

Power Distribution Transformer Faults Diagnostic Skills: Case study at Electrical Engineering Technology Students of Polytechnics in North-East Nigeria

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Abstract—This study determined the power distribution transformer faults diagnostic skills needed by Electrical Engineering Technology students of polytechnics in North-East Nigeria. Three research questions and hypotheses guided the study, employing a descriptive survey research design. The study population was 144, comprising 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 Faults Diagnostic Skills Questionnaire (PDTFDSQ) developed by the researchers. Three experts validated the instrument, and a reliability of 0.74 was obtained using the Cronbach Alpha reliability method. The mean statistic was used to answer the research questions, while ANOVA was used to test the null hypotheses of the study at a 0.05 level of significance. The study's findings revealed that the Electrical Engineering Technology students of polytechnics in North-East Nigeria required fault diagnosis (troubleshooting) skills, ICT skills and safety skills. The study recommended that the Department of Electrical Engineering Technology in all polytechnics should endeavour to expose students to faulting-finding activities so that students of Electrical Engineering will acquire fault diagnosis (troubleshooting) skills for maintaining power distribution transformers.

Index Terms— Electrical Engineering, Faults Diagnostic Skills, Nigeria, Power Distribution Transformer

I. INTRODUCTION

A polytechnic is an educational system that prepares a person for employment or self-sufficiency by giving the student the skills required in the agricultural,

industrial, and commercial sectors, resulting in a country's economic progress [1]. Polytechnics are non-university institutions of higher learning tasked with providing various courses in technical subjects, technology, industrial production, agriculture, commerce, and communication, as well as knowledge and skills associated with the handling of relevant tools and equipment, and to develop students through both theoretical and practical experience [2]. According to Ref. [3], polytechnic education is a segment of general education that prepares individuals for occupational fields and effective participation in work, lifelong learning for responsible citizenship preparation, and sustainable development promotion. As a result, polytechnics are formed to train and instil in learners (students) technical vocational skills required for productivity in the workplace.

Electrical/electronic engineering technology is a recognised programme of study in Polytechnics that aims to develop semi-skilled technicians and technologists [4]. Polytechnic electrical/electronic engineering students take various technical courses in instrumentation, control systems, telecommunications, data and information processing, digital signal processing, electrical machines, analogue electronics, digital electronics, and power system engineering. These courses are taught in theory and practice to help students build the skills needed for employment after graduation. As a result, the Nigerian polytechnic education system prioritised students' acquisition of practical skills for the nation's technical advancement. This is evident from the NBTE curriculum, which states that practical work should receive 60% of the overall score in any technical course, with the remaining 40%

going to theoretical courses in polytechnics (National Board for Technical Education [NBTE], in Ref. [5]. Against this backdrop, this study emphasises the power transformer fault diagnosis skills in the graduates of Electrical/electronic engineering technology as the demand for power transformers has recently increased due to an increase in utilities.

In recent years, electrical utilities have undergone radical transformations. Cost and competitiveness are familiar business drivers, and lean business management has become the standard. Assets must be driven harder to keep costs low while maintaining customer service and reliability. Measurements of supply quality quickly reveal poor performance. At the same time, as networks approach capacity limits and redundancy options dwindle, they have become more challenging to operate. For a power transformer to be effectively utilised in this environment, better tools for efficient network management are required [6].

Power transformers are essential for all transmission and distribution networks [7]. These are the most expensive components of a substation and can become strategic bottlenecks in a power distribution system. Substantial improvements in transformer management as a network component are now possible. New technologies designed to address the abovementioned concerns now confronting utilities accomplish this. Every day, the need for electrical energy consumption for home and industrial reasons grows, as does the necessity for power transformers to perform best in distribution networks [8]. As transformers are one of the most significant and expensive components of the electrical power supply and distribution system, power distribution companies prefer to postpone replacement investments, causing the average age of a transformer to rise. When high-voltage equipment ages, the insulation deteriorates [9],[10].

Fault diagnostic procedures generally provide the power transformer status and predict operational conditions. The impact of air, moisture, temperature, mechanical and electrical overstressing, and insulation contamination causes faults in the power transformer system. Numerous diagnostic methods are available to check the transformer's condition while it operates. Power transformer failures are caused by mechanical damage, dielectric, electric, and magnetic circuits, which must be identified and avoided [10]. These failures include insufficient oil level, seepage of water in oil, prolonged overloading, single phase loading, unbalanced loading, faulty termination (improper sized lugs, etc.), power theft, prolonged short circuit, lack of installation checks, defective design, poor quality, improper formation of core, improper core bolt insulation, burr to the lamination blades, improper brazing of joints, burr /sharp edges to the winding conductor, incomplete drying, inadequate insulation covering, and insufficient cooling ducts in the winding. Many factors generate various faults, each of which has a particular influence on the power system if not detected early enough, which could result in catastrophic failures and significant follow-up expenditures. As a result, critical faults must be identified before a failure occurs; when it does happen, effective troubleshooting is expected.

