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DEVELOPMENT OF A MAINTENANCE MANAGEMENT SYSTEM FOR ELECTRICAL DISTRIBUTION FACILITIES TO ENHANCE LABORATORY AVAILABILITY PERFORMANCE

A CASE STUDY OF TANZANIA BUREAU OF STANDARDS HEADQUARTERS – DAR ES SALAAM TANZANIA

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Abstract : Maintenance has a profound impact on the efficiency and overall budget of facilities. Today various organizations are developing and using computer-controlled programmes geared towards facility maintenance and power management systems. However, despite the rapid expansion, the area of computer-controlled maintenance management has still not been sufficiently researched by maintenance and administration sections at Tanzania Bureau of Standards (TBS) to determine the required features of Facilities Maintenance and Electrical Power Management System (FMEPMS). The aim of this research was to develop a maintenance management system for electrical distribution facilities to enhance laboratory availability performance. TBS has been chosen as a case study for this research because it is one of the biggest laboratory in the United Republic of Tanzania. The required features have been determined by examining the factors which affecting performance of the existing electrical distribution system and developing a maintenance management model for electrical distribution facilities. The methodology used to accomplish this study includes literature review, questionnaire, observation, survey, experiment, interview with experts, content analysis and statistical analysis using statistical tools of excel and SPSS as well as Power analyzer and computer. The results of this study established the requirements for maintenance management system for electrical distribution facilities to enhance laboratory availability performance which can generally termed as operational and maintenance information. The operation information are historical data, system age, maintenance schedule and planning and frequently tripping and unstable power while the maintenance information are maintenance tools and spare parts. The regression model established maintenance information requirements which shown that the availability performance of laboratories has developed with 96.17% of variation of dependent variable. The model predicts that if TBS Management does not control the identified factors which affects availability performance will be affected more.The developed system software compose of features such as personnel management, store and tools management, generation of work orders and reports, reporting of faults and services record keeping. The effectiveness of the system has been evaluated by user after been implemented. Both developer and users were satisfied with the system software.

Keywords: Maintenance management, Tanzania bureau of standards, Electrical distribution facilities, Availability performance, Facilities Maintenance, Laboratory.

1.0 Introduction

Tanzania is one of the large countries of Africa which located at East Africa and it has high population approximated to 55 million according to 2012 census. However, the computerized maintenance management system has been implemented and practiced in majority of countries in the world but in Tanzania only few government institutions have been adopted and practicing the same. With today's emerging and sophisticated equipment, management and maintenance has become one of the essential elements for the reliable results obtained from that equipment. Different fields from medical institutions to normal society institutions equipment are among the fundamental components contributing substantially to those institutions services effectiveness (Zamzam et al., 2021). Hence, proper management of the equipment in the laboratory is necessary to ensure accurate, reliable, and timely results. During testing process a well-trained technician must be available for carrying out the process which will be facilitated by availability of power, the main role of the high skilled technician is to oversee all equipment available in the laboratory. Studies reveal that, in most cases maintenance is a day-to-day activity and, in most organizations, or institutions it is the responsibility of the technical personnel (Enofe, 2009). In all sectors, poor electrical systems can lead to unnecessary expenditures, misery in human lives and suffering. Furthermore, studies reveal that, the quality of laboratory service is dependent on several factors from technical skills, quality management systems and stable electrical suplly. Moreover, power supply interruption, equipment failure, and poor infrastructure have been indicated as other factors to poor laboratory service (Enofe, 2009). This study will propose facilities maintenance and electrical power management system to enhance laboratory availability performance using Tanzania Bureau of Standards (TBS) as a case study.

1.1 Problem statement

A Well-functioning electrical distribution systems, reliable power, equipment and reasonable electric bills are the key components in any organization laboratory in both developed and developing countries. Good performance of electrical system and laboratory equipment depend on how proper the particular system and its laboratory equipment are maintained. Regardless of the efforts made by Tanzania Bureau of Standards on buying spares and maintaining electrical systems for improving performance of laboratory equipment still there are challenges associated with sustaining laboratory performance, unstable electrical power, maintenance and high electric bills. This leads to main challenges not limited to performance of laboratory equipment, frequently power interruption and high-power consumptions issues. This study will assess and develop a maintenance management system for electrical distribution facilities to enhance laboratory availability performance at Tanzania bureau of standards. Also, the study will propose guideline to equipment and electrical facilities management policies, equipment maintenance strategy and proper method of energy management.

1.2 Objectives

1.2.1 Main Objective of the Study

To develop a maintenance management system for electrical distribution facilities to enhance laboratory availability performance at Tanzania bureau of standards.

1.2.2 Specific Objectives

i To identify factors affecting effective performance of the current electrical power distribution system in the Tanzania Bureau of Standards.

ii To develop maintenance management model for electrical distribution facilities to enhance laboratory availability performance at Tanzania Bureau of Standards.

iii To develop maintenance management system for electrical distribution facilities to enhance laboratory availability performance at the Tanzania Bureau of Standards

2.0 Literature Review

This literature review focuses on reviewing the specific objective of the study: Development of a maintenance management system for electrical distribution facilities (Electrical main power house, main distribution boards, switches, circuit breakers, earth rods, supply cables, wiring installations, cable plugs, regulators and controllers) at Tanzania Bureau of Standards to enhance nine (9) laboratories availability performance; Building and Construction, Electrical, Mechanical, Chemistry, Microbiology, Food Chemistry ,Cotton and Textile (TBS Progress reort,June 2021). The review is done on the requirement for Improving the performance of laboratory equipment, maintenance of electrical system, electrical energy consumption, developing the system, validation of the system and the conceptual framework of the study.

