

Preventive Maintenance in an Electrical River Vessel System

Juliana da Cruz Brilhante¹, Fabiana Rocha Pinto²

¹Undergraduate Student of the Electrical Engineering Bachelor of the University Center FAMETRO, Amazonas, Brazil

²PhD, Teacher and Advisor of the Bachelor Degree Course in Environmental Engineering and Renewable Energy of the University Center Fametro, Amazonas, Brazil

Abstract - Maintenance planning and control, more specifically preventive maintenance, has become a critical tool for companies that want to incorporate cost reduction strategies into their facilities. This tool has made significant advances and its application is increasingly evident in the industry. There are several types of methods used to perform maintenance and most companies use the unplanned corrective maintenance method to solve any problems, which is very disadvantageous in view of the losses related to long downtime. The execution of equipment changes, in addition, the periodicity of failures that occur in the equipment are much greater in corrective maintenance systems, because there is no study that enables the prevention of these failures. In this context, this paper approaches the model of a preventive maintenance plan in a river vessel electrical system, using reliability data for the planning of the steps and choosing the periodicity of stopping to perform the tasks.

Key Words: Planning and control, preventive maintenance, failures,

1. INTRODUCTION

Maintenance is essential for any company to achieve its production goals, where it is noted that without a good maintenance plan, the machines would suffer serious damage and losses such as failure to meet the manufacturing schedule, loss of product quality. And no addition of new customers. The pursuit of the highest levels of efficiency and uninterrupted production becomes evident.

This new scenario also requires new technologies to repair its production processes and equipment. It is necessary to introduce a study and evaluation method for equipment maintenance, where, through technical evaluations, it is possible to develop a maintenance plan that performs repairs and may reduce the risk of failures and errors during the execution. The cost required to change equipment is very high, therefore, using maintenance techniques, it is possible to make adjustments in equipment without needing precisely changes, which reduces costs and consequently the generation of profits for the industry.

As a result of the globalization process, the means of transport have evolved significantly over the years, among them maritime transport, given its functionality. Maritime transport can be carried out both for the transportation of people and for the transportation of other types of cargo, such as bulk products and fuels. The versatility found in this

type of transport gives freedom of development of various types of vessels. Details of the electrical system that make up a pusher boat of a bulk transport company in the Amazon region will be presented during the work.

For the Brazilian Association of Technical Standards [1] maintenance is conceptualized as the combination of all technical and administrative actions, including supervisory actions, designed to "maintain" or "replace" an item in a state in which it can perform a required function

Today's companies face the challenge of modeling their production processes in a flexible, versatile, and customer-oriented manner to remain competitive. This leads to challenges such as increased installation complexity, decreased lead time, increased variation in production and assembly processes, growing quality and cost pressure complaints, especially shortened lead times causing increased capacity demands and production flexibility [2].

Corrective maintenance is reactionary and may occur in an unscheduled manner, still observed as repair or replacement of an asset after a defective failure has occurred. Corrective maintenance is usually performed after the failure of an aircraft asset, and the objective is to restore it to its operating state as soon as possible by repair or replacement [3].

Preventive maintenance, on the other hand, occurs on a scheduled basis and aims to reduce the likelihood of asset failure or degradation. Preventive maintenance in this sense requires assets to have an expected useful life or measurable degradation in which they need to be replaced [3].

This paper presents the proposal of a preventive maintenance plan in a river vessel electrical system, in order to reduce unplanned processes with purely corrective objectives that do not contribute to the useful life of the machinery.

2. MATERIAL AND METHOD

This study was characterized from a descriptive research using bibliographic means to describe the processes and statistical data for analysis of results. As for the approach, this study has a quantitative methodology, because it uses statistical data to analyze results of an action research [4], with collections of the work script developed in river

pushers of a transport company in Manaus, aiming for an evaluation of the creation of a preventive maintenance plan.

To check the operating status of the electrical system deployed on the vessel some steps must be followed. They make up a preventive maintenance system designed to prevent the temporary and total loss of equipment.

