Maintenance Improvement Through Implementation of RCM and FMECA on Cooling Unit Radar System

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Abstract. The readiness of military defense radar is absolute in air surveillance to keep from potential threats that may endanger the security of nation. Good maintenance is closely related to the readiness level of the defense radar system. Maintenance through the application of Reliability Centered Maintenance (RCM) and Failure mode effect and criticality analysis (FMECA) could be one solution in maintaining the readiness of the air defense system. The research begins with collecting data on function, performance, component item health status, and failure records that have occurred. Critical analysis using FMECA to support information for RCM about each item's function failure mode, probability occurrence, failure causes, and effect. This is necessary to determine the maintenance task and prevent the possibility of system breakdown or fatal damage. By applying the recommendations that have been calculated, the maintenance of the radar cooling unit is more reliable.

Keywords: Maintenance, RCM, FMECA, Critical Failures.

1 Introduction

The level of equipment reliability to ensure good operational performance is always an interesting concern to study. The high-level performance cannot be separated from maintenance that carried out by technicians with certain repair and maintenance methods. One of the current maintenance method developments is Reliability Centered Maintenance (RCM), which is maintenance development by considering reliability and ensuring operational performance within the scope of a good assessment [1]. Currently maintenance is not only a supporting sector, but as one of the main actors in the success of a production or operational activities.

Good maintenance is inseparable from data collection and failure analysis and appropriate system operations. The Failure Mode Effect and Criticality Analysis (FMECA) method performed by professional technicians can produce accurate data in recording the problem causes, failure events, and possible impacts. FMECA directs the consideration of maintenance actions that may be carried out in non-emergency situations with an effective and efficient period of implementation of activities [2]. The results that can be obtained from maintenance through the FMECA method are easier condition-based maintenance and risk priority component before system breakdown.

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So that operations can continue, or if downtime occurs, the system does not stop for too long which may result in losses. One of the FMECA applications is using the MIL-STD-1629A form which is strong enough to assess and analyzes to a critical level. Form MIL-SD-1629A made by US Department of Defense can applied to defense radar system [3].

The maintenance that must be carried out is adjusted to the problem analysis in the form of preventive maintenance, as well as repairs the damage or replacement of the components whose performance has dropped dramatically. Currently radar maintenance uses conventional maintenance techniques in the form of general preventive and corrective maintenance. This is certainly good enough, but it can be improved in term of the level effectiveness and efficiency in the strategy for processing time and possible cost used, as well as the availability of the system spare parts.

The maintenance strategy for military radar systems can be improved with a combination of the RCM and FMECA methods to get the critical parts of the radar to be focused down to the component or module level. FMECA is performed to obtain various kinds of maintenance and failure technical information. Further information on the FMECA can be in the form of calculation the severity index, occurrence index, and detection index, failure mode, possible causes, impact, and critical analysis to show maintenance priority as a consideration in the technician's decision-making process in future actions [4]. FMECA measures maintenance within the scope of critical level, while RCM is aimed at ensuring maintenance requirements are available, both the availability of spare parts and maintenance equipment as well as the technical steps that must be carried out until maintenance is complete and the system can operate normally again. RCM covers the physical assets, the problematic parts, and the system functions being worked on [5]. FMECA has three objectives, including (i) preventing future failures by implementing planned maintenance activities, (ii) reducing equipment downtime and increasing safety in the event of a system failure, and (iii) prioritizing maintenance act during non-emergencies [6]. These combination of FMECA and RCM applied to military radar system can provide better maintenance quality.

2 Literature Review

The following is a literature review that we have studied as a basis for research studies and solving research problems.

Reliability Centered Maintenance (RCM). RCM is widely used to systematize various tasks in maintenance planning. The basic principle of RCM is to ensure that all maintenance task steps have been validate before being carried out [7], [8]. The RCM goals are to ensure the reliability of maintenance actions for a system, maintain system operational security, carry out activities at a low cost [9]. This RCM method provides fewer scheduled maintenance tasks compared to traditional maintenance methods, and provides a reduced number of scheduled maintenance when revising the existing traditional maintenance ranging from 40% up to 70% efficiency [10].

RCM is an engineering framework that enables the definition of a complete maintenance program [11]. In general, the RCM process is divided into 5 stages, which represent in a generic way a synthesis of the logical sequence of work that must be performed during this analysis implementation [12]:

a. Establishment and planning of RCM.
b. Functional failure analysis.
c. Selection of tasks.
d. Application.
e. Continuous improvement.