2.1 Laboratory

Laboratory is defined as "a room or building equipped for scientific experiments, research, or teaching". In all aspect laboratory quality is the key to the results that are being tested and it is measured by considering accuracy, reliability and timeliness of the results reported (WHO, 2011).

Figure 1: Example of laboratory facilities, (Consolidated Forensic Laboratory)

2.2 Maintenance Management System

With today's advancement in technologies, more complex laboratory tools are in place that requires proper maintenance for valid results and performance. According to (Lundgren et al., 2018), digital transformation has brought complex equipment and systems that require proper maintenance. Thus, to cope with these situations, organization has brought into filed the concept of maintenance management systems. These systems are used to manage maintenance activities by organizing, planning, tracking and analyzing all the jobs you and your team do on a regular basis (Pacaiova & Glatz, 2015). Also (Garg & Deshmukh, 2006), highlighted the need of the new shift in maintenance paradigm that address issues from maintenance techniques, scheduling, maintenance management and different maintenance management systems (information systems) as indicated also in the report by the global fund (2019).

Figure 2. Example of Maintenance Management System , (Limble cmms- 1 (801) 8511218).

2.3 Electrical System

The role played by electrical in modern equipment is vital. As per Wikipedia definition an electrical system "is a network of electrical components deployed to supply, transfer, and use electric power". Also, an electric system is said to consist of all elements needed for electric power distribution not limited to overhead, underground lines, transformer etc. (Lobontiu, 2010).

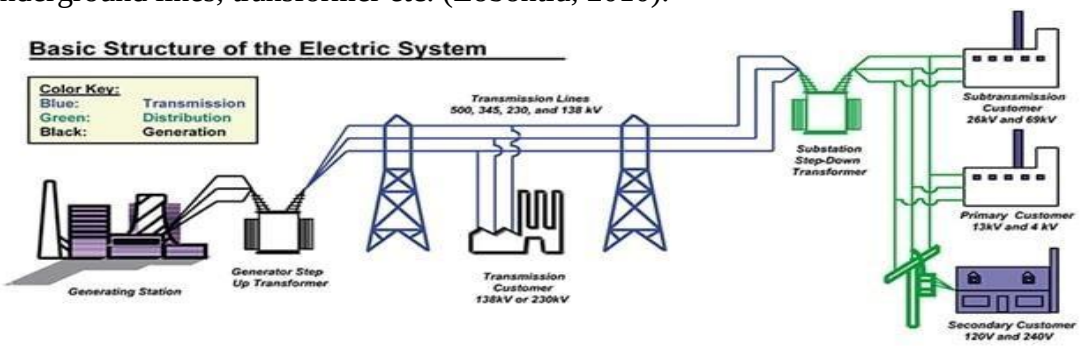

Figure .3: Example of Electrical Power System , (https://engineering.electricalequipment.org/)

2.4 Maintenance Management Model

Maintenance management is the discipline of balancing increased equipment availability and reduced costs while also maintaining low levels of LTI and retaining compliance. If performed optimally, maintenance management increases company profit and is a high competitive factor. If performed poorly, it can be a contributing factor to the closing of a company as shown in Figure 4. (Implement Consulting group, 2018 and Sylvia Gala Mong1*, Sarajul Fikri Mohamed2, Mohd. Saidin Misnan3,2018)

Figure 4: Example of models
(https://www.convergentresults.com/maintenance-work-management)

3. Methodology

Research methodology tells about strategies to which the research was carried out (Abdulai & Owusu-ansah, 2014).The data collected were obtained by means of questionnaires, site surveys to observe physical condition of the existing electrical distribution system, performing experiments by using measuring tools like power analyzer and multimeter to identify the power quality, Load study to check phase balancing of the existing system, using available data from reports and performing oral interview with experts. The data collection tools were computer, Ms excel and power analyzer. Furthermore the analysis tools were descriptive statistics by using Statistical Package for Social Science (SPSS)Version. 20 and Power analyzer.

4.0 Data Collection and Analysis

The data obtained during the research by means of questionnaires, measuring tools and physical inspection are recorded correctly and then being analyzed into tables. After analysis the same data are interpreted into simple forms of percentage as responded by the respondents.

4.1 Analysis of Appropriate for Power Availability in Handling Activities in the Laboratory with Regard to Maintenance And Repair at Tanzania Bureau Standards.

The bellow trending line show that, the maintenance management practices are not adequate in electrical distribution facilities with (77.1%) while (22.9%) are accepted maintenance are adequate for electrical distribution.

