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# DEVELOPMENT OF RELIABILITY-BASED MAINTENANCE MANUAL FOR CRAFTSMEN TRAINING ON INJECTION STATIONS MAINTENANCE IN ABUJA ELECTRICITY DISTRIBUTION COMPANY

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***Abstract:*** *This study developed a Reliability-Based Maintenance Manual for Training of Craftsmen on sufficient maintenance of Injection stations of Abuja Electricity Distribution Company. 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 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-to-failure maintenance approach in AEDC. The hypothesis results in a significant difference hence Duncan multiple range test was employed to detect the point of 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.*

***Keywords:*** *Development, Reliability-based Maintenance, Injection Stations, Craftsmen, Training manual*

## Introduction

Electrical energy is the key driver of national economy towards creating jobs and reducing poverty and unemployment. This is because electrical energy is vital for economic growth, as its production is a function of capital, labour and energy. According to Madu (2018) over the past two decades, the limited growth of Nigeria's electricity supply industry, combined with the high cost of diesel and petrol, has crippled the growth of the country's productive and commercial industries. This is worsened by the unstable access to electricity due to technical power loss.

Technical loss of electrical power occurs as current flows through wires, transformers as it changes into heat and sometimes, light energy (electrical sparks) and is dissipated as energy losses. This study focuses on the technical loses; Adoghe (2014), Claudius (2020) and France *et al.* (2016) attributed some of the reasons for technical losses in electricity distribution system to use of outdated electricity distribution equipment in some units as; poorly trained manpower, insufficient modern electricity distribution equipment as well as poor maintenance practiees among technical staff in Distribution Companies (DISCOs). The maintenance problem spans from inconsistency in technical staff capacity building and training programme; poor technical staff recruitment, insufficient funds for maintenance activities as well as adoption of ineffective maintenance practice (France *et al*, 2016). Problems like this necessitated the development of the reliability-based maintenance approach.

Development is a process that creates growth, progress, positive change or the addition of physical, economic, environmental, social and demographic components (Esiowu, 2015). 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 (manual) 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. Ashraf and Eltahar (2014) described RBM as an in-depth, highly involved process that seeks to analyze all the possible failure modes for each piece of equipment, and customize a maintenance strategy for each individual machine. The Reliability-based maintenance (RBM) was developed over a period of thirty years, but was first defined in 1978 by Stan Nowlan & Howard Heap in a report titled Reliability-based Maintenance commissioned by the U.S. Department of Defense (Adoghe *et al.*, 2012). The reliability of equipment is the probability that the equipment will continue to operate efficiently without sudden failure. (RBM) is a very powerful methodology which, when properly applied, can drive significant improvements in equipment reliability and plant performance. This constraint of insufficient and efficient maintenance can be removed by development and usage of Reliability-based maintenance manual for training of craftsmen that will eventually carry out the maintenance of equipment in the Injection stations of . AEDC.

An Injection station is the facility containing the 33 KV transformer, 33KV circuit breaker, Isolator and also the thunder arrestor that safeguard the transformer from lightning strikes. The 33KV transformer takes in 33KV through the primary side and steps it down to 11KV and send it out at the secondary side of the transformer to the 11KV circuit breakers through special cables known as pilot cables. The maintenance of these equipments is to be carried out by craftsmen.

Craftsmen are people who received skill training in a given occupation at technical college level and can perform tasks with expertise (Merriam-Webster,2015). In Nigeria education system 'craftsmen' are graduates of technical college who are trained in a given occupation (Federal Ministry of Education, 2003). Consequently, technical college graduates who received skill training in electrical trade and employed in AEDC are the craftsmen to.

Training manual according to Lan (2007) is a well prepared booklet that provide guidelines on how to carry out specific and general operations on assigned jobs. According to Sang (2010) 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, 2013). Training manual contains process or operation that is targeted towards maintenance or production of object (Milton, 2012). 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 Research Problem**

The function of the electrical power distribution system is to deliver energy to end users efficiently (Federal Republic of Nigeria FRN 2015). 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 develop an appropriate Reliability-based maintenance manual for the AEDC staff training.

**Purpose of the Study.**

The purpose of the study was to:

1. Determine the contents for Injection station maintenance.

**Research Question**

The following research question was formulated to guide the study:

1. What are the contents of the Injection station maintenance?

**Hypothesis**

$Ho_1$: There is no significant difference in the mean ratings of engineers, technologists and technicians on the contents of the Injection station maintenance.

