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Designing a Reliability Maintenance Plan for Refinery Plants: A Case Study of a Nigerian-Based Refinery and its Power Systems

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Abstracts: This study developed a comprehensive and effective reliability maintenance plan for refinery plants. Using a Refinery based in Nigeria as a case study, the research identified key factors affecting the reliability of refinery operations and proposed strategic maintenance measures to enhance operational efficiency and safety. The study utilized reliability centered maintenance (RCM) and failure modes and effect analysis (FMEA). From the evaluation, breaking down the components of the power system in the plant and addressing them individually exposes more vividly the errors in that system. Each failure mode was analyzed in terms of possible consequences on operation, function, or system status. The subject of risk assessment was presented and utilized to develop an approach for implementing the RCM in refinery power systems Finally, a proposed action plan was introduced to reduce the RPN number, thereby increasing the overall reliability and efficiency of the system component. It was observed that by reducing the RPN of each component, the overall efficiency of that component increases saving the company huge maintenance cost.

Keywords: Reliability Optimization, Operational Efficiency, Refinery, Maintenance Cost Reduction.

1. INTRODUCTION

Maintenance of equipment is a significant fraction of the total operating costs in many industry sectors. (Murthy, 2002). Effective maintenance management requires a multidisciplinary approach where maintenance is viewed strategically from the overall business perspective (Pintelton, 1992). The approach to maintenance has changed dramatically over the last century (Blischke, 2000). Up to about 1940, maintenance was considered an unavoidable cost and the only maintenance was CM (Corrective Maintenance). Whenever an equipment failure occurred, a specialised maintenance workforce was called on to return the system to operation. Maintenance management determines what planned and programmed maintenance work should be carried out, and it considers what potential problems may require an unplanned, reactive response (Cheng *et al*., 2013). One part of maintenance management is to interpret information to manage the equipment in the best possible way. To do so, a lot of information must be gathered and analysed; useful information comes from e.g., SCADA, customers, maintenance and operating personnel, economy departments, environmental considerations, rules, and regulations, etc. Furthermore, several maintenance strategies are mainly used in technical systems. The most common strategies are corrective, time-based, condition-based, and reliability-centered maintenance (Balzer *et al*., 2001). Maintenance and renewal strategies are often focused on availability and reliability; with this approach there is a risk that there will be a conflict between short-term results and long-term conditions (Leite da Silva *et al*., 2001). As a result, the focus of this study is to design a comprehensive reliability maintenance plan tailored for refinery plants, with a specific emphasis on a Nigerian based Refinery.

2. METHODOLOGY

The study utilized reliability centered maintenance (RCM) and failure modes and effect analysis (FMEA) to find the effective parameters on the reliability of the refinery plants. FMEA (also known as failure modes, effects, and criticality analysis (FMECA)) is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service and an essential tool when reliability centered maintenance (RCM) approach is adopted. Moreover, the primary objective of RCM analysis is to provide a comprehensive, systematic, and documented investigation which establishes important failure conditions of the machinery system(s), maintenance tasks or system/equipment redesigns chosen to reduce the frequency of such occurrences, and the rationale for spares inventory.

Furthermore, to quantitatively carry out the reliability assessment, reliability equation in terms exponential failure time is given as:

$$R = e^{-\lambda t} \quad (1)$$

Where R is reliability, *e* is the natural log base, λ is the failure rate and *t* is the time duration.

With low failure rates and short exposure times, the values for reliability are close to one, since failure rate, λ, is the reciprocal of mean time between failure (*MTBF) (λ = 1/MTBF)*, the expression for reliability can be rewritten as:

$$R = e^{-\frac{t}{MTBF}} \quad (2)$$

To quantitatively determine the availability of the device, which is the fraction of time a thing or system is available for use; that is, not shut down by failure. Equation (3) is used:

$$A = \frac{MTBF}{MTBF + MTTR} \quad (3)$$

Here *A* is the fraction of total time the system is available, MTBF is its mean time before failure and MTTR is the mean time to repair.

For the series of sub systems, there is an equation that puts this into perspective. It says that the failure rate for the total system, λ_T, is the sum of the failure rates, λ_n, for all the series subsystems.

i.e., $\lambda_T = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7 \ldots + \lambda_n \quad (4)$

Since MTBF is the reciprocal of failure rate, Equation (4) can be rewritten as:

$$\frac{1}{MTBF_T} = \frac{1}{MTBF_1} + \frac{1}{MTBF_2} + \frac{1}{MTBF_3} + \frac{1}{MTBF_4} + \cdots + \frac{1}{MTBF_n} \quad (5)$$

When there is redundancy in the subsystems that can affect positively in the total reliability of system and leads to total reliability improvement. The effect of redundancy on reliability of each redundant subsystem is calculated as:

$$MTBF_p = \frac{MTBF_i^{n-1+1}}{n(MTTR_i)^{n-r}} \quad (6)$$

Here *n* is the number of parallel elements in the system and, *r* is the number that is required for successful operation. As mentioned, equation having redundancy can increase the Total MTBF of system enormously and this will lead to high reliability of total DP system, subsequently, in the design stage, considering redundant subsystems would be much effective method to improve the reliability of DP system beside other modifications.

It follows then for the mean time to repair (restoration) at the system level MTTRs is calculated with Equation (7):

$$MTTR_s = \sum_{i=1}^{n} \left(\frac{MTTR_i}{MTBF_i}\right) / \sum_{i=1}^{n} \left(\frac{1}{MTBF_i}\right) \quad (7)$$

To quantitatively assess the maintainability, the random variable is time-to-repair, in the same manner as time-to-failure is the random variable in reliability. Maintainability for a system in which the repair times are distributed exponentially is given by:

$$M(t) = 1 - e^{\mu t} \quad (8)$$

Where μ = repair rate and is given as:

$$\mu = \frac{1}{MTTR} \quad (9)$$

3. RESULTS AND DISCUSSIONS

3.1. Starting the FMEA Process

This study proposed FMEA as an appropriate method for optimal implementation of RCM in power systems of refinery plants considering weaknesses in all expected operational modes of such systems.