Maintenance management practices in the electrical distribution facilities is shown in figure 5,

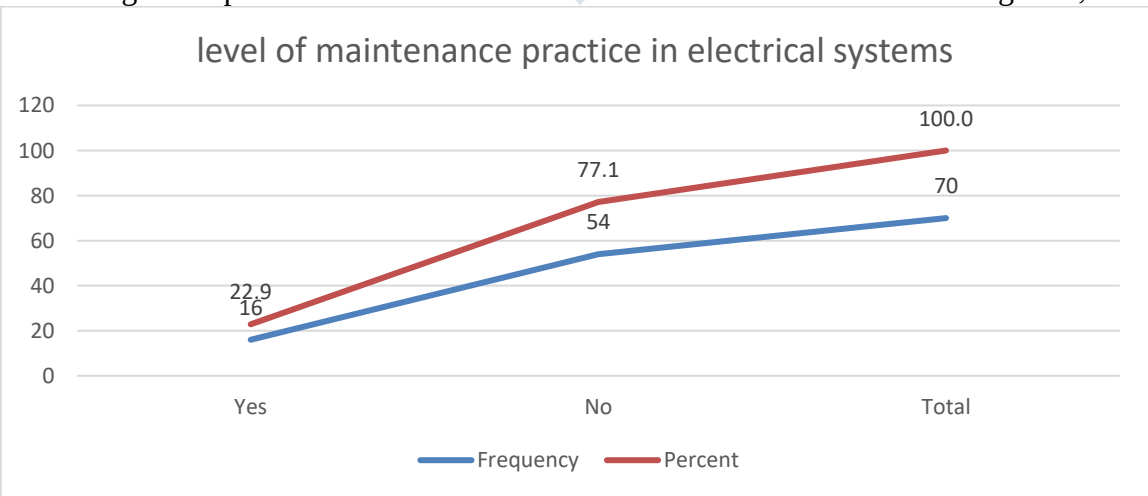

Figure 5: level of maintenance practice in electrical systems

The trending line in figure 6 bellow show that, the current maintenance management practices performed in electrical distribution facilities are corrective maintenance with (74.3%), followed by preventive maintenance with (21.4%) and breakdown maintenance (4.3%).

The current maintenance management practice performed in the electrical distribution facilities at Tanzania Bureau Standards is shown in figure 6.

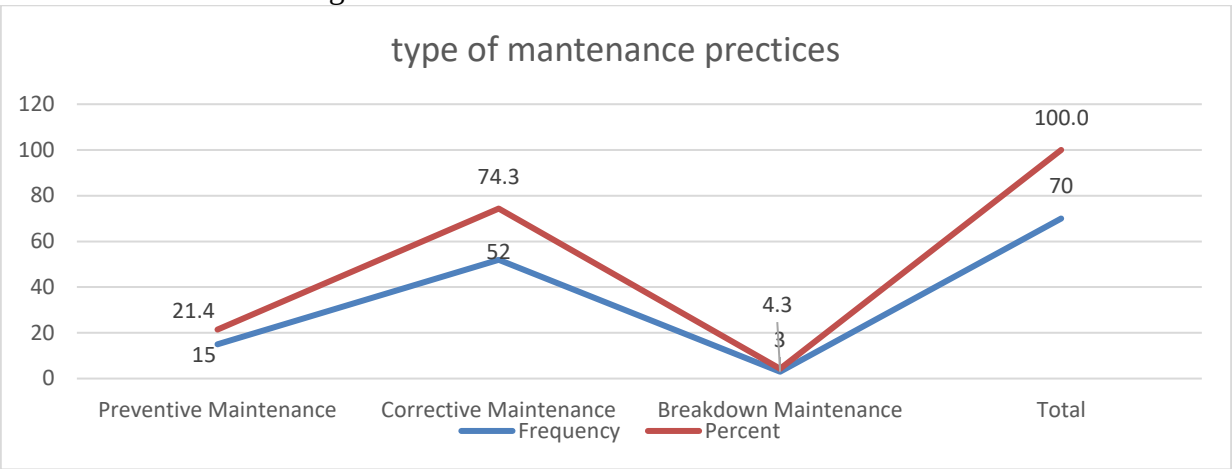

Figure 6: type of maintenance practices

The trending line in figure 7 bellow show that, spare parts due to procurement with mean (4.79) and standard deviation (0.487), budget with mean (4.24) and standard deviation (0.788), availability performance of power handling equipment with mean (4.07) and standard deviation (0.983), how do consider the current maintenance management practices for power with mean (4.00) and standard deviation (1.228) and what is the current maintenance management practices with mean (3.66) and standard deviation (1.306)

Factors to assessing the electrical distribution system to enhance power availability performance in laboratory is shown in Figure 7.