**Methodology**

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 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). 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. 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). 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.

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 twelve (22) 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. 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. 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. 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, (2015) 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**

**Table 1a: Mean and Standard Deviation of the Failure Modes and Maintenance Tasks of Isolator in the Injection Stations of the Distribution Company, N=224**

| S/N | Failure Modes / Maintenance Tasks | $\bar{x}_A$ | $SD_A$ | Remarks |
|---|---|---|---|---|
| | **Failure Modes of The Isolator** | | | |
| 1 | Surge impulse due to lightning strikes | 3.54 | .53 | Agree |
| 2 | Continuous over voltage | 3.33 | .66 | Agree |
| 3 | Combination of high voltage and high current on one side of the isolator | 3.41 | .71 | Agree |
| 4 | corroded contact points | 3.20 | .70 | Agree |
| 5 | Sooty contact points due to arcing and carbon | 3.39 | .67 | Agree |
| 6 | Dry joints | 3.22 | .73 | Agree |
| 7 | Stiff control arm (bar) | 3.33 | .667 | Agree |
| 8 | Wrong setting of male and female blades | 3.28 | .63 | Agree |
| 9 | Weak contact spring | 3.35 | .62 | Agree |
| 10 | Porcelain fracture | 3.38 | .52 | Agree |
| | **Maintenance Tasks on Isolators** | | | |
| 11 | Connecting the isolator to the earth | 3.59 | .51 | Appropriate |
| 12 | Checking and regulate or report over voltage situation daily | 3.50 | .56 | Appropriate |
| 13 | Lubricating dry joints weekly | 3.40 | .66 | Appropriate |
| 14 | Connecting a high – voltage capacitor in series with each of the two silicon dies | 3.41 | .66 | Appropriate |
| 15 | Adjusting for free movement of control arm and lubrication monthly | 3.47 | .63 | Appropriate |
| 16 | Resetting of male and female blades monthly | 3.51 | .64 | Appropriate |
| 17 | Cleaning of contact points with brush weekly | 3.40 | .59 | Appropriate |
| 18 | Cleaning accumulated soot and apply lubricating oil weekly | 3.32 | .66 | Appropriate |
| 19 | Replacing weak contact springs quarterly | 3.40 | .54 | Appropriate |
| 20 | Replacing fractured porcelain when due | 3.43 | .60 | Appropriate |

Table 1a shows the results of the extent to which the technical personnel agree or disagree with the stated failure modes and consider as being appropriate or not appropriate as maintenance tasks of Isolators in the Injection stations of AEDC. The average mean of 2.50 was used as the benchmark for 'Agree, and any mean below 2.50 was considered 'Disagree' or 'not appropriate'. Items 1-10 are on failure modes whose average mean range from 3.20 to 3.54 showing that all the respondents agree with them as failure modes. The standard deviation of the respondents on the failure modes was between 0.52 and 0.73, 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 Isolators with average mean ranging from 3.32 to 3.59 showing that all the respondents agree that the stated maintenance tasks are appropriate for the maintenance of Isolators. The standard deviation of the respondents on the maintenance tasks was between 0.51 and 0.67, 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 33KV Circuit Breaker in the Injection Stations of the Distribution Company, N=224**

