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ENHANCING SUFFICIENT PRIMARY DISTRIBUTION NETWORK THROUGH RELIABILITY-BASED MAINTENANCE TRAINNING OF PERSONNEL IN ABUJA ELECTRICITY DISTRIBUTION COMPANY

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Abstract

This study developed a Reliability-Based Maintenance Approach for Training of Craftsmen on sufficient maintenance of Prinary distribution sections of Abuja Electricity Distribution Company(AEDC). One objective was used while one research question and one hypothesis guided the study The research design adopted for the study was Survey design employing Research and Development (R&D) that was categories into three phases thus: Needs Assessment, Development of the Manual and Validation of the Manual. The population of the study was 224 which comprised of 32 Engineers, 64 Technologists and 128 Technicians. The entire population was studied. The instruments that were used for the collection of data included, Need Analysis Questionnaire (NAQ), Reliability-Based Maintenance Manual Content Questionnaire (RBMMCQ), and Reliability-based Maintenance Manual Validation questionnaire (RBMMVQ). The RBMMCQ was validated by five experts. The need analysis result indicated 100% acceptance for the need to develop the manual for Abuja electricity distribution company (AEDC). The Reliability of the instrument was 0.75 determined by using Cronbach alpha statistic. The instrument was

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administered to the respondents by six research assistants who administered and retrieved the questionnaire after responding to them; there was a 100% return rate. The data collected were analyzed using Mean and Standard Deviation through the use of SPSS Statistic version 23 to answer the research questions while ANOVA Statistic was used to test the null hypotheses at 0.05 level of significance. The findings of the study included among others that the Reliability-based Maintenance Manual is highly needed to replace the run-tofailure maintenance approach in AEDC. The hypothesis results in a non-significant difference. Based on the findings it was recommended among others that; the strategic management of AEDC should as a matter of urgency adopt the tenets of reliability-based maintenance as the most efficient maintenance practice.

Introduction

Development is the act or systematic process of using scientific and technical knowledge to build an idea or material. From the context of this study, development will be used for the creation of an organized document which can be used to achieve a sufficient maintenance approach known as Reliability-based Maintenance (RBM). Reliability-based Maintenance (RBM) is a technique initially developed by the airline industry that focuses on preventing failures whose consequences are usually very serious. RBM can constitute the panacea to maintenance issues in primary distribution sections (PDSs).

At the primary distribution section, a distribution transformer is introduced which steps down the voltage from 33kV' to 11kV (feeders) and distributs to different communities. This distribution transformer is usually a 3-phase 3-wire system which can be identified more clearly by its insulation (pin insulation) and the number of conductor that enters and leaves the transformer; three conductor comes in as input and three conductors goes out as the output. Electrical power distribution is done by the Distribution Companies of Nigeria (DISCOs); it provides last stage in the electricity supply value chain and ensures the connection between customers and the electricity grid. The DISCOs are also responsible for transforming or stepping down electricity from the high voltage of 33 kV at the transmission level, to the lower voltage levels of 11kV and further 415V depending on the category of customer (Kareem *et al.*, 2019). The DISCOs are also responsible for the marketing and sale of electricity to customers.

There are 11 DISCOs in Nigeria, arising from the unbundling of the Power Holding Company of Nigeria (PHCN) (Kareem *et al.*, 2019).However, out of the 11 DISCOs in Nigeria, the emphasis of this study is on Abuja DISCO commonly called Abuja Electricity Distribution Company (AEDC) whose areas of coverage includes Kogi State, Federal

Capital Territory (FCT) Abuja, Nassarawa and Niger States respectively. The staff that are involved in carrying out this distribution are the Craftsmen under the supervision of technicians, technologist and engineers. Craftsmen are people who received skill training in a given occupation at technical college level and can perform tasks with expertise (Stephen & Festus, 2022). In Nigeria education system 'craftsmen' are graduates of technical college who are trained in a given occupation (Federal Ministry of Education, 2022). Consequently, technical college graduates who received skill training in electrical trade and employed in AEDC are the craftsmen for whom this training manual is developed. Technicians are graduates of ordinary national diploma (OND) from Polytechnics or Monotechnics. While technologists are graduates of higher national diploma (HND) from Polytechnics or Monotechnics and Engineers are graduates of universities with B.Sc and B.Tech who studied engineering (National Board for Technical Education NBTE. 2017)