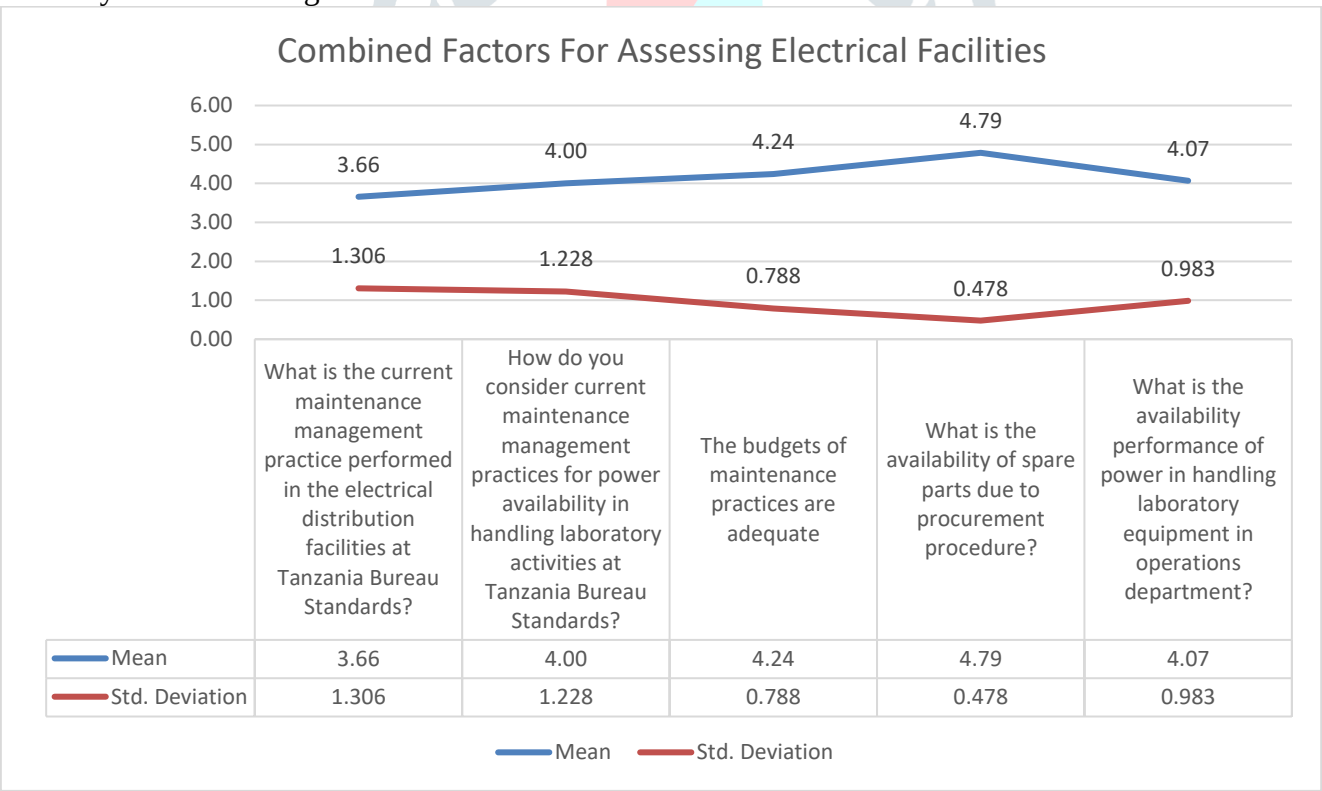

Figure 7: Combined Factors for Assessing Electrical Facilities

Practise of Computerized Maintenance Management System at TBS

The trending line in figure 8 shows that, majority respond that no computerized maintenance management system with (49%) while other majority respond that no at all a computerized maintenance (21%) respectively

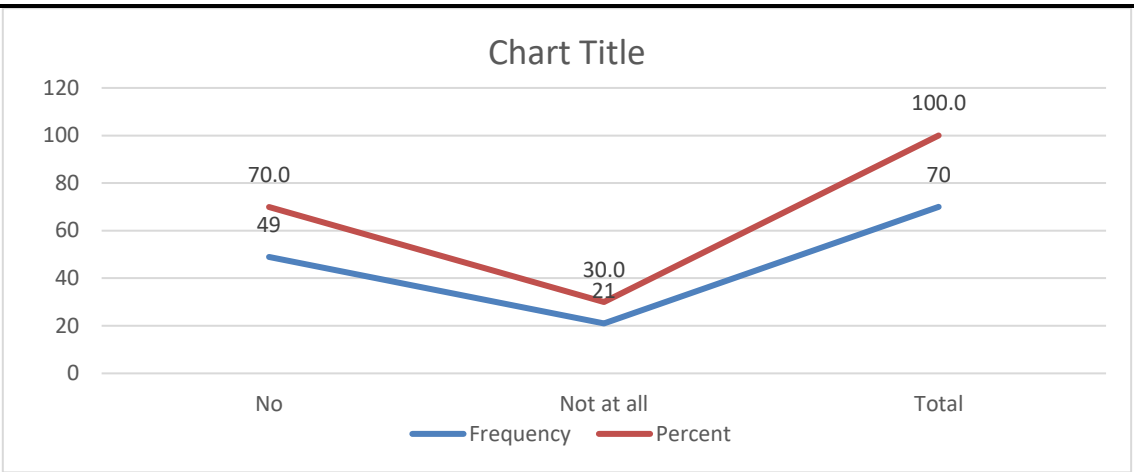

Figure 8: implementation of CMMS

Presence of Maintenance policy and strategy in the electrical distribution facilities

The trending in figure 10 shows that, majority none of above respond that (57.1%), followed there are maintenance policy and strategy in laboratory with (24.3%) while others no maintenance policy and strategy in electrical system with (18.6%)