3.2. Identification of the Power Distribution Assets in the complex

These assets were highlighted to play a very crucial part in functioning of the complex. The sensitivity of the asset was examined and found to be the leading cause of unplanned shutdowns.

3.3. Identify the Potential Failure Modes

Failure mode is the way that a system or process could fail to meet design intent or process requirements. The researcher had to assume that the failure could occur but may not necessarily occur. A clear understanding of the ways the components could fail was important since it properly directs the analysis.

3.4. Identify Potential Effects of Failure

Potential effects of failure are the effects of the failure mode as perceived by the staff and operators in the complex. The effects or impact of the failure are described in terms of what the refinery complex might notice or experience.

To determine the potential effects of failure, the researcher had to analyze the consequences of those failures and the severity or seriousness of the consequences.

3.5. Identify Potential Causes of Failure

Potential cause of failure are the indicators of how the failure may occur, usually something that can be controlled or corrected. Potential cause of failure may be a sign of process or design weakness of which the consequence is the failure mode. In course of the analysis, it was noticed that there is a direct relationship between a cause and its resultant failure mode (if the cause occurs, then the failure mode also occurs). Identifying the root cause(s) of the failure mode, in enough detail, will enable the researcher to identify the required control measures and action plan.

3.6. Current Preventive Activities

These are the controls currently in place to prevents the cause of failure. The researcher identified the maintenance action for each component in relation to the failure mode. It was noticed that some components have no maintenance action to prevent an occurrence of failure in the complex.

3.7. Current Detection Mode

The researcher considered the detection mode for each component that is already in place to show if the component is faulty.

3.8. Risk Assessment

Risk assessment was employed to determine the possible mishaps, their likelihood, consequences, and the tolerances for such occurrences.

Table1: Severity benchmark for this study

Ranking	Failure effect	Operational Impact
1-2	Minimal system effect.	Operator is unaware
3-4	Slight reduction in performance.	Operator notices.
5-6	Noticeable drop in performance	Operator is disappointed
7-8	System is inoperable	Operator is annoyed
9-10	Failure affects customer safety	Operator is annoyed and alarmed and directly affected.

i. Occurrence

Occurrence is the chance that a specific cause will occur resulting in the failure mode within the design life. A consistent occurrence ranking system was used to ensure continuity.

Table 2: Severity benchmark for this study

Ranking	Rate	Cases
1	Remote	No failure anticipated
2	Very low	Only in extreme conditions
3-5	Low	Isolated cases
6-7	Moderate	Occasional
8-9	High	Often
10	Very high	Almost Inevitable

ii. Detection

This involves ranking the existence of a cause, the resulting reason for failure or the failure mode, either by physical or analytical methods. The assembled team agreed on evaluation criteria and a ranking system, then we applied them consistently across the different components.

Table 3: Severity benchmark for this study

Ranking	Rate	Cases
1-2	Very high	Almost certain detection
3-4	High	Good chance of detection
5-6	Moderate	Might detect it
7-8	Low	Poor chance of detection
9-10	Very low	Unlikely to detect

iii. Risk Priority Number (RPN)

Risk Priority Number, or RPN, is a numeric value assigned to a process, or steps in a process, in which a team assigns each failure mode numeric values that quantify severity of impact, likelihood of occurrence and likelihood of detection.

RPN is given as:

RPN = Severity (S) x Occurrence (O) x Detection (D)

Prioritization and Action

Once the initial identification of failure modes and effects, potential causes and control and risk assessment was completed, the assembled team decided to further reduce the risk. The initial focus was towards failure modes with the highest severity rankings. When the severity is 9 or 10, we ensure that the risk is addressed through existing design controls or recommended actions.

FMEA Form

All failure modes, effects, causes, controls, risks, recommended actions were arranged for each component via an FMEA form.

Table 4: FMEA for Gang isolator

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Gang Isolator	1. unable to operate 2. Incomplete isolation/closing	1. Arcing 2. Glowing 3. Unable to close or open	7		1. Loosed contact. 2. Stiff joint. 3. Aging.	3 3 4	1. Physical observation 2. When operating.	7 7 7	147 147 196	1. Proper Quality check during installation. 2. Periodic inspections 2. Monthly servicing of the gang (greasing and tightening of bolts).	7	2 2 2	3 3 4	42 42 56

Fig.1 Actual RPN and proposed RPN for Gang isolator

From Table 4, it is seen that each cause of failure has a high RPN of over 100. These values were reduced by proposing the recommended actions. By enforcing the proposed action plans, the RPN was reduced drastically by 71% for each of the actual RPN.

Table 5: FMEA for SFC breaker

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Breaker	1. Non-tripping and closing of breaker 2. Unable to operate	1. Explosion 2. Fatal injury	9		1. Wrong relay setting	1	1. Till there is a fault	5	45	1. Periodic primary injection test on the breaker (trip test) (Every 6 months). 2. Periodic contact resistance check (Every 6 months) 2. Monthly visual inspection of breaker hardware. 3. Overhaul of deteriorated breakers. 4. Use infrared thermal camera to inspect the breaker.	9	1	3	27
					2. Faulty trip coil	2	2. When operating.	5	90			2	2	36
					3. Faulty DC circuit	3	3. Burning smell	5	135			2	3	54
					4. Faulty battery charger	2	4. Breaker gets heated up to touch	3	135			2	2	36
					5. Low Sf6 gas	3		3	81			2	3	54
					6. Moisturization	4		5	180			2	3	54
					7. CT and VT failure.	3		5	135			2	2	36
					8. Faulty spring charger	5		5	225			2	3	54
					9. Component deterioration.	2		6	108			2	3	54