The Primary distribution section suffer from three major losses in the electricity distribution system: technical losses, commercial losses and collection losses. Technical (distribution) losses are electrical losses arising from the transformation of electrical energy into different forms especially heat energy as it flows through conductors. Commercial losses are revenue losses arising from electricity theft, poor billing practices, cash theft or diversion, inaccurate customer database, wrong tariff classification of customers, unmetered customers and unaccounted energy. Collection losses are simply revenue losses arising from DISCOs' inability to collect revenues for energy billed to known customers (AEDC, 2020). DISCOs' inability to collect billed energy could be as a result of poor billing data, revenue collection inefficiencies, customer default or recalcitrance in paying their bills. Commercial and collection losses are usually collectively referred to as non-technical losses.

This study focuses on the technical loses; it is difficult to fully establish all the reasons for the losses in electricity distribution section. Some electricity is lost as it flows through wires, as it changes into heat and sometimes, light energy (electrical sparks) and is dissipated. All electrical systems and conductors have technical losses.

Xiao and Cao (2020) stated that the causes of losses in electricity distribution system include a lack of sufficient energy supply from grid; old, obsolete networks; lack of maintenance of network equipment; poorly trained manpower; poor customer data; low meter penetration; health, safety and environmental issues; and a mere absence of investments due to poor revenues, inadequate tariffs and external funding constraints. However, researches by Abdullahi, et al. (2023), Ahmad, et al. (2023) and Raza et al. (2022) attributed some of the reasons for technical losses in electricity distribution system to use of outdated electricity distribution equipment in some DISCOs units, poorly trained manpower, insufficient modern electricity distribution equipment as well

as poor maintenance practices among technical staff in DISCOs.The foregoing can be ameliorated summarily by craftsmen training.

Training manual according to Lan (2019) is a well prepared booklet that provide guidelines on how to carry out specific and general operations on assigned jobs. According to Sang (2020) training manual is a booklet of instruction designed to improve the quality of performed tasks. Training manual is an instructional guide that the instructor uses for training in order to allow active participation of learners in an instruction (Aliyu, 2019). Training manual contains process or operation that is targeted towards maintenance or production of object (Milton, 2020). The benefits of training manual as an instructional guide are enormous among which are: reduces learning difficulty and training time for new trainees, it ensures training continuity/ consistency.

Statement of the Problem

The function of the electrical power distribution system is to deliver energy to end users efficiently (Federal Republic of Nigeria FRN 2020). According to Luis, (2020). Ohanu, (2021) and Izuegbunam, *et al*. (2021). It is expected to supply basic national needs of residential, lighting, heating, refrigeration, air conditioning. Over the past five years, evidence from literature has revealed that only 60 percent of the electrical power distributed reach the end users or customers because of poor maintenance practices adopted in the distribution system equipment (Claudius, 2020).

To meet these challenges, a robust reliability-based maintenance approach is required. However, to the extent of the researcher's enquiry no empirical studies on development of reliability-based maintenance manual has neither been conducted nor adopted for the distribution system of AEDC.

Therefore, the problem of this study is the development of an appropriate Reliability-based

Aim and Objective of the Study

The aim of this study was to develop a reliability-based maintenance manual for training of Craftsmen in AEDC, Nigeria. The specific objective of the study are to determine:

The contents for Primary distribution section maintenance manual for training of craftsmen in AEDC.

Research Question

The following research question was formulated to guide the study:

What are the contents of the Primary distribution section maintenance?

Hypothesis

Ho_1: There is no significant difference in the mean ratings of engineers, technologists and technicians on the contents of the Primary distribution section maintenance.

Research Design

This study adopted the use of Descriptive Survey design, employing Research and Development (R and D). Gall, *et al* (2007) described R and D as an industry based development approach involving the use of research findings to design and develop new product such as programmes and materials which assist in improving knowledge and skills. The R and D was chosen for this study because it involves continues collaboration among researchers with maintenance crew of the distribution system and also, provide a more effective way to improve the traditional maintenance approach which rested its weight on run-to-failure theory and practice.

The Analyze, Design, Develop, Implement and Evaluate (ADDIE) Model will be employed to carry out these activities.

