Reliability Centred Maintenance Implementation For Overhead Transmission Lines In Al- Madinah Region

Nader Al Atawi, Mohammad Kanan

Abstract: Use of overhead transmission lines in Al-Madinah region is something that has been used for several decades. However, their increased failure tends to present a critical effect on supply of electricity to the consumers in the region. In normal case, the fundamental motive for any power utility is to plan, operate, and maintain power infrastructure so that consumers can receive reliable electricity services at reduced expenses. This paper therefore aims at addressing the implementation of Reliability Centred Maintenance (RCM) in overhead transmission lines particularly in Al-Madinah region.

Keywords: Reliability, Al- Madinah Region, Transmission Lines and Reliability Centred Maintenance

I. INTRODUCTION

In the modern society, the capability to use electrical energy when it is required is a fundamental presumption. Also, the introduction of complex and sensitive machines and systems into the network of overhead transmission lines has resulted to increased need for high reliability of supply. Thus, as a part of the restricting the electricity power industry, transmission utilities have tried to maximize profit while at the same time maintaining reliability. To be effective, then, these systems are required to be operated in a manner that they will sufficiently meet the needs of the customer by reducing the cost of electricity. In order to realize this goal, maintenance strategies have already been established with the key objective being to offer a trade-off that exists between the aspect of cost and reliability. Reliability Centred Maintenance (RCM), in most cases, has been employed with the purpose of coming up with maintenance strategies that offer an acceptable level of reliability in a manner that is cost effective . Thus, RCM can be defined as a technique that involves a structured framework for the purpose of analysing the different functions and potential failures of a transmission component with the key focus being to preserve reliability. As a result, RCM is required to not only put into consideration the condition of piece of equipment but also its significance in the power transmission system. Madinah being a region that favours the use of overhead transmission lines for instance from Rabig power plant to Madinah south substation, it is of great essence to ensure that there is an effective implementation of RCM. Thus, the aim of this paper is to assess the implementation of RCM in overhead transmission lines in Madinah region.

II. LITERATURE REVIEW

Currently, the concept of asset management is being implemented for the purpose of planning and running the electrical power system.

- *Industrial Engineering Department, College of Engineering (CE), University of Business and Technology, Jeddah 21448, KSA. m.kanan@ubt.edu.sa*

The primary aim of this concept is to handle tangible assets in the best way possible with the objective being to accomplish the particular goal of an establishment, while at the same time allowing for any risk. Concerning the concept of asset management, the probability of failure occurrence and its effects is one of the main risks associated with the concept. However, the principal goal is to make sure that there is maximum asset value, maximum benefit or having the least life cycle cost. Darrin [7] asserts that it is essential to understand that the only limitation in making the goal a reality, which is important in the Madinah region, is the availability of revenue or the power supply. Thus, to deal with these assets, a variety of possible actions are implemented which can either be acquired, maintained or redesigned. This introduces the concept of maintenance management, whereby it implies a method applied to handle various decisions related to these assets as well as making the appropriate decisions as regards the assets to apply actions to, the actions that require being applied, how the actions can be applied and the time to apply the actions. Thus, maintenance has the major objective of extending the life span of equipment or the average time to the next failure, whose repair may be considerably costly. [9]. moreover, emphasise that effective maintenance polices are also expected to help in reducing the frequency of service interruptions in addition to several other undesirable outcomes of such sorts of interruptions. Thus, not only the Madinah region but also in other regions, electric utilities have always been dependent on maintenance plans for the purpose of ensuring that their equipment remain in good working conditions for as long as it is feasible. It is hence the reason the Madinah region has chosen to implement Reliability Centred Maintenance concerning the overhead transmission lines. However, based on the research undertaken by Adoghe [1], it is essential to understand that the approach and procedure is still in the early stages and its application requires experience and decision-making continuously. For the Madinah region to effectively employ the RCM method, this section therefore aims to provide a brief review of the most important models and strategies addressed in the literatures and produce maintenance guidelines in connection with transmission equipment.

