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Power Distribution Transformer Maintenance Skills Required by Electrical Engineering Technology Students of Polytechnics in North-East Nigeria

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Abstract

Electric power distribution industry in North-East, Nigeria is faced with inadequate number of power transformer maintenance personnel which has led to numerous abandonment of broken down power transformers. Transformer faults have been blamed for many power outages of long duration in many towns and communities in North-East, Nigeria. It is against this backdrop that this study determined the power distribution transformer maintenance skills required by Electrical Engineering Technology students of polytechnics in North-East Nigeria. Three research questions and three hypotheses guided the study which employed a descriptive survey research design. The population of the study was 144 comprising of 135 Electrical Engineering Technology Lecturers, 3 Power Transformer Maintenance Technicians and 6 Electric Power Distribution Company-Based Supervisors. The entire population was used hence, there was no sampling. The instrument used for data collection was a structured questionnaire titled: Power Distribution Transformer Maintenance Skills Required Questionnaire (PDTMSRQ) developed by the researchers. The instrument was validated by three experts and a reliability of 0.74 was obtained using Cronbach Alpha reliability method. Mean statistic was used to answer the research questions while ANOVA was used to test the two null hypotheses of the study at 0.05 level of significance. The findings of the study revealed that the Electrical Engineering Technology students of polytechnics in North-East Nigeria required preventive, predictive and corrective maintenance skills. The study recommended the following: Lecturers should encourage the students' skill acquisition process by exposing them to various maintenance activities in order for them to imbibe the different methods of power transformer maintenance; Students should be trained to recognize sounds and sights of faulty equipment in order to predict the parts or components that needed replacement or repairs

1. Introduction

Training of manpower for industrial use and development in a society depends on the effectiveness and efficiency of the type of education imparted to the citizenry. In this sense, for the industrial revolution to occur in North-East Nigeria, the technical and vocational institutions providing technical knowledge to students which will make them fit into the industry must be effective and functional. This above notion prompted the Federal Government of Nigeria to establish the polytechnics with the sole aim of providing technical skills and knowledge that will be needed for the agricultural, industrial, commercial and economic development of the nation.

Polytechnics in Nigeria refer to tertiary educational institutions that offer specialized technical and vocational training programs typically leading to the award of diplomas and higher diploma certificates. This institution focuses on practical skills development and hands-on training in various fields such as engineering, technology, applied sciences, business studies, and other vocational disciplines (Federal Republic of Nigeria, 2004). Polytechnics play a crucial role in the Nigerian educational system by providing alternative pathways for students who seek technical and professional education beyond the traditional university system. Polytechnics in Nigeria are established and regulated by the National Board for Technical Education (NBTE), which sets standards and guidelines for curriculum development, accreditation, and quality assurance (National Board for Technical Education, n.d.). Polytechnic offers a wide range of programs at both the National Diploma (ND) and Higher National Diploma (HND) levels, with a strong emphasis on practical training, industry partnerships, and skill acquisition (Akanbi, 2017)

Electrical engineering technology as one of the program in polytechnic is designed to produce electrical engineering technicians for the following industries; manufacturing, assembling, servicing, power generation, transmission distribution and utilization, telecommunications, and other related industries (National Board for Technical Education [NBTE], 2013). The program is a four-year course divided into two separate program which the graduates of the first two years will be awarded "Diploma" as technicians while the remaining two years is for the award of "Higher National Diploma" as higher technicians or technologist. As the course deals with installation, troubleshooting, magnetism, control systems, signal processing, telecommunications, and maintenance, it become imperative for graduates of Electrical engineering technology students to be skillful in maintaining all Power Distribution Transformer.

A power transformer is an essential device associated with the handling and utilization of alternating current (AC). The transformer is of significant importance in lighting, electronics, computers, and of course electricity, transmission, and distribution. Appliances like radios, televisions, torches, grinders, refrigerators and video players employ different designs and sizes of transformers for effective operation. According to Online Power System Engineering Study Guide (2022), a transformer is a static machine used for transforming power from one circuit to another without changing frequency. Transformer can also be seen as a device that transfers electric energy from one alternating-current circuit to another more other circuits, by either increasing (stepping up) or reducing (stepping down) the voltage. The transformer in this study can be regarded as a device or static machine that transfers alternating voltage from one electrical circuit to one or more electrical circuits at constant frequency to a value higher or lower than the input voltage.