Failure Mode Effect and Criticality Analysis (FMECA). The FMECA method goes further than general failure analysis, each failure mode will be calculated its severity, potential problems are seen in more detail and get more accurate results. FMECA is a method that can be used to prevent various form of component failure, predict problems, and find optimal and economical solutions. With this method, the system can identify potential failures in the system, subsystem, and components, depending on the database it has. This method gives priority to all potential failures to determine possible actions or countermeasures. The FMECA method is well accepted for analyzing the reliability and safety of equipment, because the data are presentable and easy to use [6].

FMECA not only identifies but also investigates potential failure modes and their causes. If applied correctly, it can help identify failures with the highest criticality values based on probability and severity [13]. The FMECA method identifies behavior severity (severity index), probability of occurrence (Occurrence index), and level of detection by technicians (detection index). This identification is used to calculate the Risk Priority Number (RPN) with the calculation shown in (1).

$$RPN = S \times O \times D \quad (1)$$

Severity index (S). Severity classification is assigned to each failure mode of each subsystem and entered FMECA matrix based on the consequences in each part of the radar system.

Detection index (D). The detection index measurement is used to define and analyze the system's ability to detect and report problems with each system component and failure mode. In the FMECA matrix, information about the detection of problems in each component of the subsystem will be provided.

Occurrence index (O) and calculation. Measurement of occurrence index or the frequency value of the repeated failure in a subsystem to find out how often failure modes occur in each component of the system.

The RPN as an alternative calculation in critical analysis and reference value in the priority action plan for maintenance. The RPN value is the product of the Detection Index (D) * Severity Index (S) * Occurrence Index (O). Each on a scale of 1 to 10, it means the highest RPN value is 10x10x10 = 1000. Failure with a high RPN value indicate that the failure cannot or is difficult to detect by inspection, is very severe and the occurrence is almost certain. Failure mode can be mapped on the criticality matrix using severity code as one axis and the probability level code on the other. In quantitative assessment, the total of criticalities is calculated for each failure mode of each item and the criticality number of items is calculated for each component.

3 Methodology

The methodology used in this research is focuses on implementing RCM and FMECA for radar systems, then identifying potential critical failures in the system, and determining parts that have a potential level of damage that can affect the overall system performance. The highest-risk parts of the system are investigated using RCM to identify in more detail the maintenance actions that need to be performed when a potential failure or damage is detected.

Failure modes are identified and sorted by priority level, then recommendations for effective maintenance or repair are proposed. Making the right decisions in maintenance, especially in the field of national defense, must be of great concern [14]. The sequence of steps to be carried out is as follows:

1. Literature review and field studies.
2. Data collection, which consists of evaluating failure modes, the causes, and the impact on system performance.
3. Designing FMECA form using MIL-STD-1629A, formulating system functional diagrams, and determining maintenance using RCM.
4. Critical analysis using MIL-STD-1629A and consideration of maintenance steps using RCM-FMECA.
5. Experimental implementation on miniature workstation.

4 Result and Discussion

The radar system that is used as the research object is a solid-state radar technology in cooling system for the transmit and receive electronic equipment. This cooling system is called Cooling Liquid Production Unit (CLPU). This system is used to maintain the temperature of radar transmit and receive system activity, especially the T/R module, so that it works in good performance. Failure of the CLPU will result in the radar being unable to perform surveillance operations in the context of early detection and other air defense activities. In order to maintain a good level of CLPU readiness, effective and efficient maintenance are needed, to prevent system breakdown.

The CLPU working principle in general is to release the heat generated by various electronic equipment in the antenna, to maintain the temperature inside the antenna cabinet within operational limits. To ensure the necessary cooling, the CLPU performs the following functions:

1. Provides coolant flow in electronic equipment cooling systems.
2. Ensure coolant temperature setting.
3. Ensures heating of the pending liquid in the initial phase when the ambient temperature is too low.

4. Ensuring the cooling relationship with main electronic equipment on the antenna.

The cooling system is divided into two parts, the first is a cooling system that provides cooling flow for electronic equipment on the antenna, this liquid uses glycol and distilled water. The second system is a cooling system that exchanges the hot temperature of the coolant, this cooling system uses R124a freon. Fig. 1 shows the flow diagram of the cooling system connection at the CLPU.