MAINTENANCE SPECIFICATIONS AND CURRENT PERFORMANCE

To create a better explanation of maintenance specifications regarding RCM, the definition of maintenance should be considered in the concept of protecting machine and maintaining equipment or a plant. Generally, the challenge of how to define the level to which a machine, equipment or plant require maintenance is a frequent issue concerning the above task. As regards the research of Beehler [3], specification is a comprehensive presentation of what is essential. Thus, to the maintenance of equipment and plant requires specification. Despite being unable to comprehend it in normal cases, specifications tend to exist in the mind of the maintenance engineer. Typically, a true maintenance specification may happen to be a merchant design specification or specifications that are developed internally. Therefore, it is vital that the specification accurate and independent in its requirement. It is therefore important to ensure that the maintenance system and organisation are designed for the purpose of supporting a concept based on an acceptable standard. Moreover, it is possible to offer the specification requirement at the maintenance level by creating specifications, detailed proposals and schedules. When it comes to the maintenance context, specifications are a requirement that must be completed and not a goal. Consequently, it is vital that the variation that takes place is above the level of specification.

***Table 1**. Current Situation (Time – Based Approach)*

Table 1. Current Situation (Time – Based Approach)

Line Name	No. of Tripping										
	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17
NAKHL/ALAYS (TL205+TL206)	1	2	1	2	1	0	3	6	4	2	0
MEAST/SHORA (TL119+TL120)	6	4	6	4	2	0	2	5	4	0	1
MEDNO/AIRPO (TL103+TL104)	1	2	1	2	2	1	0	1	3	1	2
YANBU/RABIG (TL05+TL06)	3	4	3	4	2	1	3	2	1	0	1
ALMUS/MEDSO (TL19)	5	2	5	2	3	0	0	1	1	2	1
MEAST/QASSIM (TL A+TL B)	1	2	1	2	2	1	0	1	3	1	2

Even though many companies employing power distribution not only in the Madinah region but also in various other parts of the world utilise the RCM approach, the fundamental fact as regards managing physical assets highlights various challenges within the case of capturing data in connection with designing maintenance schedules. The first challenge is that collecting failure information for the purpose of creating future decisions implies managing the asset base in a manner that counters the basic aims of modern maintenance management. The second challenge is that regardless of whether an company was to progress down this path, the nature of critical failures has no need to render itself to extensive statistical review. According to Beehler [3], by way of producing an effective RCM regime, the policy designer is in operation; hence, initiating a management setting that endeavours to reduce failure information and not to increase it. Additionally, the key implication here is that the more effective a maintenance schedule is, then a smaller amount of critical failures will take place, which also shows that there is less information available to the maintenance policy designer regarding operational failures. Therefore, the more optimal a maintenance plan is, the lower the volume of data.

III. METHODOLOGY

Reliability-Centred Maintenance (RCM), is an engineered system that determines the equipment failure modes and causes that can generate functional failures; system functions and the effect of functional failures, ideal strategies for managing potential breakdowns and spare holding requirements. Therefore, RCM is the optimal mix of condition-based, interval/time-based, reactive and proactive maintenance practices [2]. The principal aim of making use of RCM is to accomplish reliability of systems in all their operating modes. Consequently, this in turn will improve the maintenance schedule and reduce the costs associated with system and maintaining equipment [5]. Moreover, Reliability-Centred Maintenance offers the fundamental information and data that is necessary for sufficient and logical decisions, whereas the data collected can be used in redefining or modifying the existing maintenance schedules. To reduce the life-cycle costs and reliability of the equipment, the maintenance practices delivered by RCM are integrated and used concurrently. Conversely, for the engineers to enhance the effectiveness of equipment to eventually increase productivity, there are some innovative maintenance approaches that should be exploited. These approaches include Reliability-Centred Maintenance, preventive maintenance, total maintenance assurance, along with total productive maintenance [6]. In general, the RCM method follows specific procedures. First, critical components and their functions are listed. Secondly, the prevailing failure modes for every component are identified. Thirdly, the critical failure modes' preventive maintenance tasks are determined [8]. Therefore, the RCM programme is formulated. As a final point, evaluation of the RCM programme's value or cost analysis is finalised.