| S/N | Failure Modes / Maintenance Tasks | $\bar{x}_A$ | $SD_A$ | Remarks |
|---|---|---|---|---|
| | **Failure Modes of The 33KV Circuit Breaker** | | | |
| 1 | Incessant switching on faulty or normal condition | 3.54 | .56 | Agree |
| 2 | Dirty surrounding of the transformer | 3.38 | .69 | Agree |
| 3 | Stiff moveable parts | 3.36 | .60 | Agree |
| 4 | Corroded contact points | 3.40 | .67 | Agree |
| 5 | Lose screws and nuts | 3.42 | .63 | Agree |
| 6 | Distorted configuration of relay setting based on consumption and expansion | 3.29 | .66 | Agree |
| 7 | Soot at terminal points caused by burning, arcing and carbon | 3.46 | .66 | Agree |
| 8 | Non attendance to current transformer (CT) gauge | 3.35 | .60 | Agree |
| 9 | Non attendance voltage current transformer (VT) gauge | 3.33 | .63 | Agree |
| 10 | Faulty relay | 3.40 | .58 | Agree |
| 11 | Wet condition of circuit breaker. | 3.45 | .54 | Agree |
| | **Maintenance Task 33KV Circuit Breaker** | | | |
| 12 | Uninstalling and clean the equipment every three months | 3.44 | .57 | Appropriate |
| 13 | Cleaning the surrounding of the breaker to remove dirt. | 3.41 | .56 | Appropriate |
| 14 | Lubricating the moveable parts | 3.43 | .59 | Appropriate |
| 15 | Lubricating the contact points weekly | 3.32 | .65 | Appropriate |
| 16 | Fastening all screws every three months | 3.42 | .62 | Appropriate |
| 17 | Reconfiguring the relay settings based on consumption and expansion. | 3.35 | .61 | Appropriate |
| 18 | Checking for burning, arcing and carbon at terminal points | 3.39 | .60 | Appropriate |
| 19 | Observing the current transformer gauge daily | 3.36 | .70 | Appropriate |
| 20 | Observation of voltage transformer gauge daily. | 3.47 | .60 | Appropriate |
| 21 | Checking the ambient temperature | 3.58 | .54 | Appropriate |

Table 1b shows the results of the extent to which the technical personnel agree or disagree and perceive as being appropriate or not appropriate with the stated failure modes/maintenance tasks of 33KV Circuit breaker in the Injection stations 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 1-11 are on failure modes whose average mean range from 3.29 to 3.54 showing that all the respondents agree with them as the failure modes of the 33KV Circuit breakers in the Injection stations of AEDC. The standard deviation of the respondents on the failure modes was between 0.56 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 12 to 21 are on maintenance tasks of the 33KV Circuit breakers with average mean ranging from 3.32 to 3.58 showing that all the respondents agree that the stated maintenance tasks are appropriate for the maintenance of the 33KV Circuit breakers in the Injection stations of AEDC. 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 33KV Transformer in the Injections Station of the Distribution Company, N=224**

| S/N | Failure Modes / Maintenance Tasks | $\bar{x}_A$ | $SD_A$ | Remarks |
|---|---|---|---|---|
| | **Failure Modes of 33KV Transformer** | | | |
| 1 | Vibrations of the transformer | 3.52 | .57 | Agree |
| 2 | Oil of low viscosity | 3.55 | .58 | Agree |
| 3 | Malfunction cooling fan | 3.42 | .58 | Agree |
| 4 | Leakage in oil tracts | 3.42 | .64 | Agree |
| 5 | Malfunctioned temperature relay | 3.35 | .67 | Agree |
| 6 | Wet silica gel for moisture absorption | 3.39 | .55 | Agree |
| 7 | Poor earth resistance of the station surroundings | 3.38 | .64 | Agree |
| 8 | Poor connection to general mass of earth | 3.46 | .62 | Agree |
| 9 | Voltage demands beyond capacity of transformer | 3.38 | .65 | Agree |
| 10 | Unsecured injection station | 3.40 | .58 | Agree |
| 11 | Insulation breakdown of pilot cables | 3.35 | .64 | Agree |
| 12 | Insulation breakdown of armed cable due to wild fire | 3.38 | .65 | Agree |
| | **Maintenance Tasks for Maintaining 33KV Transformer** | | | |
| 13 | Visual inspection | 3.54 | .60 | Appropriate |
| 14 | Checking oil level for replenishment | 3.56 | .57 | Appropriate |
| 15 | Oil filtering | 3.46 | .60 | Appropriate |
| 16 | Checking the viscosity of the oil | 3.46 | .64 | Appropriate |
| 17 | Checking the cooling system | 3.34 | .68 | Appropriate |
| 18 | Checking for leakages | 3.49 | .56 | Appropriate |
| 19 | Cleaning substation and porcelain weekly | 3.30 | .70 | Appropriate |
| 20 | Retightening joints (bolt and nuts) | 3.38 | .55 | Appropriate |
| 21 | Checking the Temperature Relay | 3.38 | .60 | Appropriate |
| 22 | Checking thica gel to observe moisture caused by heat | 3.40 | .60 | Appropriate |
| 23 | Checking and measuring the earth resistance value of the station with a mega tester every three months. | 3.40 | .66 | Appropriate |
| 24 | Checking for correct earthing of the transformer | 3.41 | .62 | Appropriate |
| 25 | Ensuring a flat base for the transformer seating | 3.41 | .69 | Appropriate |
| 26 | Reconditioning or replacement of silica gel in breather | 3.35 | .63 | Appropriate |
| 27 | Opening transformer for inspection and checking of the core-coil assemblies bi-annually | 3.49 | .63 | Appropriate |
| 28 | Opening and testing current transformers of bushings monthly | 3.36 | .69 | Appropriate |