Area of the Study

The study was carried out in the entire AEDC franchised areas which comprised of Kogi state, FCT (Abuja), Nassarawa and Niger states. The AEDC is chosen for the study because it is the distribution company with the highest power losses among the entire DISCOs. (Abiodun, 2021). The AEDC franchised area covers a landmass of 133,000 square kilometers (AEDC, 2016).

Population of the Study

The population for this study was 224, which consist of all the 32 maintenance engineers, 64 technologists and 128 technicians in AEDC (Seymour, 2021). Craftsmen were chosen for the study because they are fully involved in the practical operations of all the equipment in the AEDC. Engineers, Technologists and Technicians are involved in the supervisory roles based on their hierarchy. The entire population was studied.

Instrument for Data Collection

The instruments that were used for the collection of data included, (i) Need Analysis Questionnaire (NAQ), (ii) Reliability-Based Maintenance Manual Content Questionnaire (RBMMCQ) and (iii) Reliability-based Maintenance Manual Validation questionnaire (RBMMVQ). with a 4-point response scale of Highly appropriate (HA), Appropriate (A), Not Appropriate (NA) and Highly Not Appropriate (HNA)

Validation of the Instrument

The RBMMCQ was face and content validated by five experts comprising one Electrical Engineering Lecturers in Power option FUT Minna, two Electrical Technology Education

Lecturers in the Department of Industrial and Technology Education, Federal University of Technology, Minna as well as two Electrical Engineers from AEDC in Minna Regional office. The corrections and suggestions made by these experts were effected in the production of the final instrument prior to the actual field work.

Reliability of the Instrument

To test the reliability of the instrument which was a structured 4-point rating scale questionnaire, the researcher administered the questionnaire to a sample of thirty (30) respondents from KEDCO in Kaduna who are not part of the population. The data obtained from the pilot study was analyzed using Cronbach alpha statistics because the study deals with multiple-scored items and the coefficient of reliability was found to be 0.75

Method of Data Collection

The researcher administered the instruments to the respondents with the help of six research assistants; one per region or state. The research assistants were briefed on how to administer and collect the questionnaire. The questionnaire was collected as soon as it was responded to.

Procedure for Development of RBM Manual

The RBM manual was developed using the ADDIE model which is a five stage instructional design model that is concerned with the development of skill-based training guide for training programmes and training materials.

Method of data Analysis

The Statistical Package for Social Sciences (SPSS) version 23 was used for the data analysis and statistical computation. The research question was answered using Mean and Standard Deviation while the null hypothesis was tested using Analysis of Variance (ANOVA) at 0.05 level of significance

In taking decision on each item in the RBMCQ, a cut-off point of 2.50 on a 4-point response scale was fixed for an item that will form the content of the RBM manual. Appropriate items were included in the maintenance manual while items rejected were not included.

On successful development of the Manual, it was validated in consonance with the view of Esiowu, (2020) who reported that questionnaire method of validation is the best for industrial settings since the industries cannot compromise their 'modus operandi' for the sake of an individual's scientific enquiry to study and compare the effects of treatment

and intact groups. This, however provided certainty as to whether or not the Manual will perform sufficiently the function for which it was developed.

RESULTS AND DISCUSSION

Research Question one: What are the contents of the Primary distribution section maintenance?

This research question was answered using mean and standard deviation and the analysis presented in Table 1a,Table 1b and Table 1c for failure Modes / maintenance tasks of 11kV circuit breaker, ring main unit(RMU) and primary distribution lines (PDL) respectively which constituted the equipment under study in the primary distribution section.

Table 1a: Mean and Standard Deviation of the Failure Modes and Maintenance Tasks of the 11kV Circuit Breaker in the Primary Distribution Sections of the Distribution Company