Reliability-Centred Maintenance Components

RCM consists of detailed steps that are crucial for describing the exact methodology used in implementing the reservations of the system function [2]. Moreover, the RCM steps are helpful in identifying the failure mode, the precedence failures utilised in implementing the reservations of the system perform the preventive maintenance tasks. The Reliability-Centred Maintenance steps include:

1. Select the system and collect data
2. Define the system boundary
3. Describe the system and functional block
4. The function of the system's functional failures
5. Effect analysis of the failure mode
6. Task selection

CRITICALITY ANALYSIS

To assess how equipment and system failure affect a company's performance, criticality analysis is employed. This tool helps to analytically rank the plant assets to enhance reliability upgrading creativities, advancement of PdM/PM, classify materials and prioritise work [2]. Ranking of the potential effect of each hardware and functional failures and evaluating the success of the mission can be achieved by performing a failure mode, in conjunction with the effects and criticality analysis (FMECA). Moreover, FMECA helps to assess the maintenance requirements, maintainability, system performance, and personal safety for the RCM process [11]. There is basic information that is used regarding acknowledgement of the FMECA/FMEA that used to calculate the criticality of the equipment. Figure 1 shows the used algorithm. Assessment of the criticality is achieved depending on the impact of the faults/errors at the time of the incidence up to when the effect takes place at some stage in installation, as computed in Table 1.

$$EC = \frac{30xP + 30xS + 25xA + 15xV}{3}$$

(1)

where:

EC: is the equipment criticality, %, P is the product, S is the safety, A is the equipment standby, and V is the capital cost.

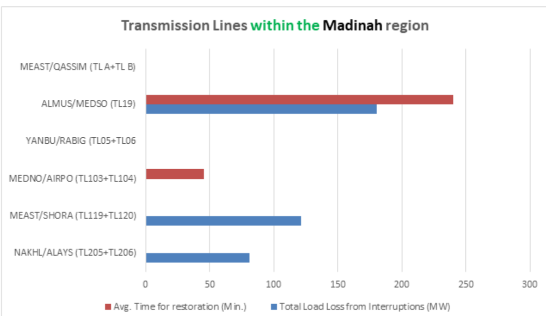

Fig 1. Algorithm for calculating equipment criticality (adapted from Afefy, 2010)

IV. RESULT AND DISCUSSION

Regarding the data collected from the systems tests conducted on the NAKHL/ALAYS power line, the results indicate that it was constructed 28 years ago. Regarding the RCM programme, all the system components have been determined, calculated and listed. Based on our study the selected lines as follows:

***Table 2**: Previous Collected Number of Tripping in 2018*

Maint. Order	Man Powers	Outage (Hours)	Cost Per order	Cost Per person		Total Cost
456	238	674	8000 SR	3200 SR	SAR	4,409,600

Table 3: The results (Condition Based RCM) 2018

Line Name	No. of Tripping										
	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	FEB
NAKHL/ALAYS (TL205+TL206)	1	2	1	0	3	6	4	2	0	1	2
MEAST/SHORA (TL119+TL120)	6	4	2	0	2	5	4	0	1	6	4
MEDNO/AIRPO (TL103+TL104)	1	2	2	1	0	1	3	1	2	1	2
YANBU/RABIG (TL05+TL06)	3	4	2	1	3	2	1	0	1	3	4
ALMUS/MEDSO (TL19)	5	2	3	0	0	1	1	2	1	5	2
MEAST/QASSIM (TL A+TL B)	1	2	2	1	0	1	3	1	2	1	2

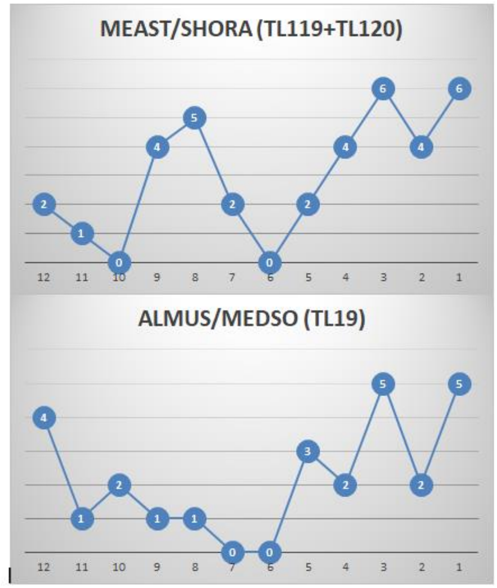

***Figure 3:** Time Interval Results*

***Table 4:** The Maintenance Cost (Condition Based RCM)*

Maint. Order	Man Powers	Outage (Hours)	Cost Per order	Cost Per person		Total Cost
31	67	49	4000SR	1700 SR	SAR	237,900