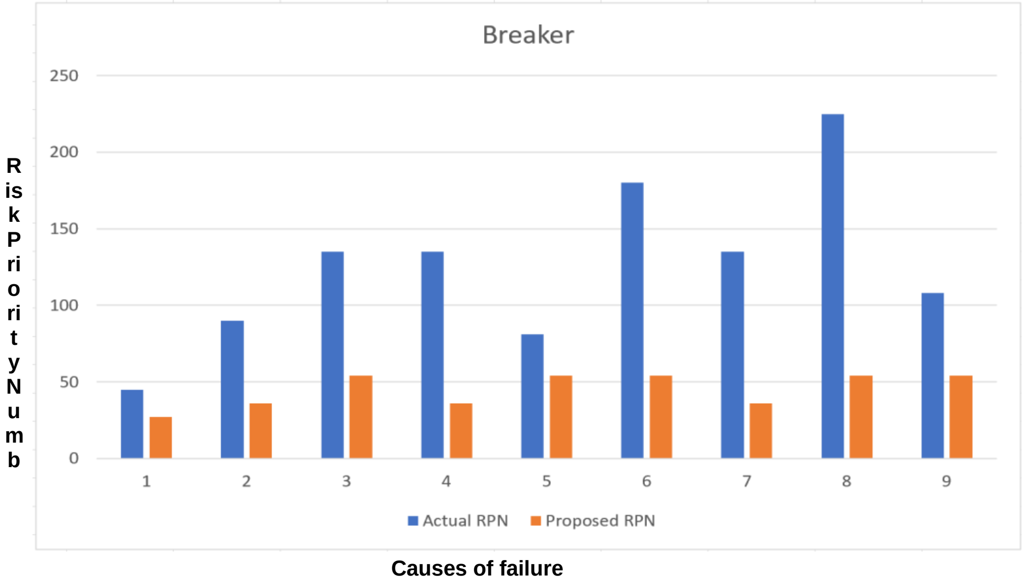


Fig 2 Actual RPN and proposed RPN for SFC breaker

From Table 4.5, it is seen that each cause of failure has a high RPN of over 100. These values were reduced by proposing the recommended actions. By enforcing the proposed action plans, the RPN was reduced drastically by about 40%, 60%, 60% 70%, 33%, 70%, 60%, 70% and 50% respectively.

Table 6: FMEA for Transformer

Risk Priority

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Transformer	1. Mechanical fault 2. Electrical Fault	1. Transformer out of service 2. Overcurrent	5	Periodic dielectric test of oil.	1. Tap changer failure	2	1. Till there is a fault 2. Abnormal humming. 3. Burning smell	7	70	1. Carry out sweep frequency response test 2. Carry out periodic Three Phase turns ratio test (every 6 months). 2. Carry out periodic insulation resistance test (every 3 months). 3. Carry out winding resistance test (every 3 months) 4. Carry out short circuit impedance measurement (every 6 months) 5. Provide relief transformer. 6. Do not use copper strands as fuse.	5	2	2	20
					2. Faulty cooling	4		6	120			1	2	10
					3. Poor earthing	3		4	60			1	1	5
					4. Overloading	8		4	160			2	2	20
					5. Bushing failure	5		3	75			3	1	15
					6. Loosed contact	5		3	75			3	2	30
					7. low oil level	4		5	100			1	1	5
					8. bad oil	4		5	100			1	1	5
					9. Unbalance load	8		8	320			2	2	20
					10. Winding failure	3		7	105			2	1	10

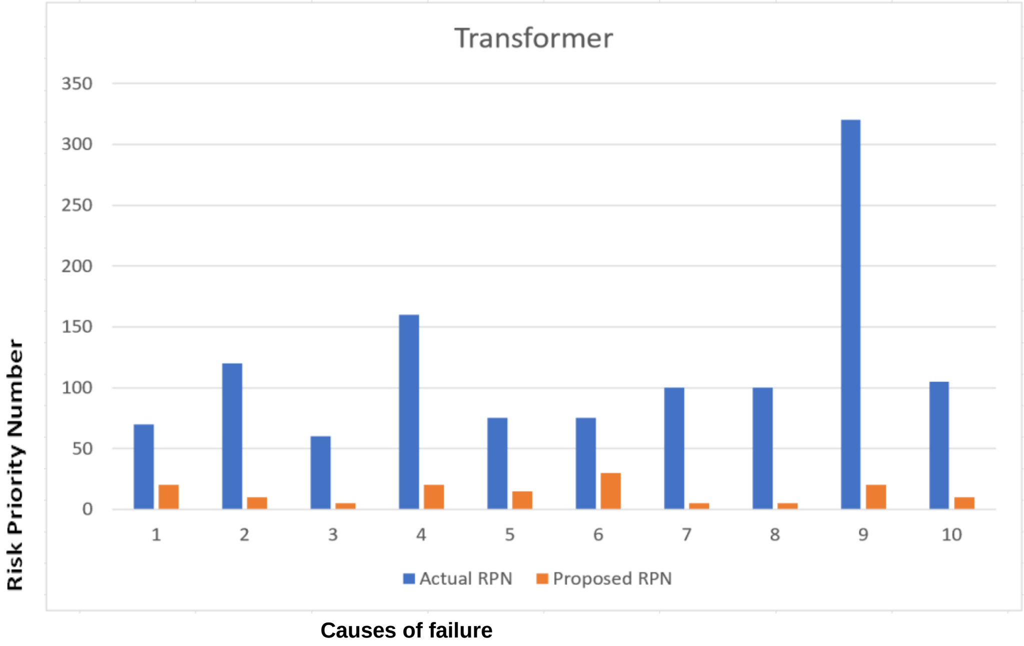


Fig 3. Actual RPN and proposed RPN for SFC breaker

Actual RPN was reduced by 71%, 91%, 91%, 87%, 80%, 60%, 95%, 95%, 93%, 90%.