There are many types of transformer which exist independently both for indoor and outdoor use apart from the ones integrated with other components in different electronic appliances. Transformers exist to include but are not limited to Air-core, Iron-core, Impedance-matching and Isolation transformers. Also, Sooper (2012) documented Panel mounted, Portable electrical, Enclosed electrical and AC power isolation transformers as types of electrical transformer. While Indiamart (2022) listed other categories to include wye or delta, tapped or center tapped, pole mounted or stationary, oil and dry transformers. Others, according to Sarajcev, *et al.* (2020), are step-up & step-down transformer, three- and single-phase transformers, instrument transformers (potential and current), two winding, auto transformer, outdoor transformer, indoor transformer, electrical power transformer and of course power distribution transformer which is the main focus of the study.

Power transformers are indispensable in the course of electricity distribution, though capital intensive. According to Sarajcev, *et al.* (2020) high voltage power transmitted cannot be distributed to the consumers directly, and therefore must be stepped down to the desired level at the receiving end with the help of step-down transformer. This is because electrical consumers vary from small domestic consumers to large industrial consumers, or alternatively low voltage to high voltage consumers. Despite the indispensable nature of power distribution transformers in power distribution process, power transformers can only function effectively only when adequately maintained.

Maintenance is the necessary support and repair of machines which involves tasks as lubricating, adjusting, and replacing of parts. Electrical maintenance is the process of ensuring that electrical equipment is kept in good working order. It includes inspecting, testing, and repairing electrical equipment as necessary to prevent problems that could lead to a loss of power or an electrical fire. Sambo, *et al.* (2020) and Foros and Istad (2020) listed types of maintenance to include preventive, predictive, and corrective. Predictive, preventive and corrective maintenance can only be effectively carried out by skilled personnel. Skill therefore is defined as the ability to do something well. That is the expertness in the performance of an act. Skill is also an established habit of doing something acquired through repetitive practice (Nwachukwu, 2016; Osinem, 2021). Osinem (2021) further added that skills are tied to specific tasks or task domains, and therefore relative. Corroborating the view that skills are tied to specific tasks, Ede (2017) identified some of the different areas where skills are utilized to include handling of tools, machines and the production of objects with speed and accuracy. Hence, skilled power transformer maintenance-personnel can be seen as a person trained in the use of tools and equipment to carry out maintenance tasks on power distribution transformers.

Preventive maintenance is performed while a machine is in working order to keep it from breaking down. Preventive maintenance is based on time or existing schedule to perform specific maintenance tasks and fluid changes, adjustment, inspections, and overhauls. It is preventive in that it presumes that these actions will protect the components from breaking down failures (BlueMoon Filteration, 2012 and Eyüboğlu, *eta al.* (2020).

On the other hand, Predictive maintenance approach involves testing and monitoring machines in order to predict machine failures. According to BlueMoon Filteration (2012) and Foros & Istad (2020), predictive maintenance is condition based maintenance; maintenance is still scheduled as in the case of preventive maintenance, but based upon the individual components proven needs rather than on an existing schedule. Condition is usually determined by a combination of non-invasive techniques; oil analysis, vibration, electronic system testing, operational data recording (temperature, speed load, working time verses idle time).

Corrective maintenance is performed after fault recognition and is intended to put the component in a state in which it can perform the required function. The equipment is used until it fails. For equipment with random occurring instant failures, corrective maintenance might be the only option (Hilber, 2018). Hilber appears to acknowledge the sudden nature transformer failure by the use of the expression "random occurring instant failures", which sometimes is the case with power distribution transformers which could break down 'randomly' but instantly as well.

Electric power distribution industry in North-East, Nigeria is faced with inadequate number of power transformer maintenance personnel which has led to numerous abandonment of broken down power transformers. According to the Chief Technical Officers in charge of Yola Electric Power Distribution Company (Adamawa, Borno and Taraba States) and Jos Electricity Distribution Plc. (Bauchi, Gombe and Yobe State) in a face-to-face interaction with the researchers remarked that the inability to restore power transformers to good working condition have always led to complete abandonment of faulty transformers. Transformer faults have been blamed for many power outages of long duration in many towns and communities in North-East, Nigeria. It is against this backdrop that this study examined the power distribution transformer maintenance skills required by electrical engineering technology students of polytechnics in North-East Nigeria. The study answered the following research questions.

1. What are the preventive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?
2. What are the predictive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?
3. What are the corrective maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?