V. DISCUSSION

The components documented relating to RCM in the discussion section are essential in describing the functioning of the power systems. The NAKHL/ALAYS transmission line is one of the electrical procedures in Madinah which was investigated to assess its failure and the possible consequences for the productivity of the system. When the power lines are under constant disruptions, the business will experience extensive maintenance costs to restore normality. Factors such as availability, mean time between failures, and mean time to repair and total maintenance costs should be assessed on all power lines in Madinah before making any significant decision. Reliability Centred Maintenance is instrumentally used to assess the working of the system based on how well it operates considering errors. Once the source of the problem is discovered, practical maintenance should ensue to ensure the issue is solved. Other factors such as the increased number of tall trees near power lines should also be addressed. Any tree that is near a powerline should be evaluated and assessed to understand its nearness and if it falls in the danger zone. Once verified, they should be cut and replaced with brand-new materials for the powerline to continue operating smoothly. Figure 8 above illustrates the restoration time and total load loss from interruptions. An assessment of the NAKHL/ALAYS (TL205+TL206) power line indicates that it transports 110 megawatts of power that it is easy to maintain. Any time a power interruption occurs, the engineers on the ground can restore it within a minimum time of 40 minutes. Anytime power is cut from transmission due to interruptions, such as permanent damage to the transmission line or a brownout, it can be corrected immediately. Additional causes of power outages include overload of the power line where demand for power is low as compared to the level of power that is required at the destination. Additionally, the power company should develop new ways of counteracting cascading failures for the entire systems to function optimally. For instance, they should have tracking systems that calculate the source of the problem for the company to reduce its power restoration time to effectively 0 minutes. The next power transmission line with a minimal power transmission time of 45 minutes is MEDNO/AIRPO (TL103+TL104). This power transmission line has been in operation for 19 years and it has managed to supply power for a long time. Likewise, its team gives the impression to have understood how to work with and restore its power within the shortest time available. The National Academies of Sciences, Engineering and Medicine [10], proposes a four step process of restoring power within the shortest time. It maintains that whenever power failure occurs, the following four steps should be employed to restore power at the earliest opportunity to avoid losses and damages. First, one should assess the location, seriousness and extent of the damage to the electricity to understand the sources of the problem. Secondly, one should provide the human and physical resources that are necessary to conduct the repair. These include trained and experienced personnel who understand what should be carried out to restore power within the shortest time. Additionally, the individuals should have a means of transport to facilitate their transportation to the designated place. Moreover, they should have the equipment necessary to resolve the problem. Next is the prioritisation of the site as well as the criticality of the load in various places. The location found should be investigated for the technical team to find the shortest route with the required resources to undertake the assessment. The final process in the model is conducting essential repairs through implementing the desired steps. In this stage, all errors are corrected and power restored. Should there be any problems with the transmission line, this is seen in the final assessment that arises to correct the problem. Castillo [4], assert that continuous assessment of power lines helps to cure their problems. This model works best in finding a lasting solution to the frequent power outage issues in the country. The National Academies of Sciences, Engineering and Medicine (2017), continues to stress that the solution to the problem of frequent power losses is to have a trained team of technical personnel. They should frequently undergo advanced training, planning, communication and continued refinement of the team as the appropriate strategy as regards facilitating work power systems restoration. The power institution should highlight the increased use of drills as the best approach for training personnel to understand the role of restoration. When these individuals are well equipped with the necessary facilities, it will be easy to determine how to address their issues. The rest of the facilities, that is, MEAST/ SHORA and ALMUS/MEASO (TL19) have extensive restoration phases that are on average 120 and 240 minutes. Albeit the former carries 110 KW and it was constructed six years ago, its management continues to be inadequate, which is why they continue to take extensive periods in relation to repairing power failures. The latter transmission line titled MEASO, carries a large amount of power adding up to 380 KW with a restoration time of 240 minutes. The team is unprepared or the line has been lengthened which therefore takes more time to travel in their attempt to resolve a single problem. The results in Figure 8 provide supplementary information regarding the total loss of power as a consequence of interruptions. Any single interruption generates excessive loss of power. For instance, ALMUS/MEDSO (TL19) is the oldest transmission system at 36 years of age and it loses close to 180 Megawatts every time an interruption occurs. This means that the institution should train its personnel to reduce their period of power restoration to decrease energy wastages whenever an interruption occurs. [12], determined similar results in the research they completed. The system should be evaluated to ensure its loading capacity is within the recommended level because a reduction only exacerbates the condition and might cause brownouts and eventual power outages in major designated areas. When the duration of power restoration is kept to a minimum, it reduces both maintenance cost and repair time. As long as Equipment Crucially (EC) is managed well, the system can remain stable and easy to use. In the assessment of EC, equipment standby, product and product safety, besides the values of functioning power transmission lines should be similar to the information presented in Table 2. There are percentages for which equipment standby should remain for the system to be stable. Without these systems, functioning in this way means that it is difficult for the company to access and restore the system so that it works correctly. This research methodology could fail as it does not provide options for solving the power issues. It should be prepared for the system to collect information from secondary sources on how experts have acceptable and workable ways of managing power transmission issues. In order to be effective, the study would have explained the suggested methods and proposed them as appropriate for handling and improving the reliability of the power transmission systems. Hence, adverse results would emerge as not being able find the best way to resolve issues in power systems to decrease costs and solve unavailability issues.