S/N	Failure Modes / Maintenance Tasks	$\bar{x}_A$	SD_A	Remarks
	Failure Modes of the 11kV Circuit Breaker			
1	Incessant switching (on faulty or normal conditions).	3.58	.54	Agreed
2	Stiff moveable parts	3.46	.58	Agreed
3	Corroded contact points	3.44	.57	Agreed
4	Loose screws and nuts	3.33	.66	Agreed
5	Distorted configuration of relay settings of feeder based on consumption 3.44 and expansion		.60	Agreed
6	Soot at terminal points caused by burning arcing and carbon	3.43	.55	Agreed
7	Non – attendance to current transformer (CT) gauge	3.33	.60	Agreed
8	Non – attendance to voltage transformer (VT) gauge	3.41	.68	Agreed
9	Faulty relay	3.40	.65	Agreed
10	Wetted circuit breaker due to droplets of water leaking on it.	3.43	.59	Agreed
	Maintenance Tasks for Maintaining 11kV Circuit Breaker			
11	Uninstalling and clean the equipment every three months.	3.39	.59	Appropriate
12	Cleaning the surroundings of the breaker to remove spider waves every three months.	3.45	.65	Appropriate
13	Lubricating the moving parts.	3.45	.63	Appropriate
14	Lubricating the contact points weekly.	3.31	.71	Appropriate
15	Fastening all screws every three months.	3.38	.64	Appropriate
16	Reconfiguring the Relay settings based on consumption and expansion	3.46	.66	Appropriate
17	Checking for burning, arcing and carbon at terminal points.	3.34	.59	Appropriate
18	Observation of current transformer gauge daily.	3.41	.64	Appropriate

S/N	Failure Modes / Maintenance Tasks	$\bar{x}_A$	SD_A	Remarks
19	Observation of voltage transformer gauge daily	3.48	.61	Appropriate
20	Checking the ambient temperature daily.	3.41	.60	Appropriate

KEY: $\bar{x}_A$ =Average Mean of Respondents Ratings, $SD_{A=}$ Average Standard Deviation of Respondents.

Table 1a showed the results of the extent to which the technical personnel agreed or disagreed perceived as being appropriate or not appropriate with the stated failure modes/maintenance and tasks of the 11kV Circuit breakers in the Primary distribution sections of AEDC. The average mean of 2.50 was used as the benchmark for 'Agree' or 'Appropriate' and any mean below 2.50 was considered 'Disagree' or 'not appropriate'. Items 110 are on failure modes whose average mean range from 3.33 to 3.58 showing that all the

respondents agree that the stated failure modes should stand as the realistic failure modes of the 11kV Circuit breakers in the Primary distribution sections of AEDC. It is important to highlight that none of the stated failure modes fall short of inclusion therein The standard deviation of the respondents on the failure modes was between 0.54 and 0.68, indicating that there was no meaningful deviation of respondents' perception from each other, and the standard deviation mean of the group.

Items 11 to 20 are on maintenance tasks of the 11kV transformers in the Primary distribution sections with average mean ranging from 3.31 to 3.49 showing that all the respondents agreed that the stated maintenance tasks are appropriate for the maintenance of 11kV Circuit breakers in the Primary distribution sections of AEDC. It is important to highlight that none of the stated maintenance task fall short of inclusion therein. The standard deviation of the respondents on the maintenance tasks was between 0.59 and 0.71, indicating that there was no meaningful deviation of respondents' perception from each other, and the standard deviation mean of the group.

Table 1b: Mean and Standard Deviation of the Failure Modes and Maintenance Tasks of the Ring Main Unit (RMU) in the Primary Distribution Sections of the Distribution Company

S/N	Failure Modes / Maintenance Tasks	$\bar{x}_A$	SD_A	Remarks
	Failure Modes of Ring Main Unit (RMU)			
1	**Low gas level**	3.60	.60	Agreed
2	**Low oil level**	3.46	.64	Agreed
3	**Bushy ring main unit premises**	3.36	.69	Agreed
4	**Unsecured ring main unit**	3.34	.64	Agreed
5	**Uncontrolled movement of ring main unit keys**	3.45	.60	Agreed