The following null hypothesis guided the study:

1. There is no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians and electric power distribution company supervisors on the preventive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.
2. There is no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians and electric power distribution company supervisors on the predictive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.
3. There is no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians and electric power distribution company supervisors on the corrective maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

2. Methodology

The study employed a descriptive survey research design. This Design according to Fwah, et al. (2024), is a quantitative method that focuses on describing the characteristics of a phenomenon rather than asking why it occurs This study was conducted in North Eastern Nigeria. The population of the study was 144 comprising of 135 Electrical Engineering Technology Lecturers, 3 Power Transformer Maintenance Technicians and 6 Electric Power Distribution Company-Based Supervisors that are currently working in YEDC and JED in North-East, Nigeria. The entire population was used for the study and so there was no sampling. Instrument used for data collection was a structured questionnaire developed by the researchers tagged: Power Distribution Transformer Maintenance Skills Required Questionnaire (PDTMSRQ). The instrument was made of two section A and B. Section A of the instrument solicited personal information from respondents; section B solicited information leading to the answers to the research questions.

The instrument was validated by three lecturers of which two were from the Department of Electrical Technology Education, Modibbo Adama University, Yola and one was from Federal Polytechnic, Damaturu, Yobe State. The reliability of the instrument was determined by trial-testing the instrument on six electrical engineering technology lecturers, two power transformer maintenance technicians and two electric power distribution company supervisors. In order to determine the internal consistency of the instrument, Cronbach Alpha (α) method was used to determine the reliability coefficient of the instrument which 0.74 was obtained. Copies of the instrument were later on distributed to the respondents and retrieved with the help of two research assistants as soon as they were completed. The three research questions were answered using arithmetic mean and standard deviation while the three null hypotheses were tested using Analysis of Variance (ANOVA) at 0.05 level of significance. The decision to accept or reject a null hypothesis was based on the p-value; whenever the p-value (Sig.) was lower than the α-value, the null hypothesis was accepted and vice versa. The description of all the task items based on level of skill acquisition was based on upper and lower real limit of numbers.

3. Results

Research Question 1: What are the preventive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?

Table 1 *Mean responses on the preventive maintenance skills required in power distribution transformers*

		NL = 135; NT = 3; NS = 6; N = 144					
S/N	**Preventive Maintenance Skills Required: Ability to**	$\bar{x}_L$	$\bar{x}_T$	$\bar{x}_S$	$\bar{x}_G$	**σ**	**Remark**
1.	Carry out inspection for leakages	4.76	4.67	4.50	4.75	0.90	Required
2.	Check cracks in porcelain bushings	4.69	4.67	4.50	4.68	1.06	Required
3.	Check for auxiliary equipment	4.81	4.33	4.33	4.78	0.89	Required
4.	Check drying material in the dehydrating breather	4.19	4.33	4.17	4.19	0.46	Required
5.	Measure temperatures of joints using a heat-sensitive camera	3.65	3.67	3.67	3.65	1.03	Required
6.	Measure temperatures of bushings using a heat-sensitive camera	4.13	4.33	4.17	4.13	0.34	Required
7.	Identify transformer breather	3.94	3.67	3.50	3.92	0.30	Required
8.	Check oil samples in conservator type transformers	3.76	3.67	3.50	3.74	1.84	Required
9.	Locate bushing gaskets	3.64	3.67	3.83	3.65	0.95	Required
10.	Detect leaks	3.90	3.67	3.83	3.90	0.45	Required
11.	Cover gaskets, valves and gaskets of the tap changer	4.90	4.67	4.83	4.90	0.42	Required
12.	Determine if a gasket had lost its elasticity	4.96	4.67	4.67	4.94	0.24	Required
13.	Detect causes of excessive heating	4.90	4.67	4.67	4.89	0.44	Required
14.	Cleaning contaminated bushings	4.17	4.33	4.17	4.17	0.40	Required
15.	Weld leaking joints	4.11	4.33	4.33	4.13	1.11	Required
16.	Clean glasses on the gas relay, thermometer and liquid level indicator	3.75	3.67	3.83	3.75	0.96	Required
17.	Carry out functional inspection and testing of applicable accessories	3.69	3.67	3.83	3.69	0.90	Required
18.	Move tap changer through all positions	4.08	4.00	4.17	4.08	0.47	Required
19.	Take liquid sampling from bottom drain valve for larger units as required	4.37	4.33	4.17	4.36	0.79	Required
20.	Check drying material in the dehydrating breather	4.01	4.00	4.17	4.01	0.17	Required
21.	Amend surface treatment defects	4.53	4.67	4.50	4.53	0.83	Required