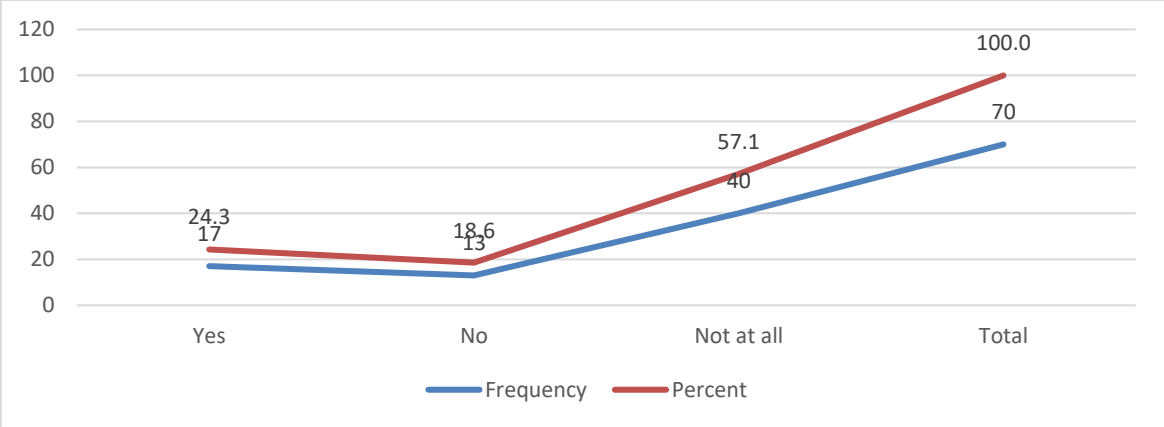

Table 10: policy and strategy for electrical distribution system

4.2 Load Study

Load study stated as the most important and essential approach to investigating problems in power system operating and planning. Based on a specified power transmission network structure, load flow analysis solves the steady operation state with node voltages and branch power flow in the power system. (Wang and Xi-Fan, 2008)

The load study was conducted across TBS offices and laboratories to establish relationship between the existing loads so as to compare it with installed electrical facilities capacity. Also the load can be used to give the projection of energy consumption bills between supplier and consumer. During the same, it was observed that majority of electrical power cables has already overloaded compared to existing cables size (see figure 12) bellow.