Table 7: FMEA for distribution line

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Distribution line	1. Open circuit fault	1. Unplanned outage.	7		1. Snap jumper	8	1. Physical observation	6	336	1. Weekly patrol and maintenance (restringing of lines.)	7	6	3	126
	2. Closed circuit fault	2. Low voltage			2. Faulty pin/disc insulator	6	2. Till there is a fault	8	336			6	4	168
	3. Earth fault				3. weak conductor	8	3. Burning smell	7	392	2. Proper customer complaint system		3	3	63
					4. Undersize conductor	7		7	343	3. Implementation of SCADA system		3	3	63
					5. Sagged line	9		6	432	4. Use steel reenforced Aluminum conductor		3	3	63
					6. Climbers and clippers shunting the line.	9		8	504			5	4	140
					7. Fallen HT pole	8		3	168			5	3	105

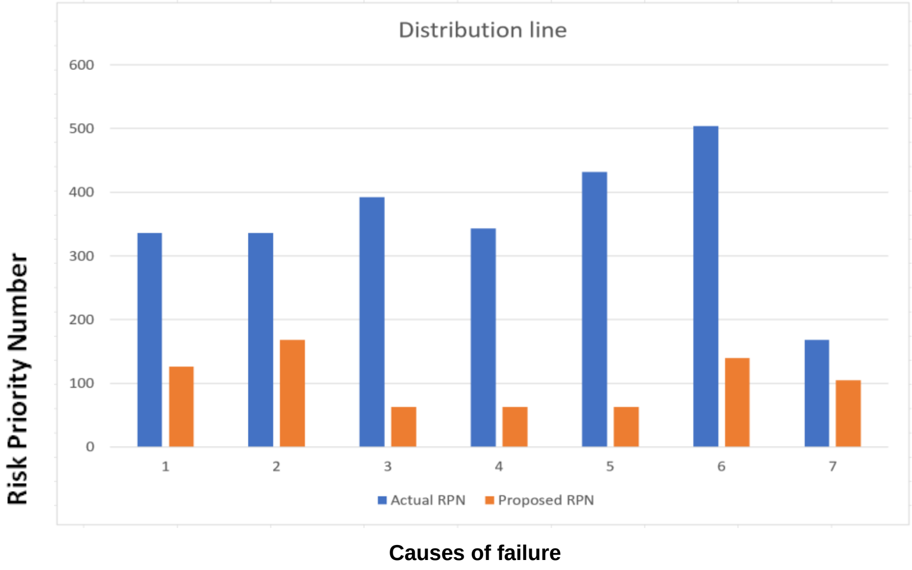


Fig. 4 Actual RPN and proposed RPN for distribution lines

By applying the recommended actions, the actual RPN was reduced by 62%, 50%, 83%, 81%, 85%, 72%, and 37% respectively.

Table 8: FMEA for pin and disc insulator

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Pin and Disc insulator	1. Crack and shattering	1. Line to ground fault	7	.	1. Lightning flash 2. Substandard material 3. Product failure due to aging 4. Poor installation	6 7 7 6	1. Physical observation of port flash at night 2. Till there is a fault 3. Use of insulation resistance tester	8 8 8 8	336 336 392 336	1. Proper quality assurance test during installation 2. Change older insulators 3. Implementation of SCADA systems	7	5 3 3 2	4 4 4 4	140 84 84 56

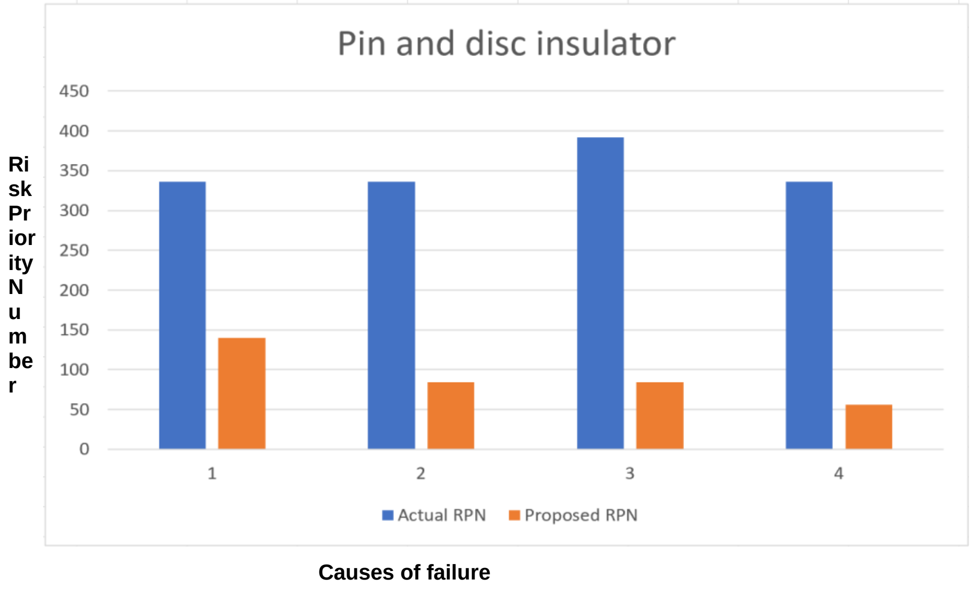


Fig 5. Actual RPN and proposed RPN for pin and disc insulators

The actual RPN was reduced by 58%, 75%, 78% and 83%.