.

CONCLUSION

The purpose of this research is to ascertain how best to improve quality in the delivery of power in the transmission lines by reducing the average restoration time and reducing the wastage of megawatts due to interruptions in the transmission lines. The objective is to ensure that people have an adequate supply of power regardless of the age of our transmission systems. The study investigates the load and supply amidst increasing levels of power disruptions to prevent recurrent problems for consumers. The study uses a methodological framework that investigates the working statistics of five power lines. It studies their age, restoration time after a disruption, as well as load wastage in megawatts after an interruption. It later assesses the data using Equipment Criticality and the assessment of the RCM logic tree to understand what should be carried out in the event of a power interruption. Based on the findings, it suggests several recommendations, as shown below.

REFERENCES

[1] Adoghe, A.U., 2010. Reliability Centred Maintenance (RCM) for Asset Management in Electric Power Distribution System(Doctoral dissertation, Covenant University).

[2] Afefy, I.H., 2010. Reliability-centred maintenance methodology and application: a case study. Engineering, 2(11), p.863.

[3] Beehler, M.E., 1996, September. Reliability centred maintenance for transmission systems. In Transmission and Distribution Conference, 1996. Proceedings., 1996 IEEE (pp. 96-101). IEEE.

[4] Castillo, A. (2014). Risk analysis and management in power outage and restoration: A literature survey. Electric Power Systems Research, 107, 9-15.

[5] Chalifoux, A. and Baird, J., 1999. Reliability Centred Maintenance (RCM) Guide Operating a More Effective Maintenance Program (No. CERL-TR-99/41). CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL.

[6] Conachey, R.M., and Montgomery, R.L., 2003. Application of reliability-centred maintenance techniques to the marine industry. SNAME, Texas.

[7] Darrin, W., 2009. How to effectively manage assets by criticality. Reliable Plant Magazine, CMRP.

[8] Fore, S. and Msipha, A., 2010. Preventive maintenance using Reliability Centred Maintenance (RCM): A case study of a ferrochrome manufacturing company. South African Journal of Industrial Engineering, 21(1), pp.207-234.

[9] Heo, J.H., Kim, M.K. and Lyu, J.K., 2014. Implementation of reliability-centred maintenance for transmission components using particle swarm optimization. International Journal of Electrical Power & Energy Systems, 55, pp.238-245.

[10] National Academies of Sciences, Engineering, and Medicine. (2017). Enhancing the Resilience of the Nation's Electricity System: Restoring Grid Function After a Major Disruption. Washington, DC: The National Academies Press. https://doi.org/10.17226/24836.

[11] Pobporn, W., Noohawm, O. and Rerkpreedapong, D., 2010. Reliability Centred Maintenance (RCM) Implementation on PEA Power Distribution Systems: A Case Study of Bang-Pa-In Branch Office. ADVISORY AND EDITORIAL BOARD, p.41.

[12] Van Hentenryck, P., Coffrin, C., & Bent, R. (2011, August). Vehicle routing for the last mile of power system restoration. In Proceedings of the 17th Power Systems Computation Conference (PSCC'11), Stockholm, Sweden.