Total Rated Power and Load Current for each Building

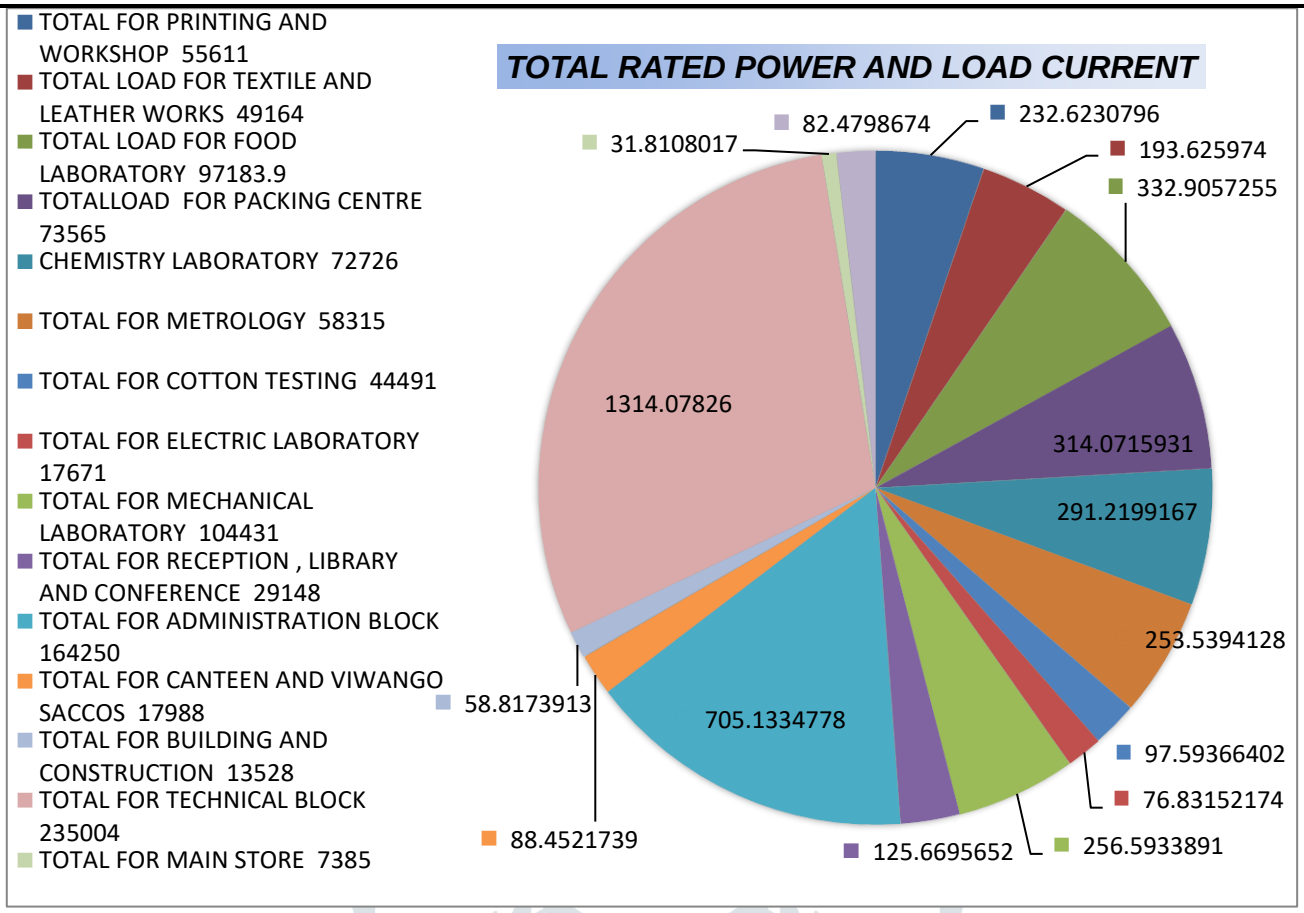

Figure 11: load study

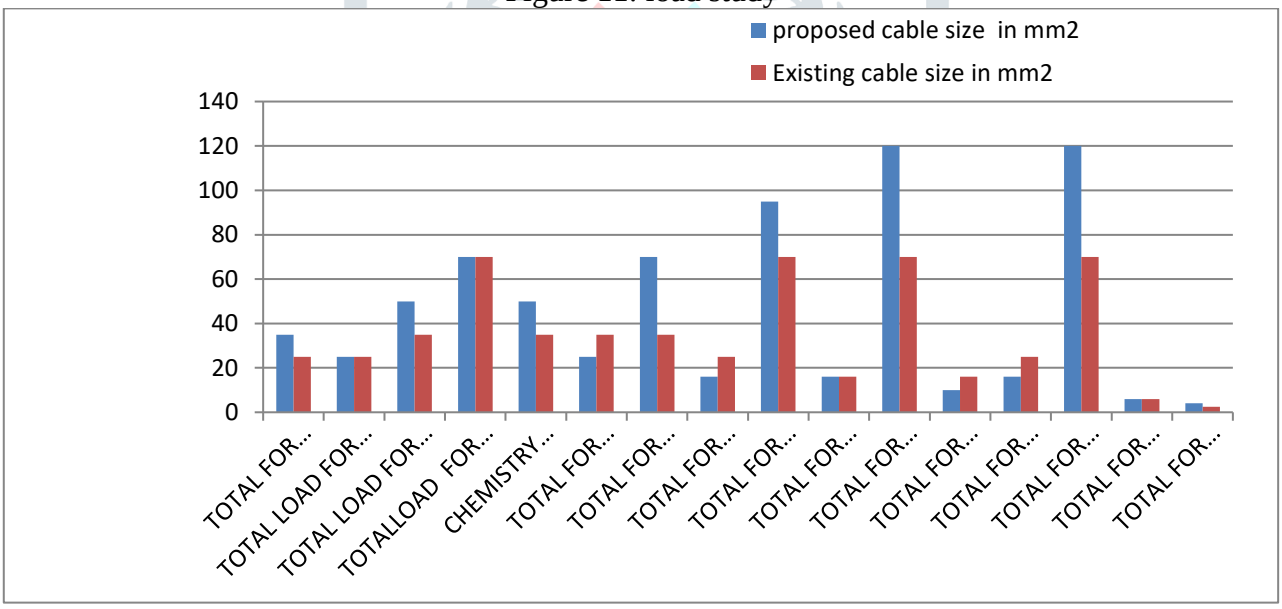

Figure 12: Comparison of cable sizes

4.3 Power Quality check

The power quality audit (PQA) is normally performed to identify the power quality issues before the impact to the organization electrical system. This gives more information about reliability and stability of power before affecting the electrical facilities performance.

The several parameters were checked to establish the reliability, efficiency and safety of an organization's electrical system. The power logger fluke brand from DIT was connected in the outgoing power terminals of TBS power house for troubleshooting, logging, and creating detailed reports in conjunction with the easy-to-use PowerLog-430-II software for five (5) days consecutively under assistance of Mr. Mawazo from electrical department.

According to an international standards and best practice, the following parameters are observed during the analysis of power quality issues.

i. Frequency; ii. Unbalances; iii, Supply Voltage and current ;iv. Voltage and power harmonics (harmonics and interharmonics); v. Flicker; and vi. Power factor.

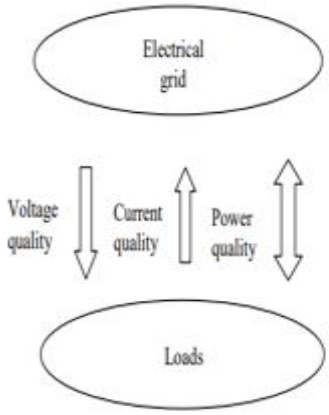

Figure 13 power logger

During the power quality analysis it was established that the quality of power in the organization is not good as the system consists of poor power factor values ranging from 0.85 to 0.90, the flickers were detected, voltage imbalances and high frequency value.