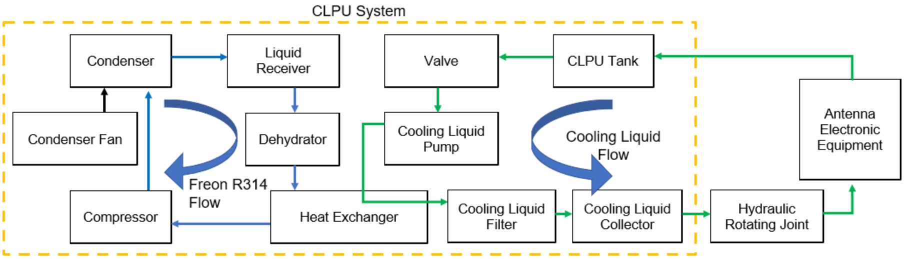

Fig. 1. Cooling liquid flow diagram in CLPU system.

The block diagram of the CLPU system shows the two types of cooling systems used in this military radar. the CLPU starts with the activity of the refrigerator system to prepare the appropriate temperature to support the performance of the radar system. The working of the refrigerator system is the same as the common air conditioning system, but for the part that emits cold air it is positioned on the heat exchanger item. The cooling liquid flow system works starting from the CLPU tank, pre-heating is done at the CLPU tank to prepare the liquid to have the appropriate liquidity level. Valves are used to adjust the volume of liquid that must be flowed or open the coolant flow cap. Cooling pump serves to encourage the circulation rate of coolant to the radar system in the antenna. The filter is positioned before the liquid flows into the collector with a regulated volume and to maintain the cleanliness of the coolant flow in the cooling system in the radar antenna electronic equipment. The hydraulic rotating joint functions as a liaison between the stationary part and the rotating part of the antenna. Various important items in the CLPU with FMECA information can be seen in Table 1.

The next step is compiling a list of decisions from CLPU system items. Decision choice information will be the basis for maintenance or repair procedures that can be done. The failure mode consequences of the evaluated FMECA become task requirements. The consequences of the decision list include Hidden failure (H), Safety (S), Operational (O), Environment (E) and Nonoperational (N). this can be used as a consideration for proper maintenance of the intended item.

Referring to the list of decisions, maintenance actions are carried out based on preventive scheduled maintenance, condition-based maintenance, inspection tasks, and no-maintenance. Reference information is obtained from the FMECA assessment which is further explained in the RCM worksheet. The RCM decision worksheet of the CLPU can be seen in Table 2.

Data are collected from recordings and observations by radar technicians and operators. Data in the form of recording the time of failure occurred which is processed into Mean Time to Failure (MTTF) data using the Weibull distribution. The MTTF value is used to determine the appropriate maintenance interval for the item.

The Risk Priority Number (RPN) calculation from the FMECA method is also an additional consideration in the priority items to be concern. The RCM method is a maintenance recommendation to sort activities based on the period of each item. Identification of failures and selection of appropriate maintenance steps is important because it is based on criticality of the item and its failure mode. This preventive and predictive maintenance provides an appropriate maintenance calendar design to address the risk of fatal damage and system breakdown.

Table 1. FMECA recapitulation information worksheet

Item	Function	Failure Mode and Causes	Mission Phase/Effect	S	O	D	RPN
Condenser	Exchange heat from refrigerant liquid to the air	Leakage, clogged, or too hot. Clog of dirt.	Temperature does not reach the operating settings	6	3	3	54
Condenser Fan	Blowing air to trigger heat exchange from refrigerant liquid to the air	No air blowing. Power supply fault, or sensor fault.	Refrigerant temperature overheats	5	3	3	45
Compressor	Compressing refrigerant liquid	No refrigerant flow. Power supply fault.	Temperature does not reach the operating settings	7	3	4	84
Dehydrator	Dryer filter of the refrigerant liquid	Refrigerant mixed with water. Expired cartridge.	Temperature does not reach the operating settings	3	5	3	45
Liquid Receiver	Storage to hold liquid refrigerant after condenser, to ensure the liquid entering expansion device	Pre-heating refrigerant failure. Heating coil failure.	The corresponding unit cannot operate only with a positive temperature	3	3	4	36
Heat Exchanger Evaporator	To transfer heat from Cooling liquid CLPU to refrigerant liquid without mixing them	No coolant different temperature value. Leakage, clogged, or Lack of freon.	Temperature does not reach the operating settings	5	3	5	75
Cooling Liquid Pump	To ensure transmission of cooling liquid to electronic equipment and return to	No coolant flows. Power supply fault, sensor fault.	No coolant circulations, radar system cannot operate due to	7	3	4	84