Step 1: Metrics

MTBF (Mean Time between Failure) is a metric that refers to the average time that intersects an irregularity with a major claim (lapse). These failure times may be data results. The mean time to repair (MTTR) refers to the average time that a failure occurrence takes to be resolved after its detection, that is, the time that is used to resolve a particular claim. The goal is always to increase MTBF and decrease MTTR, measured with the following formulas.

$$MTBF = \frac{\text{RECOMMENDED HOURS SUMMARY}}{\text{NUMBER OF MAINTENANCE STOPS}} \quad (1)$$

$$MTTR = \frac{\text{REPAIR TIME SUMMARY}}{\text{NUMBER OF INTERVENTIONS CARRIED OUT}} \quad (2)$$

Step 2: Criticality Matrix

In a work environment, not all equipment has the same criticality, some equipment can vary its degree of criticality without directly affecting productivity and the harmony of operating processes. Some equipment is not used often and system operation does not depend on its operation (non-critical equipment). On the other hand, there is equipment that must be in perfect working order for the efficiency of these operating processes (critical equipment).

Table 1: Equipment Criticality Assessment Criteria

Evaluation Criteria				
Initials	Evaluation Factor	A (High)	B (Medium)	C (Low)
SE	Safety and environment	Accident and environmental damage	Increased exposure to risks and accidents	No risks
Q	Quality	Product defects, poor quality and downtime	Quality and production become variable	o process results
P	Production	Process failures and consequently stops	Part of the process is interrupted	No interruption
Evaluation Criteria				
Evaluation criteria				
OR	Occupancy rate	2 shifts plus overtime	2 shifts	No process overloads

BF	Break frequency	Less than 3 months	Average 2 times per year	Rarely
MT	Maintainability	Time and cost for repairs are high	Time for repairs and costs are acceptable	Costs and repairs are irrelevant

Step 3: FMEA

From English, Failure Mode and Effect Analysis, the FMEA had its first reference in 1949 when the US Army developed a military procedure MIL-P-1629, entitled "Procedures for Performing a Failure Mode, Effects and Criticality Analysis." This was used as a reliability assessment technique to determine the effect of failures on a system or equipment. Failures were ranked according to their impact on mission success and the safety of personnel and equipment [5].

FMEA is one of the most important parts of a step study for setting up a good maintenance plan. Assuming that this method directs us to the best maintenance method that each equipment or process needs, at this stage the modes and effects of a failure will be analyzed and, from this analysis, it will be possible to define what type of preventive maintenance will be performed for claims prevention.

Step 4: Setting Downtime

In a preventive maintenance plan, the definition of downtimes is key to the smooth running of the planned processes. In this step the downtimes for the execution of the planned task steps will be defined. This analysis will be determined from the information obtained in the previous steps.

A maintenance stop is an event that requires a lot of attention from managers and employees. The maintenance downtime is decided to provide the best interval to repair damage and symptoms before they become failures.

3. RESULTS AND DISCUSSION

This article approaches the creation of a preventive maintenance plan on a vessel of a bulk cargo shipping company in Manaus. This section aims to apply the proposed method in a study of real data related to the electrical system of a river vessel.

The maintenance work in the company is basically performed in 2 distinct groups, directed and supervised directly by those in charge of ship maintenance and the ship maintenance manager. Naval mechanical maintenance consists of a group of 4 mechanics in the first shift, and 3 more mechanics in the second shift. Naval electrical maintenance, on the other hand, consists of 2 industrial electricians in the first shift and 1 industrial electrician in the second shift.

In general, maintenance tasks are subdivided into planned and unplanned corrective maintenance and preventive maintenance. However, although there is a preventive maintenance system, the workshop ferry services are focused on corrective maintenance that meets the demand of the company's existing river pushers.

To focus on naval electrical maintenance, the company has new and old equipment, such as clamp meters and multi-tests, computers with software to update the radar system of vessels, dc source for testing batteries and voltmeter.

Maintenance is scheduled according to the load delivery schedule on each pusher. It is of utmost importance to deliver the boats within the given deadlines, given the losses the company suffers from delayed scheduling of cargo delivery. The company also rents some vessels to other separate companies. These boats are serviced on a different schedule, based on planned and unplanned corrective maintenance.