Table 9: FMEA for Electric

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
HT/LT poles	1. Cracked or broken pole	1. Unplanned outage	8	1. Stay installation	1. Collision	5	1. Physical observation	4	160	1. Proper quality assurance check during installation	8	5	4	160
	2. Short pole	2. Damages			2. Inferior pole	6	2. Till there is a fault	7	336			4	3	96
					3. Terrane	4		7	224	2. Proper installation considering the terrane		4	5	160
					4. Faulty stay system	6		8	384			4	5	160
					5. Poor installation	6		8	384	3. Proper installation of stay system. 4. weekly patrol of the line		2	2	32

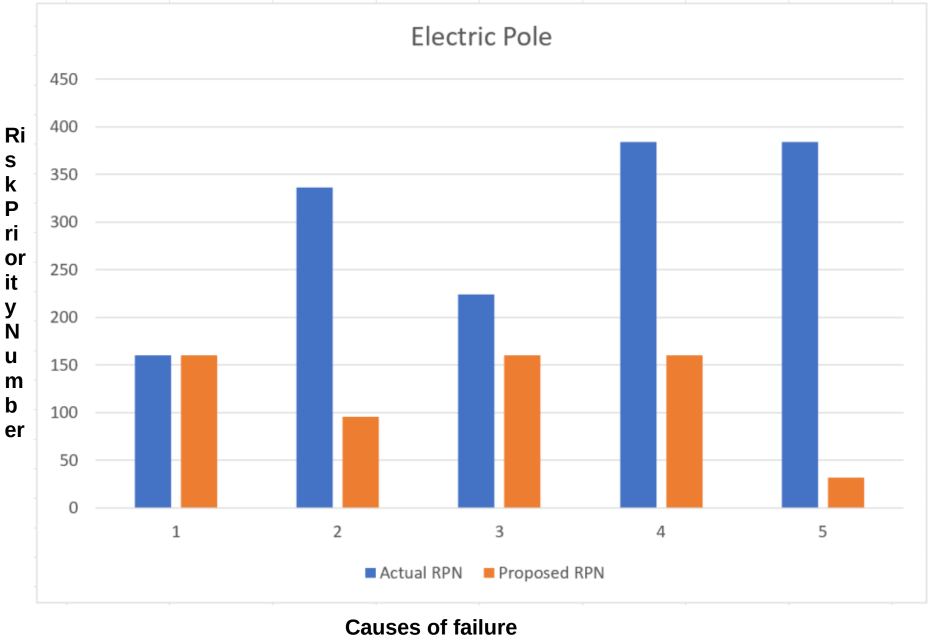


Fig 6. Actual RPN and proposed RPN for Electric pole

Actual RPN was reduced by 0%, 71%, 28%, 58%, 91%.

Table 10: FMEA for Lightning arrestors

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Lightning arrestor	1. Crack or shattering	1. Line to ground fault	8		1. Lightning	6	1. Physical observation	2	96	1. Proper quality assurance check during installation	8	3	4	96
	2. Failure to protect the transformer	2. Damage to the transformer			2. Poor installation	6	2. Till there is a fault	7	336	2. Proper installation		1	3	24
					3. Inferior product	5		8	320	3. Periodic replacement of old Lightning arrestors.		1	2	16
					4. Equipment failure	7		2	112	4. Weekly check		5	5	80

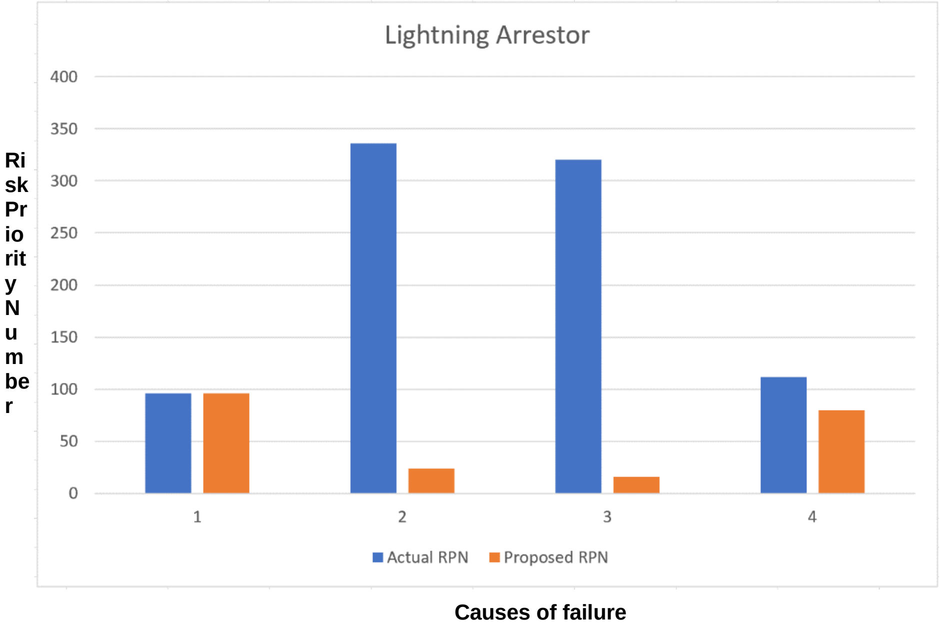


Fig 7. Actual RPN and proposed RPN for Lightning arrestors

Actual RPN was reduced by 0%, 92%, 95%, 28%.