22.	Apply humidity remover	4.26	4.00	4.33	4.26	0.69	Required
23.	Carryout tap-changer maintenance	3.70	3.67	3.83	3.71	1.00	Required
24.	Detect insulation failure	4.05	4.33	4.17	4.06	0.53	Required
25.	Detect manufacturing defects	3.86	3.67	3.83	3.85	1.14	Required
26.	Detect overloading	3.85	3.67	3.83	3.85	0.73	Required
27.	Detect line surge	3.90	4.00	4.17	3.92	0.48	Required
28.	Detect improper maintenance	3.96	3.67	3.83	3.94	0.23	Required
29.	Detect lightening	3.72	3.67	3.83	3.72	1.48	Required
30.	Detect sabotage	4.04	4.00	4.17	4.04	0.33	Required
31.	Detect moisture	4.88	3.67	4.50	4.84	0.63	Required
32.	Detect oil contamination	4.84	4.00	4.50	4.81	0.73	Required
33.	Detect low insulation resistance	4.81	4.33	4.33	4.78	0.89	Required
34.	Determine why automatic protection device trips as soon as the transformer is energized	3.91	4.33	4.17	3.93	0.48	Required
35.	Determine when tap changer or bolted links are incorrectly positioned or connected	3.65	4.33	3.67	3.67	1.03	Required
36.	Determine causes of unexpected secondary voltage	4.04	4.00	4.17	4.04	0.26	Required
37.	Determine causes of non-symmetrical voltages on the secondary side	3.94	3.67	3.50	3.92	0.34	Required
38.	Detect blown fuse in one phase	3.76	3.67	3.50	3.74	1.84	Required
39.	Determine causes of non-symmetrical load on the secondary side	3.64	4.33	3.83	3.66	0.95	Required
40.	Determine causes of spurious triggering during operation	3.90	4.00	3.83	3.90	0.46	Required
41.	Determine causes of incorrect thermometer operation	4.90	4.67	4.83	4.90	0.42	Required
42.	Determine causes of triggering and alarm incorrectly	4.96	5.00	4.67	4.94	0.23	Required
43.	detect relays incorrect timing	4.90	4.67	4.67	4.89	0.44	Required
44.	Measure abnormal operating temperature by thermography	4.12	4.67	4.17	4.13	0.46	Required
45.	Determine the cause of earth failure on one phase	3.67	4.33	4.33	3.71	1.03	Required
46.	Measure unexpected voltage to earth	3.85	3.67	3.83	3.85	0.70	Required
47.	Date and time of the occurrence	3.86	4.00	3.83	3.86	0.63	Required
48.	Data for installed overvoltage protection	4.37	4.33	4.17	4.36	0.79	Required
49.	Network data were connections or other relevant things made when the disturbance took place	4.66	4.67	4.17	4.64	0.82	Required
50.	Determine the nature of loads and possible relay operations which took place elsewhere in the network	4.01	4.00	4.17	4.01	0.17	Required
51.	Record accurate weather data (thunderstorm, rain, etc.)	4.35	4.33	4.50	4.35	0.64	Required
52.	Determine the nature of the gas filled in the relay gas (colour and quality)	4.04	4.00	4.33	4.05	0.27	Required
53.	Determine the nature of the oil is sooty	4.39	4.33	3.83	4.37	1.04	Required
54.	Take thermometer readings	3.74	3.67	4.17	3.76	0.95	Required
55.	Determine the nature of the coolers or tank if damaged	4.04	4.00	3.83	4.03	1.02	Required
56.	Identify the visible marks of arcing on e.g. the bushings, cover or conservator	3.69	3.67	3.83	3.69	0.95	Required
57.	Carry out Gas-in-oil analysis for LDT units and power transformers	3.70	3.67	4.17	3.72	1.15	Required
58.	Perform transformer insulation resistance	4.16	4.33	3.83	4.15	0.38	Required

59.	Measure no-load current by means of a variable low voltage source	3.69	3.67	3.83	3.69	1.52	Required
60.	Determine the voltage ratio	4.04	4.33	4.17	4.05	0.32	Required
61.	Compare DC resistances of windings with the DC resistance measured during delivery test	4.01	4.00	4.17	4.01	0.26	Required
	Overall Mean				**4.14**		**Required**

$\bar{x}_L$ = Mean of Lecturers, *$\bar{x}_T$ = Mean of* Technicians, $\bar{x}_S$ = Company-Based Supervisors *$\bar{x}_G$ = Grand Mean response of Respondents, σ= standard deviation of Respondents, N = Number of Respondents, MP= Moderately Possesses, SP = Slightly Possessed*

Table 1 revealed the preventive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The respondents indicated that with the overall mean of 4.14, all of the items listed in Table 1 are the preventive maintenance skills required in power distribution transformers as the mean responses for each item is above the criterion level of 3.50.

