the rate of damage will increase with increasing time. This happens because these components experience wear and tear and material fatigue, causing these components to deteriorate more quickly with increasing age. Damage can occur due to internal factors. This period is also known as the wear out period.

2.5 Risk Matrix

Risk matrix is an analysis that combines the impact of a failure by the frequency of occurrence of the failure. The results can be categorized from low risk to high risk. Impacts or consequences are grouped between events that do not cause minor injury or loss to the most severe impacts that cause major damage to the system. While likelihood is given a range between risks that rarely occur (improbable) to risks that can occur at any time (frequent). The risk of a failure is analyzed by looking at the consequences and existing control measures. Sources of information should include previous records, existing habits, relevant incident experience, control experience, relevant literature, experiments, prototype and expert opinions.

The data obtained from experts in the field of Kelvin Hughes navigational radar maintenance are then analyzed for the criticality level of the components. Component criticality analysis is carried out using a risk matrix to classify components into critical categories according to the specified criteria. The criticality level is determined by the influence of the level of damage to the system and the failure rate.

Table 1. Failure Rate Qualitative Data

No	Failure Rate	Description
1.	Very Unlikely	Occurs once every 1000 years
2.	Remote	Occurs once every 100 years
3.	Occasional	Occurs once every 10 years
4.	Probable	Occurs once a year
5.	Frequent	Occurs once a month or more often

Table 2. Risk Matrix

Likelihood	Severity			
	Minor	Major	Critical	Catastrophic
Frequent	Accept	Medium	High	High
Probable	Accept	Medium	High	High
Occasional	Accept	Accept	Medium	High
Remote	Accept	Accept	Accept	Medium
Improbable	Accept	Accept	Accept	Medium

2.6 Weibull Distribution

Knowing the probability model of equipment damage data is the first step that must be taken to calculate equipment reliability. The various equipment breakdown data will be depicted in a probability distribution according to the data entered. Modeling the system with the number of failures with time can vary, constant along time, increasing with time or decreasing with time.

According to Kapur and Pecht (2014), Weibull distribution developed by Waloddo Weibull in 1939 and widely introduced in 1951. This distribution is widely used in the analysis of component life calculations. This distribution is a flexible distribution because by changing its shape, it can become another distribution. Equipment failure rate in areas of decreasing failure rate, constant failure rate and increasing failure rate can be described by Weibull distribution.

According to Jardine and Tsang (2013), if the value location parameter in the three-parameter Weibul distribution is equal to zero, it will be a two-parameter Weibull distribution. According to Kapur and Pecht (2014), the Weibull distribution can be presented in the two or three parameters. Probability density function Weibull distribution for the three parameters are :

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}$$

where :
= scale parameter/characteristic life
β = shape
γ parameter = location parameter
and β is positive. Reliability function of Weibull distribution can be expressed by :

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}$$

Failure rate can be expressed by:

$$\lambda(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}$$

Mean Time to Failure can be expressed by:

$$MTTF = \gamma + \eta\Gamma(1 + \frac{1}{\beta})$$

2.7. Research Methodology

Research Approach used to achieve the objectives in this study is a quantitative approach. Data was collected by means of interviews, observations, questionnaires, damage reports and maintenance journals. In this study, a closed questionnaire was used for the expert followed by the calculation of thevalue RPN, distribution test, calculating the reliability value, determining the time interval for component replacement and analysis of maintenance costs.

Data sources in this study are primary data and secondary data. The primary data sources were observations in the KRI Class Type-Z, interviews and questionnaires with competent personnel in the maintenance of the Kelvin Hughes Navigation Radar. Secondary data is data that has been collected by other people. Secondary data in the form of theories, previous literatures, reports of damage to radar in the KRI and maintenance units.

The research subjects are competent personnel from Benglek Lantamal V, Ship Maintenance Service, Third Party Technicians, Satkor Koarmada II and Type-Z Class. While the object of research is the three Type-Z Class.

3. RESULT AND DISCUSSION

3.1 Risk Priority Number

To determine the critical components of radar, data were taken from the results of questionnaires from experts in the field of Kelvin Hughes Radar maintenance. These data include severity rating, occurrence ratings and detection ratings. Severity (S) is a factor that indicates how serious the impact of a damage on the next process. Occurance (O) is a factor that shows how often failures occur in a certain period. Detection (D) is a factor that shows how a working control system is able to detect a failure in the system operating process. Fill in using scale guidelines for Severity, Occurance and Detection values. From the results of the questionnaire, the value of the Risk Priority Number (RPN) is shown in Table 3.

Table 3. Risk Priority Number (RPN)

No	Component	RPN
1	Modulator (K6)	365.25
2	Tx Microcontroller (K9)	302.62
3	Diode Limiter (K8)	292.63
4	Low Noise Front End (K12)	261.75
5	Power Supply TRx (K10)	2600.05
6	Magnetron (K11)	256.12
7	Circulator (K7)	239.96
8	Motor Starter (K3)	209 ,54
9	Spull Motor (K4)	207.51
10	Processor CPU (K13)	192.54
11	Harddisk (K14)	192.35
12	Vanbelt (K5)	188.71
13	RAM (K15)	185.37
14	Gearset Motor (K1)	176.27
15	MCB (K17)	166.51
16	UPS Battery (K16)	162.04
17	Azimut/Heading Line (K2)	160.40

3.2 Risk Matrix

After obtaining the value and RPN, then carried out risk matrix analysis which is a combination of severity of consequency and severity of frequency. Components categorized in “high” risk rating have a top priority in maintenance.