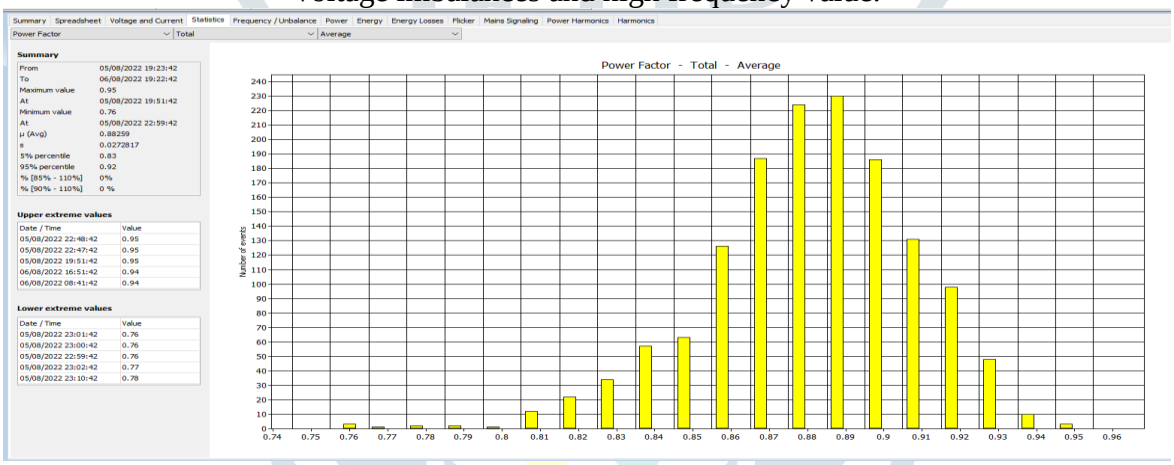

Figure 14 power factor analysis

5.0 Development of Appropriate Model for Electrical Distribution Facilities to Enhance Laboratory Availability Performance at Tanzania Bureau Of Standards

Analysis assumptions

In regression analysis, the researcher considered the following assumptions;

i. First assumption: Coefficient of determination in the modal summary should explain the independent variables above 50%.
ii. Second assumption: At 5% level of significant and 95% confident level, the significant value (P value) in the ANOVA and coefficient regression should be $P < 0.000\text{-}0.05$.
iii. Third assumption: At 5% level of significant and 95% confident level, the value of predictions or independent variables should be $P \leq 0.000 - 0.05$.

Table 1: Model summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.758[a]	.809	.134	1.142

a. Predictors: (Constant), Electrical system age, Spare parts Availability, Unstable power and frequently tripping, Availability of Maintenance tools, Availability of historical data

From the first assumption which holds in a model that if R value ≥ 50% then variables in the hypothesis have strong relationship that means a model summary from the field which have a value R square of 75.0% have shown there is a strong relationship between dependent and independent variables.

Table 2: Anova analysis

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	21.776	6	3.629	2.781	.018[b]
	Residual	82.224	63	1.305		
	Total	104.000	69			

Dependent Variable: Electrical Distribution Facilities to Enhance Laboratory Availability Performance

b. Predictors: (Constant), Electrical system age, Spare parts Availability, unstable power and frequently tripping, Availability of Maintenance tools, Availability of historical data

ANOVA, the significance value (P value) is 0.000 which is less than 0.05. Therefore, this implies that the hypotheses of this study are positively correlated since at 5% level of significant and 95% confident level, the significant value (P value) in the ANOVA and coefficient regression lie between values of P < 0.000-0.05.

TABLE 3: FACTORS FOR REGRESSION EQUATION

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.526	.621		4.066	.000
	Spare parts Availability	.066	.139	-.060	-.472	.009
	Availability of Maintenance tools	.131	.182	.101	.718	.005
	Effectiveness of Maintenance schedule and planning	.320	.228	.246	1.404	.001
	Availability of historical data	.103	.247	-.074	-.418	.000
	Unstable power and frequently tripping	.005	.190	.004	.026	.009
	Electrical system age	.335	.193	.265	1.734	.088

The regression equation was; $\mathbf{Y= 0.526 + 0.066X_1 +0.131X_2 + 0.320X_3 +.0.103X_4 +0.005X_5 +.0.335X_6 +\alpha}$
Where by Y = Electrical Distribution Facilities to Enhance Laboratory Availability Performance
X_1 = Spare part availability, X_2 = Availability of maintenance tools, X_3 = Effectiveness of Maintenance schedule and planning, X_4 = Availability of historical data, X_5 = Unstable power and frequently tripping, X_6 = Electrical system age, α = error terms

6. **Developing Maintenance Management System for Enhancing the Availability of Laboratory in Electrical Distribution Facilities**

Based on the study findings and observation, the maintenance management system for improving electrical distribution facilities handling laboratory availability was developed. All key maintenance activities at the TBS are has been taken in Figure. 15 The system allows flow of information from different users to the Maintenance Monitoring Control Unit where all maintenance work is managed according to priorities and resources availability. Basing on the developed system and assumptions made, computation of availability performance after full implementation of developed maintenance management system for improving laboratory handling equipment is 96.17% as shown in Table 3. This implies that the developed maintenance management system is effectively done and thus, improves electrical distribution facilities Handling Laboratory Availability Performance at Tanzania Bureau of Standards.