Troubleshooting is a way of narrowing down a rational and

systematic issue. According to Ref. [11] and Ref. [12], troubleshooting is discovering and eliminating problems or flaws in electronic or computer equipment. In this situation, troubleshooting concerns the electrical equipment-power distribution transformer. The safety of the power transformer and the technician is crucial when troubleshooting the power transformer, whether it is active or inactive.

Safety is the absence of danger to personnel or equipment. Safety is keeping oneself and others safe from harm or danger. Safety entails being careful not to trip, bump, or run into things and avoiding accidents by being mindful of what one is doing. Transformer technicians must have strong safety skills to do maintenance jobs without endangering themselves, their coworkers, or their equipment [13]. As a result, it is necessary to establish the diagnostic and safety capabilities that Polytechnic's Electrical engineering graduates require to carry out work on power transformers.

The study specifically determined:

- The fault diagnosis (troubleshooting) skills needed for maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.
- The skills in ICT needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.
- The safety skills needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

The following research questions were formulated to guide the study.

- What are the fault diagnosis (troubleshooting) skills needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?
- What skills in ICT are needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?
- What safety skills are needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?

The following null hypotheses were tested at a 0.05 level of significance.

- 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 fault diagnosis (troubleshooting) skills needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.
- 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 ICT skills needed to maintain power distribution transformers by Electrical Engineering

Students of Polytechnics in North-East Nigeria.

- 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 safety skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

II. RESEARCH METHOD

This study was conducted in North Eastern Nigeria, employing a descriptive survey research design. The study population was 144, comprising 1355 Electrical Engineering Technology Lecturers, 3 Power Transformer Maintenance Technicians and 6 Electric Power Distribution Company-Based Supervisors currently working in YEDC and JED in North-East Nigeria. The entire population was used for the study, so there was no sampling. The instrument used for data collection was a structured questionnaire developed by the researchers labelled Power Distribution Transformer Faults Diagnostic Skills Questionnaire (PDTFDSQ). The instrument solicited information that answered the research questions. The instrument was validated by three lecturers, two from the Department of Electrical Technology Education, Modibbo Adama University, Yola and one from Federal Polytechnic, Damaturu, Yobe State. The instrument's reliability 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. To determine the instrument's internal consistency, the Cronbach Alpha (α) method was used to determine the reliability coefficient of the instrument, of which 0.74 was obtained. Copies of the instrument were later 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 a 0.05 significance level. 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 the level of skill acquisition was based on upper and lower real numbers limits.

III. RESULTS

A. Research Question 1: What fault diagnosis (troubleshooting) skills are needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?

Table 1 shows the fault diagnosis (troubleshooting) skills needed for the maintenance of power distribution transformers by Electrical Engineering students of Polytechnics in North-East Nigeria. The respondents indicated that Electrical Engineering students of Polytechnics needed all the skills listed with a grand mean value of 4.18.

TABLE I
MEAN RESPONSES ON THE FAULT DIAGNOSIS
(TROUBLESHOOTING) SKILLS NEEDED IN POWER
DISTRIBUTION TRANSFORMERS MAINTENANCE

N _L = 135; N _T = 3; N _S = 6; N = 144							
S/N	Fault Diagnosis (Troubleshooting) Skills: Ability to	$\bar{x}_L$	$\bar{x}_T$	$\bar{x}_S$	$\bar{x}_G$	σ	Remark
1.	Perform voltage ratio test on transformer	3.86	3.67	3.83	3.85	1.14	Needed
2.	Use an ohmmeter to carry out a winding resistance test on the transformer	3.85	3.67	3.83	3.85	0.73	Needed
3.	Perform continuity test on transformer	3.90	4.00	4.17	3.92	0.48	Needed
4.	Improve power factor by connecting capacitors to the transformer	3.96	3.67	3.83	3.94	0.23	Needed
5.	Document information on the condition of the transformer	3.72	3.67	3.83	3.72	1.48	Needed
6.	Determine the condition of the lightning protection system of the transformer	4.04	4.00	4.17	4.04	0.33	Needed
7.	Identify the causes of the fault	4.88	3.67	4.50	4.84	0.63	Needed
8.	Inspect the operation of the online tap changer in the transformer	4.84	4.00	4.50	4.81	0.73	Needed
9.	Inspect the differential relay operation.	4.81	4.33	4.33	4.78	0.89	Needed
10.	Interpret the result of gas analysis.	3.91	4.33	4.17	3.93	0.48	Needed
11.	Measure core loss as a means of checking for short circuits.	3.65	4.33	3.67	3.67	1.03	Needed
12.	Measure the exciting current of the transformer.	4.04	4.00	4.17	4.04	0.26	Needed
13.	Observe abnormal developments in the operation of the transformer.	3.94	3.67	3.50	3.92	0.34	Needed
14.	Recognise faults and their possible causes.	3.76	3.67	3.50	3.74	1.84	Needed
15.	Recognise the exact fault or malfunction of the transformer.	3.64	4.33	3.83	3.66	0.95	Needed
16.	Reconnect the disconnected wiring of the transformer.	3.90	4.00	3.83	3.90	0.46	Needed
17.	Test transformer parameters, e.g. voltage, power, current, etc.	4.90	4.67	4.83	4.90	0.42	Needed
18.	Use RMS meter	4.96	5.00	4.67	4.94	0.23	Needed
19.	Use an earth meter to carry out grounding testing.	4.90	4.67	4.67	4.89	0.44	Needed
Grand Mean		4.18					Needed

$\bar{x}_L$ = 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.