Table 11: FMEA for XLPE Cable

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
XLPE cable (35mm or 75mm)	1. cable failure	1. Unplanned outage	8		1. Poor termination	4	1. Physical observation	5	160	1. Proper quality assurance check during installation	8	1	2	16
	2. Termination failure	2. Fire			2. Bad cable log	3	2. Till there is a fault	4	96	2. Use ideal outdoor Raychem termination kit		1	2	16
					3. Stress on cable	4		3	96	3. Use logging machine for the cable log instead of hitting with hammer.		3	3	72
					4. Inferior cable	5		5	120	4. Weekly patrol of the line		2	3	48

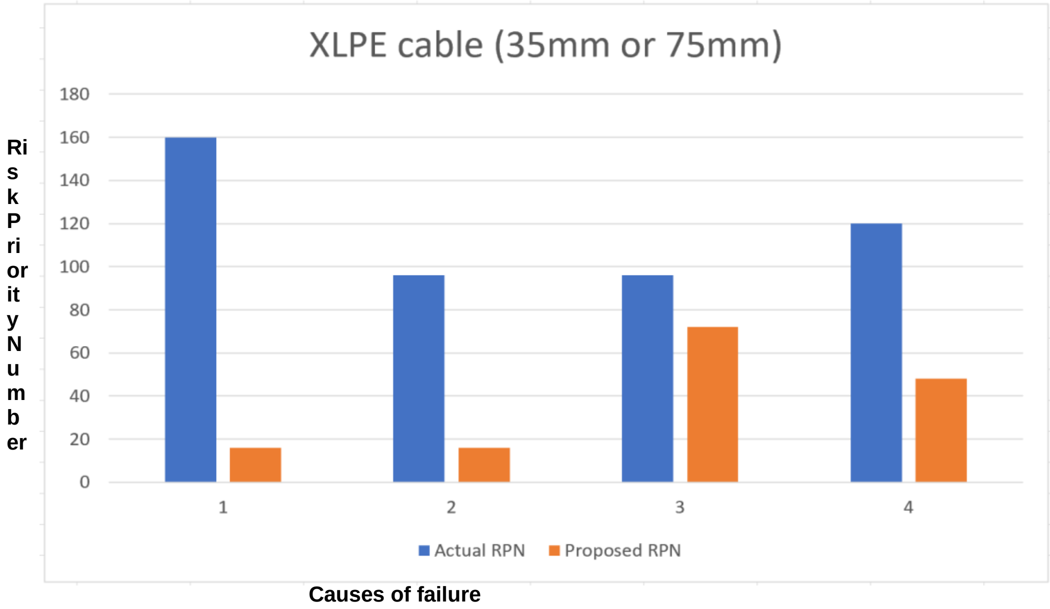
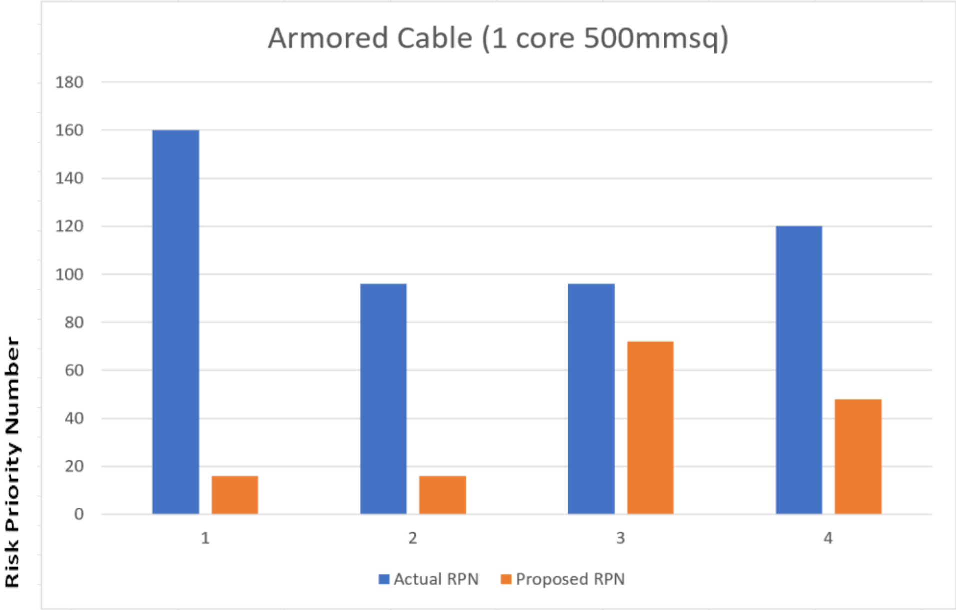


Fig 8: Actual RPN and proposed RPN for XLPE Cable

Actual RPN was reduced by 90%, 83%, 25%, 60%.

Table 12: FMEA for Armored Cable

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Armored Cable (1x500mm)	1. cable failure 2. Termination failure	1. Blackout 2. Fire 3. Damage of transformer bushing	8		1. Poor termination 2. Bad cable log 3. Stress on cable 4. Inferior cable	4 3 4 5	1. Physical observation 2. Till there is a fault	5 4 3 5	160 96 96 120	1. Proper quality assurance check during installation 2. Ensure the cable is of Reasonable length. 3. Use clipping tool for the cable log instead of hitting with hammer. 4. Weekly patrol of the line	8	1 1 3 2	2 2 3 3	16 16 72 48



Causes of failure

Fig 9. Actual RPN and proposed RPN for Armored Cable (1 core 500mmsq)

Actual RPN was reduced by 90%, 83%, 25%, 60%.