Item	Function	Failure Mode and Causes	Mission Phase/Effect	S	O	D	RPN
	cooling liquid after its passing across over-heated materials		electronic temperature problem				
Valve	To control fluid flow	Uncontrollable fluid flows. Power supply fault, sensor fault.	Pressure liquid fault, over pressure and under pressure failure	5	4	3	60
CLPU Tank	The container most of cooling liquid after flowing to electronic equipment	Leakage, low pressure for coolant. Heating resistor fault, sensor fault.	Ambient temperature increase.	5	3	4	60
Cooling Liquid Collector	The cooling liquid reservoir whose temperature has been regulated before flowing to the antenna	Clogged, coolant high pressure. Dirt, sensor fault.	Low pressure coolant, increased temperature on antenna electronic equipment	6	3	4	72
Hydraulic Rotating Joint	Connecting cooling liquid paths from static parts to moving parts and vice versa	Leakage, creaking sound. Dirt, over pressure, seal defect.	Short circuit for electronic equipment, low pressure coolant.	7	4	7	196
Liquid Filter	Cleaning the cooling liquid	Coolant becomes dirty. Dirt, expired filter.	Coolant becomes dirty, temperature increase.	5	2	3	30
Hose Pipe	Distribute cooling liquid	Surface abrasion, leakage, expired.	Coolant becomes dirty, temperature increase.	5	2	5	50

Table 2. RCM Decision Worksheet

RCM II Worksheet						Subsystem: CLPU						Date:	
Information Reference		Consequence Evaluation				H1 S1 E1 O1	H2 S2 E2 O2	H3 S3 E3 O3	Default Action			Proposed Task	Can be Done by
No	Item	H	S	E	O				H4	H5	S4		
1	Condenser	Y	N	N	Y	N	N					Scheduled restoration task, repair	Technician

RCM II Work-sheet		Subsystem: CLPU											Date:
Information Reference		Consequence Evaluation				H1 S1 E1 O1	H2 S2 E2 O2	H3 S3 E3 O3	Default Action			Proposed Task	Can be Done by
No	Item	H	S	E	O				H4	H5	S4		
2	Fan Condenser	Y	N	N	Y	N	N					Scheduled discard task, new fan	Technician
3	Compressor	Y	N	N	Y	N	N	Y				Scheduled restoration task, repair	Technician
4	Dehydrator	Y	N	N	Y	N	N					Failure finding interval, checking	Technician
5	Liquid Receiver	Y	N	N	Y	N	N					Scheduled restoration task, repair	Technician
6	Evaporator	Y	N	N	Y	N	Y	Y				Scheduled restoration task, repair	Technician
7	Pump	Y	Y	N	Y	N	Y	Y				Scheduled restoration task, repair or new	Technician
8	Valve	Y	N	N	Y	N	N					Scheduled discard task, new	Technician
9	CLPU Tank	Y	Y	N	Y	N	N					Scheduled restoration task, repair	Technician
10	Liquid Collector	Y	Y	N	Y	N	N					Scheduled discard task, new	Technician

RCM II Worksheet						Subsystem: CLPU						Date:	
Information Reference		Consequence Evaluation				H1 S1 E1 O1	H2 S2 E2 O2	H3 S3 E3 O3	Default Action			Proposed Task	Can be Done by
No	Item	H	S	E	O				H4	H5	S4		
11	Hydraulic Rotating Joint	Y	Y	Y	Y	N	Y	Y	Y		Y	Failure finding interval, checking	Technician
12	Liquid Filter	Y	N	N	Y	N	N					Scheduled discard task, new	Technician
13	Hose Pipe	Y	Y	N	Y	N	N					Scheduled discard task, new	Technician

5 Conclusion

Improvement of maintenance and repair steps in this study using the RCM and FMECA methods provides important information in preventing severe damage. The application of RCM and FMECA can show critical items that become a priority when a failure is detected. MTTF calculations can provide predictions of the maintenance time that must be done and preparation for the availability of the required spare parts. The RPN shows that Hydraulic rotating joint is the highest value at 196, it means the technicians needs to aware to prioritizing the item if there are some CLPU failure information. This paper describes recommendations for the preventive maintenance 7 components, the scheduled replacement 5 components, and the inspection maintenance 1 component. The limitations of this study are that the system calculations are still in the data stage that has been previously recorded and are not current or current data, then the application of the method is still in the simulation stage. this can be developed further as follow-up research for sharpening and maturation so that it can be applied to the actual system maintenance and which is currently operating. The RCM and FMECA frameworks in this paper are described to initiate improvements to the maintenance of radar systems. CLPU maintenance steps using RCM-FMECA start from manual recording by technicians and are calculated further with discussions and calculations based on FMECA. Furthermore, it is necessary to develop a concept that is adapted to operational conditions. RCM and FMECA provide good results in improving CLPU system maintenance to achieve the goal of good radar system performance.

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