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S/N	Failure Modes / Maintenance Tasks	$\bar{x}_A$	SD_A	Remarks
	Failure Modes of Ring Main Unit (RMU)			
6	**Corroded contact points**	3.38	.59	Agreed
7	**Sooty contacts due to arcing and carbon**	3.41	.65	Agreed
8	**Loose bolts and nuts**	3.44	.58	Agreed
9	**Corroded terminals**	3.38	.65	Agreed
10	**Use of under- rating cables**	3.43	.58	Agreed
	Maintenance Tasks for Maintaining Ring Main Unit	3.59	.55	Appropriate
11	**Cleaning of the surroundings of the ring main unit.**	3.47	.70	Appropriate
12	**Observation of gas level**	3.57	.56	Appropriate
13	**Observation of oil level**	3.45	.57	Appropriate
14	**Ensuring that the RMU must be under lock and key after work**	3.41	.63	Appropriate
15	**Effective control of the key to the ring main unit**	3.41	.63	Appropriate
16	**Brushing the contact points of the RMU weekly**	3.43	.66	Appropriate
17	**Applying grease to the contact points of the RMU**	3.41	.55	Appropriate
18	**Tightening of bolt and nuts**	3.41	.62	Appropriate
19	**Sand paper terminals of the RMU when need be.**			
20	Checking and using appropriately rated cables.	3.50	.54	Appropriate

KEY: $\bar{x}_A$ =Average Mean of Respondents Ratings, $SD_{A=}$ Average Standard Deviation of Respondents.

Table 1b showed the results of the extent to which the technical personnel agreed or disagreed and perceive as being appropriate or not appropriate with the stated failure modes/maintenance tasks of the Ring Main Units in the primary distribution sections of AEDC. Items 1-10 are on failure modes whose average mean range from 3.34 to 3.60 showed that all the respondents agree that the stated failure modes should stand as the realistic failure modes of the Ring Main Units in the primary distribution sections of AEDC. It is important to highlight that none of the stated failure modes fall short of inclusion therein The standard deviation of the respondents on the failure modes was between 0.58 and 0.69, indicating that there was no meaningful deviation of respondents' perception from each other, and the standard deviation mean of the group. Items 11 to 20 are on maintenance tasks of the Ring Main Units in the primary distribution sections, with average mean ranging from 3.41 to 3.59 showing that all the respondents agreed that the stated maintenance tasks are appropriate for the maintenance of the Ring Main Units in the primary distribution sections, of AEDC. It is important to highlight that none

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of the stated maintenance task fall short of inclusion therein the standard deviation of the respondents on the maintenance tasks was between 0.54 and 0.70, indicating that there was no meaningful deviation of respondents' perception from each other, and the standard deviation mean of the group.

Table 1c: Mean and Standard Deviation of the Failure Modes and Maintenance Tasks of the Distribution Lines in the Primary Distribution Sections of the Distribution Company

S/N	Failure Modes / Maintenance Tasks	$\bar{x}_A$	SD_A	Remarks
	Failure Modes of Distribution Lines in the Primary Distribution Section			
1	Broken cross arm	3.5	1.67	Agreed
2	Broken poles	3.5	1.57	Agreed
3	Tilted poles	3.4	4.60	Agreed
4	Broken strain insulators	3.3	8.66	Agreed
5	Broken overhead conductors	3.4	6.57	Agreed
6	Weak jointing of overhead conductors	3.3	8.63	Agreed
7	Absence of stay wire at require points	3.4	3.58	Agreed
8	Termite destruction of wooden poles	3.4	5.62	Agreed
9	Bushy area around poles	3.5	6.60	Agreed
10	Branches of trees over conductors	3.5	1.54	Agreed
11	Uncontrolled vegetation overgrowing under overhead conductors	3.5	3.55	Agreed
	Maintenance Tasks or Maintaining the Primary Distribution Lines			
12	Inspection of the distribution lines using Binoculars to check cracks of insulators and non-alignments of parts on top of the poles monthly.	3.5	7.59	Appropriate
13	Conducting line clearing on monthly basis	3.4	7.57	Appropriate
14	Carrying out line inspection weekly	3.3	8.60	Appropriate
15	Carrying out disconnection exercise of all illegal KEYconnections monthly	3.4	0.68	Appropriate
16	Making sure that all new connections of industrial premises to the distribution system are done based on due process.	3.4	2.60	Appropriate
17	Ensuring that the three phases carry approximately the same load	3.3	3.69	Appropriate
18	Making married joints of overhead cables where there is a breakage.	3.4	3.54	Appropriate
19	Using the right size of cables for the distribution (150mm).	3.3	8.59	Appropriate

Key: $\bar{x}_A$ =Average Mean of Respondents Ratings, $SD_{A=}$ Average Standard Deviation of Respondents.