Table 13: FMEA for Feeder Pillar Unit(800Amps)

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Feeder Pillar (800Amp)	1. Burnt termination bar	1. Low/high Voltage	7		1. Poor Termination	7	1. Physical observation	7	343	1. Proper quality assurance check during installation	7	2	6	84
	2. Burnt fuse carrier	2. Unplanned outage			2. Using galvanized copper bar instead of pure copper bar	6	2. Periodic check	8	336	2. Use original fuse carrier		2	5	70
	3. Termination failure.	3. Cable burn			3. Loosed contact	7		8	392	3. Use Clipping tool and ensure proper termination is done.		3	5	105
		4. Damage on transformer			4. Wrong fuse	9		8	504	4. Used only standard fuse with corresponding fuse rating 5. Weekly maintenance 6. Load balancing		2	5	70

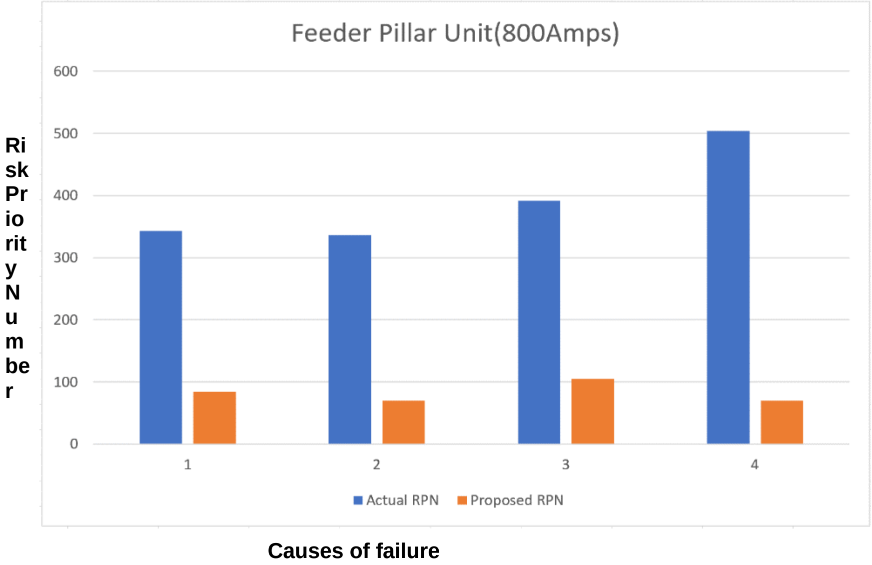


Fig 10: Actual RPN and proposed RPN for Feeder Pillar Unit(800Amps)

Actual RPN was reduced by 75%, 79%, 73%, 86%.

Table 14: FMEA for Riser cable (4x150mm)

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Riser cable (4x150mm)	1. Cable burn	1. Low/high voltage	9		1. Poor termination	8	1. Physical observation	5	360	1. Use bi-metallic line tap	9	3	2	54
	2. Voltage fluctuation	2. Damage of electronic appliances			2. Line bridge	5	2. Till there is a fault	4	180	2. Use Clipping tool for the cable log instead of hitting with hammer.		5	2	90
		3. Blackout			3. Loosed contact	8		6	432	3. Ensure proper termination and spacing is done.		4	3	108
					4. Inferior fuse carrier	8		8	576	4. Use original fuse carrier		2	2	36
					5. Inferior bi-metallic line tap	8		8	567	5. Weekly patrol of the line		1	1	9

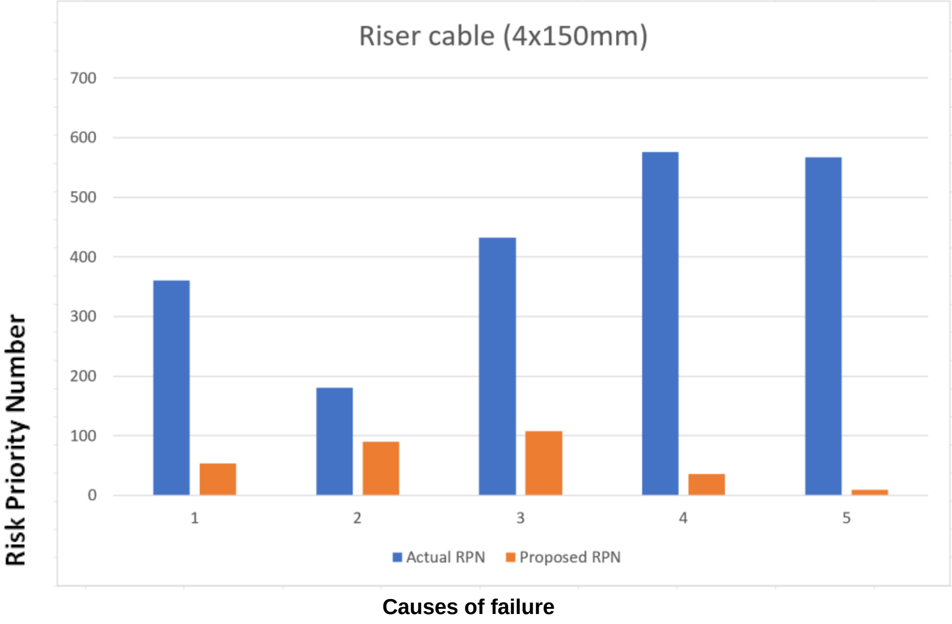


Fig 11: Actual RPN and proposed RPN for Riser cable (4x150mm)

Actual RPN was reduced by 85%, 50%, 75%, 93%, 98%.

Table 15: FMEA for LV Network

Item	Potential failure mode	Potential effects of failure	Severity	Current preventive activity	Potential cause of failure mode	Occurrence	Current detection mode	Detection	RPN	Recommended action(s)	Severity	Occurrence	Detection	RPN
Distribution line	1. Open circuit fault 2. Closed circuit fault 3. Earth fault 4. Cut line	1. Blackout. 2. Low voltage	8		1. Snap jumper	8	1. Physical observation 2. Till there is a fault 3. Burning smell	6	384	1. Weekly patrol and maintenance (restringing of lines, cutting of trees). 2. Proper customer complaint system 3. Load balancing	8	4	3	120
					2. Faulty spool insulator	6		8	384			6	4	192
					3. weak conductor	8		7	448			3	3	72
					4. Imbalanced line	8		8	512			2	2	32
					5. Sagged line	9		6	432			2	1	16
					6. Climbers and clippers shunting the line.	9		8	576			5	4	160
					7. Fallen LT pole	8		3	192			3	3	72