The company has few maintenance indicators, based on unit maintenance cost in relation to the time spent on each maintenance performed. Each operator assigned to separate maintenance is also responsible for completing the work orders on all pushers, answering if the task was completed, and reporting possible setbacks that may occur during the task performed. In the service orders the future corrective maintenance that will be done in future maintenance is also informed.

A major problem faced by the ship maintenance team is due to the delay in purchasing materials. As the company is more focused on corrective maintenance demands, the materials are urgently related and ordered to the company's purchasing sector, which makes the acquisition of these materials slow, due to the great demand in the sector.

Given this situation, a preventive maintenance plan in a specific pusher will be proposed, in order to insert planned maintenance into the existing electrical equipment on the vessel, in order to reduce unplanned corrective maintenance actions.

For seven months, a thorough study was done on the vessel's internal premises. The equipment that makes up the vessel's electrical system was analyzed, such as: general distribution board (GDB), general management board (GMB) and navigation equipment. Through this analysis which equipment would be included in the preventive maintenance was decided, following the script of steps mentioned.

Step 1: Metrics

Maintenance indicators serve as a translation of the behavior of production equipment and systems against maintenance actions. These relate the running machine times between interventions, the number of interventions and also the time to repair [6].

Applying the metric of equation 1, we have:

$$MTBF = \frac{\sum 11 \times 216 + 100}{12} = \frac{2476}{12} = 206$$

The pusher analyzed is departing from Manaus to Belém. The ferry takes 9 days between leaving Manaus and arriving in Belém. Trips are interspersed with stops for Corrective Maintenance. For the analyzed equipment, there were calls made by the seafarers every 216 hours of relay operation, which is equivalent to 1 round trip to the final cargo destination, and on the last trip the pusher had to be rescued before finishing the route due to malfunction of the equipment, totaling 100 hours of good operation on its last trip. Thus, it was found that the problem in relays is of high criticality, and that the average time of operation of the equipment, before failures occur, is 206 hours, considering that the travel time for delivery of cargo is 216 hours.

$$MTTR = \frac{\sum 88 + 16}{12} = \frac{104}{12} = 8,66$$

The repair time for maintenance of corrective failures is 8 hours. Twelve interventions were recorded, totaling 88 hours, and the last one needed 2 shifts to be resolved, totaling 16 hours. Corrective maintenance interventions take an average of 9 hours and 6 minutes to complete. Considering that the electrical maintenance team works 8 hours per day per employee, correctives require 2 employee shifts to perform maintenance.

Step 2: Criticality Matrix

The term criticality is used as a measure of the importance of an asset to achieve the organization's strategic objectives. In many cases this translates as a measure of the consequences of an asset failure, i.e. the impact it has on the company as a whole. Criticality should consider in a unified manner all relevant aspects of asset value generation [7].

In this stage the equipment of the general distribution board and general management board, located in the pusher engine room, was analyzed. It was found that the equipment that received the most calls for corrective maintenance was the relay.

The general switchboard is responsible for protecting the equipment that makes up the pusher engine room. After the analysis, the grade A criticality level in low voltage supervisors was found. The equipment analyzed interrupts the production process because the busbar supply system of the general management board is only released when the input voltage adjustment range from the generator comes into alignment with the voltage range adjusted on the timer component of the relay

It was also found that the cost generated by repairs can cause major damage to the industry, taking into account the cost generated by maintenance-oriented labor and the repairs the equipment needs. In some cases, the break or failure of the relay resulted in the burning of other equipment connected to it.

Step 3: FMEA

In this stage, data collection was done for the elaboration of the FMEA, aiming to direct the best preventive action. The application of this tool was done by a team of technicians, managers and supervisors, with an implementation time of approximately 3 months, with daily meetings to analyze the method operation.

The process of filling in the questions that are asked in an FMEA began. The completed fields follow a few steps, initially having equipment analysis of the general distribution board and general management. First, an analysis was made to find out which equipment had the highest history of complaints, being done by technicians who perform corrective maintenance. It was found that in the general distribution and general management boards, the higher incidence of failures resulted from malfunction in main and auxiliary relays.