Table 4. Rating of Risk Component

No	Component	Rating of Risk
1	Modulator (K6)	High
2	Tx Microcontroller (K9)	High
3	Diode Limiter (K8)	High
4	Low Noise Front End (K12)	High
5	Power Supply TRx (K10)	High
6	Magnetron (K11)	High

7	Circulator (K7)	Accept
8	Motor Starter (K3)	Medium
9	Spull Motor (K4)	Accept
10	Processor CPU (K13)	Medium
11	Harddisk (K14)	Medium
12	Vanbelt (K5)	Medium
13	RAM (K15)	Accept
14	Gearset Motor (K1)	Medium
15	MCB (K17)	Accept
16	UPS Battery (K16)	Medium
17	Azimut/Heading Line (K2)	Accept

From Table 4. It can be seen that from the 17 components analyzed, components that have obtained high risk rating is Modulator, Tx Microcontroller, LNFE, Power Supply, Trx Magnetron and Diode Limiter.

3.3 Components Distribution

After knowing the critical components, the critical component damage data is processed using weibull software to determine the appropriate distribution and determine distribution parameters, namely shape parameter, scale parameter and location parameter of each critical component. Although diode limiter has high risk rating, but it can not be calculated by weibull software because failure data of diode limiter not enough as entry data. The parameter values for critical components are shown in Table 5. Parameter values, are used to determine the Mean Time To Failure (MTTF) value which will also be used to determine the reliability of each component.

Table 5. Parameter Distribution

No.	Components	Parameter Distribution		
		β	**η**	γ
1	Modulator	1.2835	5472.5	642.7
2	TxMicrocontroller	2.8428	7804.8	0
3	Power Supply TRX	3.1536	7181.07	0
4	Magnetron	1.8090	6083 , 96	1328.6
5	LNFE	0.9397	2853.896	4722.5

3.4 Time to Replace

The minimum readiness value of equipment to be able to carry out operational tasks is 0.65 based on regulations from the TNI-AL leadership. Therefore, the time for the proposed replacement of critical components can be searched using parameter values (β, η, Ɣ) and MTTF with a reliability value of more than 0.65.

Table 6. Reliability After Replacement

No	Component	Time (Hours)	Reliability
1	Modulator	3482	0.6500
2	Tx Microcontroller	5803	0.6501
3	Power Supply Trx	5498	0.6500
4	Magnetron	5148	0.6500
5	LNFE	5887	0, 6500

From Table 6. it can be seen that with a minimum reliability value of 0.65, LNFE has the longest replacement time of 5887 hours, while the fastest replacement time is Modulator with 3482 hours.

3.5 Cost of Component Replacement

As a consideration in preventive maintenance, it is necessary to know the comparison of the cost of replacing radar components beforeout carryingpreventive maintenance with afterout carryingpreventive maintenance. Data on component replacement costs was obtained from the Sub-discipline of Sewaco Disharkap Koarmada II. These costs include component prices, repair time before components are damaged, repair times after components are damaged, labor costs for planned maintenance and labor costs for repairs after damage occurs. From the calculation of replacement costs before and after the component is damaged, it can be seen that replacing the component before it is damaged will save the repair budget. Savings are obtained from the difference in the cost of replacing components after being damaged by replacing components before they are damaged or in accordance with the proposal.

Table 7. Replacement Cost Savings

No	Component	Savings	(%)
1	Modulator	10,596,000	14.13%
2	Tx Microcontroller	3,844,000	11,82%
3	Power Supply Trx	4,576,000	16.63%
4	Magnetron	4,576,000	7,96%
5	LNFE18,26	4,020,000	18,26%

Table 7. shows the savings obtained when carrying out component replacement according to the proposed time. From the table it can be seen that all components provide savings with the largest savings on LNFE and the smallest savings on Magnetron. By adding up the savings for each component, a total savings of IDR 27,612,000 or 12.87% is obtained if the component replacement is carried out according to the proposal. In addition to saving, the condition of the radar will always be ready and avoid emergency failure.

4. CONCLUSIONS

From the results of data processing and analysis carried out, it can be concluded as follows:

a. Critical components of the MK VII X-Band Navigation Radar in KRI Type-Z Class based on an analysis of 17 radar components, there are 5 components, namely Modulator with RPN 365.25, Tx Microcontroller with RPN 302.62 , Power Supply Trx with RPN 260,05 , Magnetron with RPN 256.12 and LNFE with RPN 261.75.

b. The time interval replacement of critical components MK VII Radar Navigation X-Band in Class KRI Type-Z is Modulator with replacement time 3482hours,Tx Microcontroller with replacement time 5803 hours, Power Supply TRX with replacement time 5498 hours, Magnetron with replacement time 5148 hours and LNFE with replacement time 5887 hours.

c. Analysis of the cost of replacing critical components of the MK VII X-Band Navigation Radar at KRI Type-Z Class by following the proposed component replacement before the component is damaged, there is a savings of 12.87% or Rp. 27,612,000.00.

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