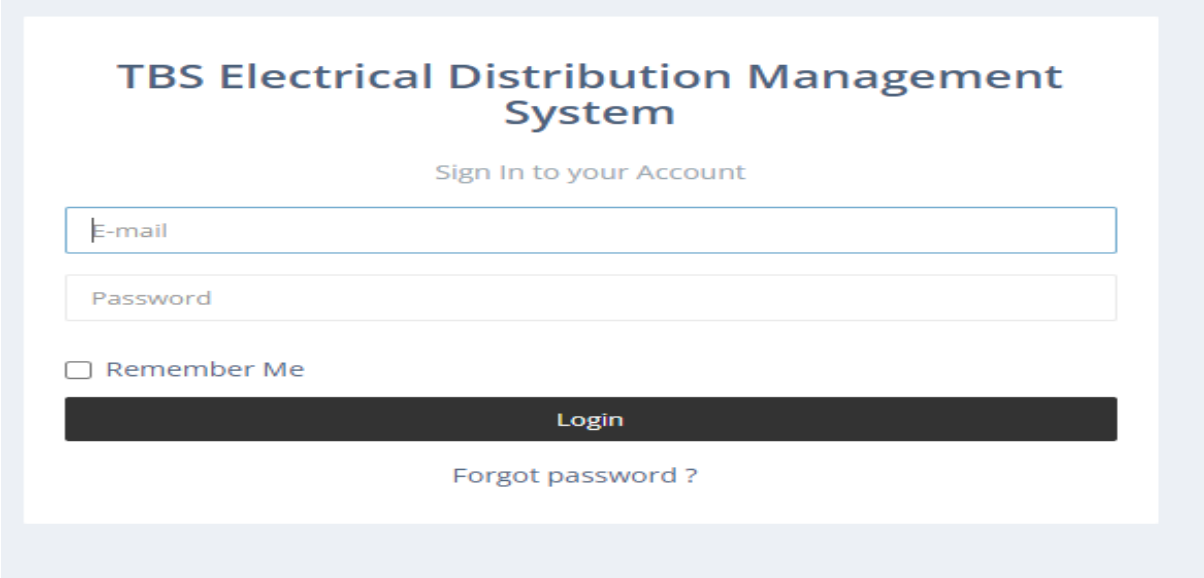

Figure 15 maintenance management system

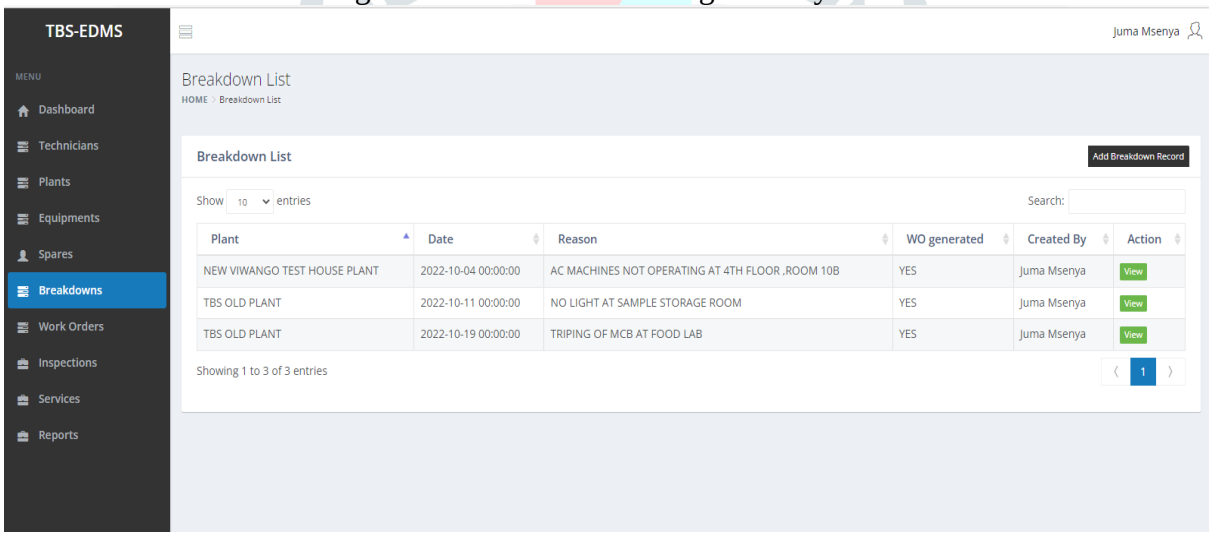

FIGURE 16 MAINTENANCE PLANNING, SCHEDULING AND BREAK DOWN ACTIVITIES

7. CONCLUSION AND RECOMMENDATION

Conclusion

The research depicts six (6) main factors which are significantly affecting maintenance availability performance at TBS based on the coefficients of parameter which are availability of maintenance historical data (0.103), spare parts availability (0.066), electrical system age (0.335), availability maintenance schedule and planning (0.320), Availability of maintenance tools (0.131) and unstable power and frequency tripping (0.005). Based on the identified factors, the researcher developed and validated a Maintenance Management Model with predictability accuracy of 95% confidence level.

Quantitative data on the above factors have been processed on SPSS and the availability performance model has been developed with 96.17% of variation of the dependent variable (laboratory electrical distribution facilities availability performance Hence the maintenance management system has been developed by

considering improvement of availability of historical data of maintenance, Strong supervision of maintenance practices, effective maintenance schedule and planning, Availability of maintenance tools, electrical system age and unstable power and frequency tripping.

Recommendation

It is recommended that the Tanzania Bureau of Standards shall update its electrical distribution facilities to new technology and also control and monitor its maintenance management practices at a specified time interval (daily, weekly, monthly) to ensure that the maintenance management system works and complies with the maintenance management standards. The engineering management shows how the system is working and where it can be improved.

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