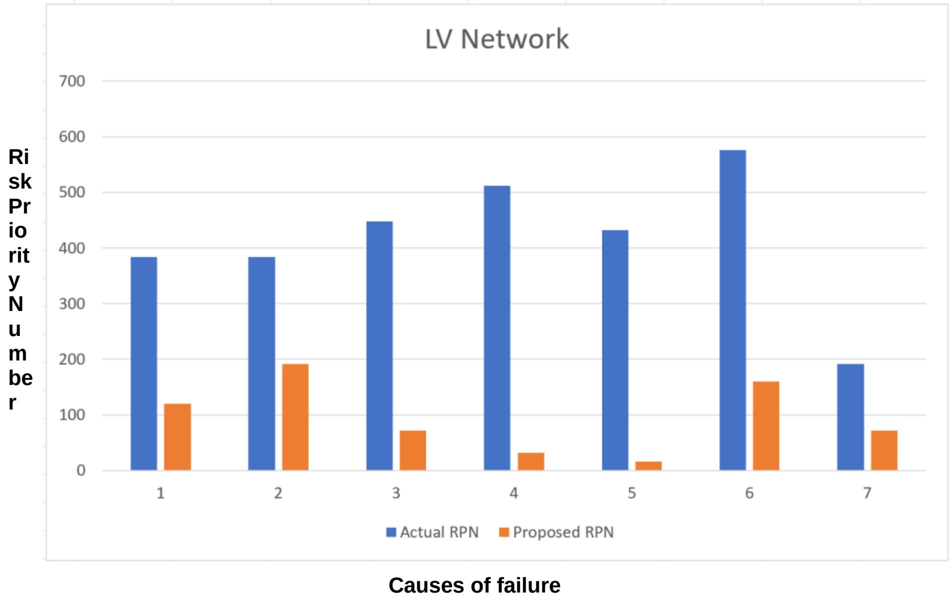


Fig 12. Actual RPN and proposed RPN for LV Network

Actual RPN was reduced by 68%, 50%, 83%, 93%, 96%, 72%, 62%.

Discussion of findings

The essence of the work is to identify and prevent known and potential problems in the refinery complex due to power outage in the plant. To do that the researcher made some assumptions, one of which is that problems have different priorities. Thus, finding that priority is important and the thrust of the methodology. As previously mentioned, the idea of performing FMEA on the power system in the plan, was to eliminate and/or reduce known and potential failures before they reach the operator and cause downtimes and unplanned shutdowns. In line with this, I made sure that all critical, significant, and major components have a documented remedy for controlling, improving, and correcting their failure modes. The recommended action is the map that will improve power in the refinery plants.

From the evaluation, breaking down the components of the power system in the plant and addressing them individually exposes more vividly the errors in that system. These problems have been simply addressed by recommending actions to either prevent or control them. The recommended actions were meant to reduce the current RPN. This was achieved by targeting the measures to reduce the occurrence and means to better detect the failure. By keeping the severity number constant for all components, assuming the worst possible situation and by reducing the occurrence or detection, the RPN number was reduced. The recommended actions were deduced from system SOP, manuals and experience of the team.

Each failure mode was analyzed in terms of possible consequences on operation, function or system status. Particular attention was paid to the impact the failure will have on the overall functionality of the system and how the system will react/behave after the failure is realized. The consequences of each identified failure affecting the item were captured in the analysis to provide a basis to evaluate and allow recommendation for corrective actions.

A visual inspection of the occurrence column, the detection column, the severity column, and the RPN column generally will identify the high-risk areas in the plant. In the severity column, the high-risk item may be identified as such; in the severity column the high-risk item usually had a number higher or equal to 7, and in the RPN column, the number higher or equal to 100 indicated that there might be a high-risk item. These high-risk numbers simply imply that they should be given higher priority over the others. The need for taking effective preventive/corrective actions, with appropriate follow-up on those actions, cannot be overemphasized. This why actions were communicated to all affected activities.

RCM programs have been preached by many companies, but no serious impact have been seen in the distribution of power within a plant (Smith, 2004). If FMEA approach, which ensures that reliability centered maintenance is embedded in the plant’s power distribution, there will be drastic improvements in service deliveries and efficiency of the plant.

The asset management strategies in the plant can be categorized on short-term, mid-term or long-term time scales. Operational issues of the power systems are related to short term asset management, while the maintenance of systems assets is associated with mid-term asset management and the strategic planning of systems is a part of long-term asset management (Lebow and Vainberg, 1998). The long-term goal is to eliminate every single failure. The short-term goal is to minimize the failures if not eliminate them. Of course, the perseverance for those goals must be taken into consideration in relations to the organization’s (refinery) needs for a reliable power system.

CONCLUSION

This study developed an asset management strategy that centered on the reliability of refinery power system components to ensure continuous safe operation of the plants’ power systems using Failure modes and effects analysis. Reliability Centered Asset Management (RCM) provides an effective means to take both the refinery operators and the power suppliers into account when performing asset management. Although implementation of this technique for the power system has been studied earlier, the proficiency of the implementation has not been applied thoroughly. This study proposed methods for optimal implementation of RCM for power systems. To do so, the subject of risk assessment was presented and utilized to develop an approach for implementing the RCM in refinery power systems. According to the FMEA approach, first, the conditions of all system components were assessed and used to evaluate the component reliability. In the second step, all potential failure modes, causes, and effects were listed for each component of the system. Thirdly, a severity number was given to the failure modes and a value was also given for each cause of failure to identify the occurrence and detection rates using the benchmark given in the study. A risk priority number is then calculated. Finally, a proposed action plan was introduced to reduce the RPN number, thereby increasing the overall reliability and efficiency of the system component. Data obtained for the refinery power system were used to evaluate and demonstrate the effectiveness of the proposed method. It was observed that by reducing the RPN of each component, the overall efficiency of that component increases saving the company huge maintenance cost.

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