Table 1c showed the result of the extent to which the technical personnel agreed or disagreed and perceived as being appropriate or not appropriate with the stated failure modes/maintenance tasks of the primary distribution lines in the primary distribution

sections of AEDC. The average mean of 2.50 was used as the benchmark for 'Agree' or 'Appropriate' and any mean below 2.50 was considered 'Disagree' or 'notappropriate'. Items 1-11 are on failure modes whose average mean ranges from 3.38 to 3.56 showing that all the respondents agree that the stated failure modes should stand as the realistic failure modes of the primary distribution lines in the primary distribution sections of AEDC. It is important to highlight that none of the stated failure modes fall short of inclusion therein The standard deviation of the respondents on the failure modes was between 0.54 and 0.67, indicating that there was no meaningful deviation of respondents' perception from each others, and the standard deviation mean of the group.

Items 12 to 19 are on maintenance tasks of the primary distribution lines in the primary distribution sections with average mean ranging from 3.33 to 3.47 showing that all the respondents agree that the stated maintenance tasks are appropriate for the maintenance of the primary distribution lines in the primary distribution sections of AEDC. It is important to highlight that none of the stated maintenance task fall short of inclusion therein The standard deviation of the respondents on the maintenance tasks was between 0.54 and 0.69 the primary distribution lines in the primary distribution sections, indicating that there was no meaningful deviation of respondents' perception from each other, and the standard deviation mean of the group.

Findings of the study

The following findings emerged from the study based on the data collected, analyzed and summarized thus:

1. The Primary distribution section maintenance with respect to 11kV circuit breaker, ring main unit(RMU) and primary distribution lines (PDL) : cleaning accumulated soot and applying lubricating oil weekly, reconfigurating settings weekly, checking of oil leakages and temperature relay daily respectively.
2. There is no significant difference in the mean ratings of engineers, technologistsand technicians on the contents of neither the 11kV circuit breaker, Ring main unit nor the primary distribution lines.

Discussion of Findings

The findings on the content of the Primary distribution sections' maintenance shows that the respondents agree with the stated maintenance tasks of the main equipment in the Primary distribution sections' namely: 11kV circuit breaker, RMU and the Primary distribution lines as well as their respective failure modes. This is indicating that the equipment and parts were well designed, produced and operated on and the maintenance tasks are appropriate. This finding concurs with Ibrahim, *et al. (* 2019) and

Aliyu (2013), who reported that equipment and parts in AEDC are reliable but the maintenance approach employed to keep them in good order is not sufficient. Similarly this finding agrees with Kahrobaee, (2014) who reported that successful operation of the primary distribution lines depends solely on the condition of equipment maintenance approach employed to keep them in good working order.

The finding of the corresponding hypothesis indicated that there was no significant difference in the mean ratings of engineers, technologists and technicians on the stated content of Primary distribution sections' maintenance. The non-existence of a significant difference in the mean ratings of engineers, technologist and technicians perception is justified by the fact that they all operate on the same equipment and atmosphere. This finding is supported by Catelani *et al. (* 2020) who conducted a study on a system approach towards reliability-centered maintenance of wind turbines. The result showed that the three groups of respondents do not differ significantly in their perception of the required maintenance tasks for the wind turbines. This finding also falls in line with Adoghe, (2010) who stated that the reports by groups can always be similar when trainees are given same treatment.

Conclution

The run-to-failure maintenance practice which was the most popular practice in AEDC was grossly inadequate and inconsistent in providing sufficient maintenance of equipment and distribution lines. Consequent upon that, it was concluded that a reliability-based maintenance manual be developed for the training of craftsmen who will use the knowledge acquired from their training to provide adequate maintenance of equipment and distribution lines in AEDC.

This need is aggravated by the fact that the run-to-failure fall shot of providing lasting solutions to the myriad of maintenance issues that plague the distribution of electrical power to end users. Consequently, the training of AEDC craftsmen using the developed reliability-based maintenance manual is imperative and indeed a panacea to incessant power failure that bedevil the company.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. The strategic management of Abuja Electricity Distribution Company should as a matter of urgency adopt the tenets of reliability-based maintenance as the most efficient maintenance practice in the Injection stations.
2. AEDC should organize in-house-workshop to harmonize the variance in opinions between the engineers and technicians.

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