Research Question 2: What are the predictive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

Table 2 *Mean responses on the predictive maintenance skills required in power distribution transformers*

		N_L = 135; N_T = 3; N_S = 6; N = 144					
S/N	**Predictive Maintenance Skills Required Are:**	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$
62.	Ability to carry out ground resistance test.	4.04	4.33	4.50	4.07	0.33	Required
63.	Ability to carry out impedance test	3.64	4.33	4.33	3.68	1.00	Required
64.	Ability to carry out insulation absorption test.	3.90	4.00	4.17	3.92	0.49	Required
65.	Ability to carry out open and short-circuit test on transformers.	4.90	4.67	3.67	4.85	0.52	Required
66.	Ability to carry out power factor test on the transformer.	4.96	4.00	4.17	4.90	0.32	Required
67.	Ability to carry out sound connections at terminals and joints.	4.90	3.67	3.50	4.82	0.54	Required
68.	Ability to collect oil sample for testing.	4.17	4.33	3.50	4.15	0.49	Required
69.	Ability to detect bushings that are bad.	4.11	3.67	3.83	4.09	1.12	Required
70.	Ability to detect design errors that can cause failure of transformer.	3.75	3.67	3.83	3.75	0.95	Required
71.	Ability to detect substances that contaminate transformer oil.	3.69	4.00	4.83	3.74	0.93	Required
72.	Ability to determine suitable oil for transformer cooling.	4.08	3.67	4.67	4.10	0.48	Required
73.	Ability to determine the strength of the cellulose used for winding insulation.	4.37	3.67	4.67	4.37	0.80	Required
74.	Ability to fill minor leakages on transformer coolant containers/hose attached to the transformer.	4.01	4.00	4.17	4.01	0.20	Required
75.	Ability to gather maintenance information from user or owner's report about the transformer.	3.64	3.67	4.33	3.67	0.99	Required
76.	Ability to inspect and discover leakages on the transformer.	3.90	4.00	3.83	3.90	0.53	Required
77.	Ability to interpret dissolved gas in oil analysis (DGA) data as a means of detecting fault.	4.90	4.33	3.83	4.85	0.51	Required
78.	Ability to measure and record current and voltage of the transformer while in operation.	4.96	4.33	4.17	4.91	0.31	Required
79.	Ability to monitor and detect faulty desiccants.	4.90	4.33	4.17	4.86	0.48	Required
80.	Ability to monitor and detect faulty surge arrestors.	4.17	4.00	4.17	4.17	0.39	Required
81.	Ability to observe signs of overheating in a working transformer.	4.11	3.67	4.50	4.12	1.13	Required
82.	Ability to recharge gas blanket.	3.75	3.67	4.33	3.77	0.97	Required

83.	Ability to recognize parts that wear or spoil easily after some weeks or months of regular use.	3.69	4.33	3.83	3.71	0.92	Required
84.	Ability to recognize signs of overload in power transformer.	4.08	4.00	4.17	4.08	0.48	Required
85.	Ability to remove dust from tank and other casings that cover important parts.	4.37	4.67	3.83	4.35	0.81	Required
86.	Ability to represent in drawing changes that have occurred due to maintenance.	4.01	5.00	3.83	4.02	0.38	Required
87.	Ability to select and apply paints to metal parts to check corrosion.	4.53	4.67	4.17	4.51	0.84	Required
88.	Ability to select and use lubricants to prevent corrosion of metal parts.	4.26	4.67	3.83	4.25	0.68	Required
89.	Ability to take and keep record of repairs and replacement activities.	3.64	4.33	3.83	3.66	0.95	Required
90.	Ability to test and detect the state of the thunder arrester.	3.90	3.67	4.17	3.91	0.50	Required
91.	Ability to test insulation resistance	4.90	4.00	4.17	4.85	0.53	Required
92.	Ability to test lightning protection system.	4.96	4.33	3.67	4.89	0.39	Required
93.	Ability to test the state of the earthing or grounding.	4.90	4.67	4.17	4.87	0.45	Required
94.	Ability to tighten up loose bolts and connection in terminals.	4.17	4.33	3.50	4.15	0.41	Required
95.	Ability to top up coolant when shortage is observed.	4.11	4.00	3.50	4.08	1.15	Required
96.	Ability to use and reset the red line indicator after taking readings.	3.75	4.67	3.83	3.77	0.93	Required
97.	Ability to use vacuum cleaner to remove dust from coils, connector and insulators.	3.69	4.00	3.83	3.70	0.92	Required
98.	Ability to wipe water and dust from the bushing.	4.08	3.67	4.83	4.10	0.48	Required
99.	Ability to work on transformer fans.	4.37	4.33	4.67	4.38	0.78	Required
	Overall Mean				**4.21**		**Required**

$\bar{x}_L$ = *Mean of* Lecturers, $\bar{x}_T$ = *Mean of* Technicians, $\bar{x}_S$ = Company-Based Supervisors $\bar{x}_G$ = *Grand Mean response of Respondents, σ= standard deviation of Respondents, N= Number of Respondents, MP= Moderately Possesses, SP = Slightly Possessed*

Table 2 revealed the predictive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The respondents indicated that with an overall mean of 4.21, all of the items listed in Table 2 are the predictive maintenance skills required in power distribution transformers as the mean responses for each item are above the criterion level of 3.50.