The relay's main function is to monitor the voltage of a circuit within the protection panel. Thus, if any equipment is disconnected or if there is any short on the panel, the relay is quickly de-energized and its normally closed contact opens [8].

The relay acts on the main bus power input of the circuit, and has the function of monitoring the voltage that enters the main busbars of the board, through a voltage adjustment range (220 to 240V). This adjustment range sets a minimum and a limit required so that there is no damage to other circuit equipment. Table 2 below analyzed all data found from the application of FMEA in voltage supervisory relays, and also directed the preventive maintenance plan that this equipment needs.

Table 2: Application of FMEA in voltage supervisory relays.

Description			Description Failure mode and effect analysis							
Analysis of voltage supervisory relays installed on pusher			Department / Name:		Abbreviations SEV: Severity DETC: Detection OC: Occurrence RPN: Risk Priority Number					
			Technician: Person 1							
Function			Technician: Person 2		Cause	O	S	D	N	Recommended action
			Technician: Person 3							
Mode Failure Effect			In Charge: Person 4		C	E	E	P	R	
			Manager: Person 5							
Effect			Cause		O	S	D	N		
					C	E	E	P		
					O	V	T	R		
Protect the general circuit	Failure to read desired voltage setting	Damage to switchgear equipment	Dirt and oxidation on contacts	7	6	8	336	-		
			Problems reading voltage adjustment	8	9	8	576	In this case, it is advisable to change the equipment		
			Damaged contact sensitivity	7	7	6	294	-		
			Timer element malfunction	8	9	5	360	Adjust the relay adjustment range in alignment with the voltage that will be generated correctly by the generator, without vibrations.		
			Repair only in poor condition	9	9	8	648	Preventive actions with defined downtime		
			Assembly and disassembly strikes	9	7	9	567	Equipment handling training		

The interpretation of the FMEA was made by analyzing the data obtained in the RPN cell, which means risk priority number. This number was obtained by multiplying the data found in the occurrence, severity and detection sections. A target range for preventive maintenance has been established, where ratings below 500 are acceptable and pose no imminent risk to panel operation.

Step 4: Setting Downtime

By taking a conservative approach to maintenance costs with a view to getting the most out of your components while making the most of their service life, you can also compromise system reliability due to uncertainty about the life of each component [9].

The stopping base for maintenance purposes is the preventive one. However, in the maintenance plan, the time was taken to perform corrective maintenance that is properly informed in the pusher work orders.

By analyzing the data found in this article, the ideal downtime was defined. The criticality matrix of the equipment found that the relays installed in the machine room are the main causes of failure. Therefore, the downtime was defined based on the observation of events that happened with this equipment. In the Preventive Maintenance Plan, all actions advised by the FMEA failure mode and effect analysis will be performed.

Initially, the best preventive maintenance downtime for this type of equipment will be done monthly, aligning a specific date that matches the travel route plan for cargo delivery. Once a month, preventive actions aimed at eliminating relay faults, and consequently preventing the pusher from stopping, should be carried out at the Manaus ferry workshop. An industrial electrician will make the adjustments defined in the FMEA. Aligning with preventive maintenance, corrective maintenance and will also be done on the pusher--navigation instruments should be checked, battery testing should be done and AIS module upgraded. Following these recommendations it is expected that the pusher will reduce the number of relay failures and that the damage of delayed loading and equipment replacement will be reduced.

3. CONCLUSIONS

The results were obtained through a study conducted on equipment, which aimed to stipulate its useful life and a better time interval for the intervention. Preventive maintenance was chosen as the best method to use. This method aims at preventing possible failures before they compromise the actual operation of the equipment.

By adopting further analysis using the transportation of the collected data, it is possible to obtain reliable indices, which allow the decisions made by the managers to be totally directed to the real equipment problem, eliminating an unproductive work time.

Based on these criteria, downtime estimates can be made with prevention and not just for corrective actions, aiming at a better organization within the company's internal maintenance sector, taking into account results that will directly impact the company's profits.

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