Table 4.1c shows the results of the extent to which the technical personnel agree or disagree and perceive as being appropriate or not appropriate with the stated failure modes/maintenance tasks of the 33KV Transformers in the Injection stations 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 1-12 are on failure modes whose average mean range from 3.35 to 3.55 showing that all the respondents agree with them as the failure modes of the 33KV Transformers in the Injection stations. The standard deviation of the respondents on the failure modes was between 0.55 and 0.57, indicating that there was no meaningful deviation of respondents' perception from each other, and the standard deviation mean of the group. Items 13 to 28 are on maintenance tasks of Isolators with average mean ranging from 3.30 to 3.56 showing that all the respondents agree that the stated maintenance tasks are appropriate for the maintenance of the 33KV Transformers in the Injection stations of AEDC. The standard deviation of the respondents on the maintenance

tasks was between 0.55 and 0.65, indicating that there was no meaningful deviation of respondents' perception from each other, and the standard deviation mean of the group.

**Table 2: One-Way Analysis of Variance (ANOVA) of Mean Ratings of the Engineers, Technologists and Technicians on the Content of the Injection Station Maintenance**

| Source | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 369.895 | 2 | 184.947 | 4.452 | .013 |
| Within Groups | 9181.145 | 221 | 41.544 | | |
| Total | 9551.040 | 223 | | | |

Table 2 indicates that the P-value is 0.013 which is less than the confidence level of 0.05. Thus; the null hypothesis was rejected in favor of the alternative meaning that there is a significant difference in the mean ratings of the engineers, technologists and technicians on the injection station maintenance. In the realization of the fact that significant difference exist among the groups under study, it became imperative to trace where the significant difference lies. This was however done by employing Duncan Multiple Range Test whose result revealed that the significant difference is between the mean ratings of engineers and those of technicians.

**Findings of the study**

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

1 The Injection station maintenance with respect to Isolators, 33KV Circuit breaker and 33KV Transformer are: cleaning accumulated soot and applying lubricating oil weekly, reconfigurating settings weekly, checking of oil leakages and temperature relay daily respectively.
2 There is significant difference in the mean ratings of engineers, technologists and technicians on the contents of the injection station maintenance.

**Discussion of Findings.**

The findings on the content of Injection station maintenance shows that the respondents agree with the stated maintenance tasks of the main equipment in the Injection stations namely: Isolator, 33KV Circuit breaker and the 33KV Transformer as well as their respective failure modes. This is because none of the listed equipment is faced with the problem of imperfection on either specifications of the equipment, material or operation. This finding concurs with Abiodun (2021) and Ohanu (2021). in separate studies reported that the major setbacks in operation of equipment are omissions namely: lack of efficient craftsmanship, high quality material and good design.

The finding of the corresponding hypothesis indicated that there was a significant difference in the mean ratings of engineers, technologists and technicians on the stated content of Injection stations maintenance of the distribution station. With the existence of the, significant difference in the mean ratings of engineers, technologists and technicians on the stated content of Injection stations' maintenance of the distribution stations, Duncan Multiple Range Test was employed and it was revealed that the significant difference existed between the mean ratings of engineers and those of technicians. The inter predation of this finding is that the engineers and the technicians' perception on the maintenance activities on the injection station rest on the two extremes of highly required (HR) and required(R) while the perception of the technologist was ranging halfway between the two, therefore there wasn't any significant difference between the technologists and either the engineers or technicians. This finding is in line with the study carried out by France, *et' al*, (2016), on injection station maintenance who reinstated that perception of engineers and that of technicians can differ significantly due to their level of understanding of maintenance tasks of injection stations.

## Conclusion

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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