Research Question 3: What are the corrective maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

Table 3 *Mean responses on the corrective maintenance skills required in power distribution transformers*

		N_L = 135; N_T = 3; N_S = 6; N = 144					
S/N	**Items**	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$	$\bar{x}_L$
100.	Ability to apply to remove rust from corroded parts using sandpaper	4.01	3.67	4.67	4.03	0.29	Required
101.	Ability to identify photograph or digital images replaced parts	4.53	3.67	4.17	4.49	0.85	Required
102.	Ability to handle transformer oil effectively	4.26	4.00	4.33	4.26	0.69	Required
103.	Ability to test transformer circuitry	3.70	3.67	3.83	3.71	1.02	Required
104.	Ability to conduct insulation resistance test on HV, LV and ground	4.05	4.33	3.83	4.05	0.53	Required
105.	Ability to perform insulation resistance test on the transformer	3.86	4.00	4.17	3.88	1.13	Required
106.	Ability to carry out recovery voltage test for oil transformer	3.64	4.67	4.17	3.68	0.97	Required
107.	Ability to carry out step voltage test on dry type transformer	3.90	4.00	4.17	3.92	0.43	Required

108.	Ability to check oil condition	4.90	3.67	4.50	4.86	0.48	Required
109.	Ability to transformer winding with insulating resin	4.96	4.33	4.33	4.92	0.28	Required
110.	Ability to clean the tank with safe cleaning agent	4.90	3.67	3.83	4.83	0.55	Required
111.	Ability to connect the transformer to external installation.	4.17	3.67	4.17	4.16	0.44	Required
112.	Ability to detect faulty components in the transformer	3.64	4.00	3.83	3.65	0.96	Required
113.	Ability to determine winding resistance test.	3.90	3.67	3.83	3.90	0.54	Required
114.	Ability to differentiate oil resistant materials from heat resistant materials.	4.90	3.67	4.17	4.85	0.52	Required
115.	Ability to dismantle and repack stacked cores.	4.96	4.00	3.83	4.89	0.36	Required
116.	Ability to keep accurate record of the condition of the transformer.	4.90	3.67	3.83	4.83	0.57	Required
117.	Ability to measure polarization index for dry type transformer	4.17	4.00	4.17	4.17	0.49	Required
118.	Ability to measure the insulation power factor test	4.11	4.33	3.67	4.10	1.13	Required
119.	Ability to record and interpret the nameplate information	3.75	4.33	4.17	3.78	0.93	Required
120.	Ability to remove clamping from the core	3.69	4.33	3.50	3.69	0.91	Required
121.	Ability to remove the upper blockings from the slots	4.08	4.00	3.50	4.06	0.55	Required
122.	Ability to rewind damaged or burnt winding	4.37	4.00	4.17	4.35	0.80	Required
123.	Ability to paint sandpapered parts	4.01	4.33	4.17	4.02	0.28	Required
124.	Ability to use winding equipment	4.53	4.67	4.83	4.54	0.82	Required
					4.22		**Required**

$\bar{x}_L$ = *Mean of* Lecturers, $\bar{x}_T$ = *Mean of* Technicians, $\bar{\boldsymbol{x}}_{\boldsymbol{S}}$ **=** Company-Based Supervisors $\bar{x}_G$ = *Grand Mean response of Respondents, σ= standard deviation of Respondents, N= Number of Respondents, MP= Moderately Possesses, SP = Slightly Possessed*

Table 3 revealed the corrective maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The respondents indicated that with an overall mean of 4.22, all of the items listed in Table 3 are the corrective maintenance skills required in power distribution transformers as the mean responses for each item is above the criterion level of 3.50.

Hypothesis 1: There is no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians, and electric power distribution company-based supervisors on the preventive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

Table 4 *ANOVA on the preventive maintenance skills required in power distribution transformers by electrical engineering students*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.009	2	.005	.068	.934
Within Groups	9.425	141	.067		
Total	9.434	143			

Table 4 shows that there was no statistically significant difference between groups as determined by one-way ANOVA $F(2,141) = 0.68$, $p = 0.934$). The F-values of 0.068 of the analysis is greater than the α-value of 0.05 significant level at 141 degree of freedom (df). Therefore, the null hypothesis is accepted.

Hypothesis 2: There is no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians, and electric power distribution company-based supervisors on the predictive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

Table 5 *ANOVA on the preventive maintenance skills required in power distribution transformers by electrical engineering students*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.125	2	.063	1.074	.344
Within Groups	8.221	141	.058		
Total	8.346	143			

Table 5 shows that there was no statistically significant difference between groups as determined by one-way ANOVA $F(2,141) = 1.074$, $p = 0.344$). The F-values of 1.074 of the analysis is greater than the α-value of 0.05 significant level at 141 degree of freedom (df). Therefore, the null hypothesis is accepted.

Hypothesis 3: There is no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians and electric power distribution company supervisors on the corrective maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

Table 6 *ANOVA on the preventive maintenance skills required in power distribution transformers by electrical engineering students*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.287	2	.144	2.581	.079
Within Groups	7.851	141	.056		
Total	8.138	143			

Table 6 shows that there was no statistically significant difference between groups as determined by one-way ANOVA $F(2,141) = 2.581$, $p = 0.079$). The F-values of 2.581 of the analysis is greater than the α-value of 0.05 significant level at 141 degrees of freedom (df). Therefore, the null hypothesis is accepted.

4. Discussion of Findings

The findings of the study revealed that students of Electrical Engineering in Polytechnics required preventive maintenance skills in power distribution transformers. The supporting hypothesis also revealed that there was no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians, and electric power distribution company-based supervisors on the preventive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. This finding is in agreement with Mkandawire, *et al.* (2011) and Malewski, *et al.* (2018, August). asserted that the maintenance of physical assets in power distribution is paramount as such the application of maintenance strategies in the management of critical physical assets helps not only the equipment to perform maximally but also to serve for a prolonged period of time. Murugan and Ramasamy (2015) and Belani (2020) also emphasize that the more equipment is utilized the more it loses its functionality thereby dropping in its performance level. The workman or technician needs to understand the time frame for each piece of equipment and the period at which maintenance will be applied to enhance the productivity of such equipment.

The finding of the study also revealed that Electrical Engineering Students of Polytechnics required predictive maintenance skills in power distribution transformers as the accompanying hypothesis revealed that there was no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians, and electric power distribution company-based supervisors on the predictive maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The findings are in agreement with Arif, *et al.* (2017). and Muhangi (2016) who reported that predictive skills are an important aspect of any maintenance activities which has to do with equipment that has wear and tear. Muhangi noted that an adequate and effective prediction helps in quailing a breakdown that will cause total and prolonged downtime in service delivery.

The findings of the study revealed that Electrical Engineering students required corrective maintenance skills in power distribution transformers and the complementary hypothesis revealed that there was no significant difference between the mean responses of electrical engineering technology lecturers, power transformer maintenance technicians, and electric power distribution company supervisors on the corrective maintenance skills required in power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The findings are in agreement with Abdelfatah, *et al.* (2011) who affirmed that technical engineering students in Egypt lack corrective maintenance skills in power distribution transformers, and as such it was recommended that rigorous training should be imparted to the students in order to acquire many skills in power distribution transformers maintenance. Yuan (2015) also lamented the inadequate skills in solving problems in substation equipment maintenance and repair as there is a dearth of skilled personnel to carry out adequate maintenance without inviting expatriates from other countries. Maintenance skills are very important in the field of engineering and as such the students in the field must make it a requirement for them to excel in their chosen career.

5. Conclusion

This study aims to aid the improvement of power distribution transformer maintenance experts who will be able to address transformer issues with the appropriate maintenance skills. As a result, the impartation of Electrical Engineering education as it relates to power distribution transformers in Polytechnics is critical as students who are exposed to the power transformer maintenance operations, will help to resolve power outages caused by transformer failures.

6. Recommendations

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

1. Lecturers should encourage the students' skill acquisition process by exposing them to various maintenance activities in order for them to imbibe the different methods of power transformer maintenance
2. Students should be trained to recognize sounds and sights of faulty equipment in order to predict the parts or components that needed replacement or repairs.
3. The knowledge of corrective maintenance is of essence as such students should be made to distinguish between the various maintenance method

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design ISAAC, John Ibanga; data collection: MUSA, Ladan and Ibrahim Mohammed Dawasa; analysis and interpretation of results: ISAAC, John Ibanga; draft manuscript preparation: ISAAC, John Ibanga. All authors reviewed the results and approved the final version of the manuscript.

References

Abdelfatah, M., El-Shimy, M., & Ismail, H. M. (2011). Reliability analysis of 220 kV power transformers in Egypt. *Ain Shams Engineering Journal*, *2*(3-4), 183-194.

Arif, A., Wang, Z., Wang, J., & Chen, C. (2017). Power distribution system outage management with co-optimization of repairs, reconfiguration, and DG dispatch. *IEEE Transactions on Smart Grid*, *9*(5), 4109-4118.

Belani, M. (2020, April). Evaluating virtual reality as a medium for vocational skill training. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1-8).

BlueMoon Filteration(2012). Maintenance concepts. Retrieved on 10th February, 2023 from *www.**bluemoons**systems.com/**Maintenance**.aspx*

Ede, E. O. (2017,). *Occupational analysis& course construction in industrial technical education (*3rd Ed). Nsukka: Godjiksons publishers.

Eyüboğlu, O. H., Dindar, B., & Gül, Ö. (2020, October). Risk assessment by using failure modes and effects analysis (fmea) based on power transformer aging for maintenance and replacement decision. In *2020 2nd Global Power, Energy and Communication Conference (GPECOM)* (pp. 251-255). IEEE.

Foros, J., & Istad, M. (2020). Health index, risk and remaining lifetime estimation of power transformers. *IEEE Transactions on Power Delivery*, *35*(6), 2612-2620.

Fwah, K. G., Ibanga, I. J., & Philip, S. (2024). Digital Skills Competencies Required by Electrical Engineering Lecturers for Effective Utilization of Open Educational Resources in Polytechnics in Northeast Nigeria. ALSYSTECH Journal of Education Technology, 2(2), 89-109.

Grisaru, M. (2022). Artificial intelligence challenges for power transformer maintenance. *Transformers Magazine*, *9*(SE2), 30-41.
Hilber V. (2018). Maintenance optimization for power distribution systems. Retrieved on 12th February, 2023 from www.kth.diva-portal,org/smash/get/diva2:1342!/fulltzxol
Indiamart. (2012). Types of power transformer. Retrieved on 12th February, 2023 from http://www.indiamart.com
Malewski, R., Subocz, J., Szrot, M., Płowucha, J., & Zalewski, R. (2018, August). Condition Assessment of Medium-Power Transformers Using Diagnostic Methods: PDC, FDS, FRA to support decision to modernize or replace service-aged units. In *Proc. of CIGRE 2008* (pp. A2-209).
Mkandawire, B. O. B., Ijumba, N. M., & Whitehead, H. (2021). Application of maintenance tools and strategies in integrated risk management of critical physical assets. *International Journal of Agile Systems and Management*, *4*(3), 261-279.
Muhangi, U. (2016). *Transformer power protection and alert system* (Doctoral dissertation, Busitema University.).
Murugan, R., & Ramasamy, R. (2015). Failure analysis of power transformer for effective maintenance planning in electric utilities. *Engineering Failure Analysis*, *55*, 182-192.
National Board for Technical Education (2013). *Electrical Engineering Technology - National Diploma:* Curriculum and Course Specifications. Kaduna – Nigeria: UNESCO-Nigeria Project in Support of Revitilization of Technical and Vocational Education in Nigeria.
Nwachukwu, C.E (2016). *Designing appropriate methodology in Vocational and Technical Education.* Enugu: University trust publishers
Online Power System Engineering Study Guide (2022). Electrical power transformer. Retrieved on 11th February, 2023 from http://www.electrical4u.com/index.php
Osinem, E. C. (2021). *Managing agricultural education and training: Resources, principles& methods.* Enugu: belony international publishers.
Sambo, A.S, Garba, B., Zarmara, I.H, & Gaji, M.M (2020).Electricity generation and the present challenges in the Nigria power sector. Retrieved on 12th February, 2023 from www.worldenergy.org/documents/congresspapers/70. pdf
Sarajcev, P., Jakus, D., & Vasilj, J. (2020). Optimal scheduling of power transformers preventive maintenance with Bayesian statistical learning and influence diagrams. *Journal of Cleaner Production*, *258*, 120850.
Shuvo, S. S., & Yilmaz, Y. (2020, November). Predictive maintenance for increasing ev charging load in distribution power system. In *2020 IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm)* (pp. 1-6). IEEE.
Sooper A. (2012). Application of different types of electrical transformers. Retrieved on 15th February, 2023 from http://www.sooperarticle.com/popular-article.
Yuan, D. (2015, December). Problems in Substation Equipment Maintenance and Repair. In *2015 4th National Conference on Electrical, Electronics and Computer Engineering* (pp. 1407-1410). Atlantis Press.