B. Research Question 2: What skills in ICT are needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?

Table 2 shows the skills in ICT needed for the maintenance

of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The respondents indicated that Electrical Engineering students of Polytechnics needed all the ICT skills listed with a grand mean value of 4.06.

TABLE II

MEAN RESPONSES ON THE SKILLS IN ICT NEEDED IN POWER DISTRIBUTION TRANSFORMERS MAINTENANCE

$N_L = 135$; $N_T = 3$; $N_S = 6$; $N = 144$

S/N	Preventive Maintenance Skills Required: Ability to	$\bar{x}_L$	$\bar{x}_T$	$\bar{x}_S$	$\bar{x}_G$	σ	Remark
1.	Collect accurate transformer information for input into the computer.	4.12	4.67	4.17	4.13	0.46	Needed
2.	Manipulate digital and electronic measuring equipment.	3.67	4.33	4.33	3.71	1.03	Needed
3.	Translate transformer test data into HTML form.	3.85	3.67	3.83	3.85	0.70	Needed
4.	Use different browsers to access information on the internet.	3.86	4.00	3.83	3.86	0.63	Needed
5.	Connect to the online virtual hospital for transformer diagnosis and repair.	4.37	4.33	4.17	4.36	0.79	Needed
6.	Use GSM to collect information from transformer monitoring equipment.	4.66	4.67	4.17	4.64	0.82	Needed
7.	Interpret information on electronic monitoring equipment attached to the transformer.	4.01	4.00	4.17	4.01	0.17	Needed
8.	Use web page and web address	4.35	4.33	4.50	4.35	0.64	Needed
9.	Download information from the internet.	4.04	4.00	4.33	4.05	0.27	Needed
10.	Use an online Dictionary and thesaurus.	4.39	4.33	3.83	4.37	1.04	Needed
11.	Send and receive e-mail.	3.74	3.67	4.17	3.76	0.95	Needed
12.	Carry out internet banking and shopping.	4.04	4.00	3.83	4.03	1.02	Needed
13.	Guard against internet security and virus protection.	3.69	3.67	3.83	3.69	0.95	Needed
	Grand Mean				4.06		Needed

$\bar{x}_L$ = 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.

C. Research Question 3: What safety skills are needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria?

Table 3 shows the safety skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The respondents indicated that Electrical Engineering students of Polytechnics needed all the safety skills listed with a grand mean value of 4.15.

TABLE III

MEAN RESPONSES ON THE SAFETY SKILLS NEEDED IN POWER DISTRIBUTION TRANSFORMERS MAINTENANCE

$N_L = 135$; $N_T = 3$; $N_S = 6$; $N = 144$

S/N	Preventive Maintenance Skills Required: Ability to	$\bar{x}_L$	$\bar{x}_T$	$\bar{x}_S$	$\bar{x}_G$	σ	Remark
1.	Identify the essential components and the use of first aid	3.70	3.67	4.17	3.72	1.15	Needed
2.	Check the location of the inlet and outlet cooling air	4.16	4.33	3.83	4.15	0.38	Needed
3.	Check the separation space between transformer radiators	3.69	3.67	3.83	3.69	1.52	Needed
4.	Avoid actions that can cause dangerous static charge (voltage)	4.04	4.33	4.17	4.05	0.32	Needed
5.	Choose the correct type of conductor for earthing.	4.01	4.00	4.17	4.01	0.26	Needed
6.	Connect all conducting equipment to earth by connecting them to the tank.	4.04	4.33	4.50	4.07	0.33	Needed
7.	Control danger in handling energised transformer.	3.64	4.33	4.33	3.68	1.00	Needed
8.	Control exposed conductive parts that can pose the risk of electric shock during testing.	3.90	4.00	4.17	3.92	0.49	Needed
9.	De-energized the transformer before maintenance.	4.90	4.67	3.67	4.85	0.52	Needed
10.	Disconnect series-parallel, double-voltage, and delta-wye switches on the energised transformer	4.96	4.00	4.17	4.90	0.32	Needed
11.	Disconnect earth safely after testing.	4.90	3.67	3.50	4.82	0.54	Needed
12.	Disconnect the primary and secondary windings before maintenance.	4.17	4.33	3.50	4.15	0.49	Needed
13.	Earth the transformer casing before maintenance.	4.11	3.67	3.83	4.09	1.12	Needed
14.	Give artificial respiration to	3.75	3.67	3.83	3.75	0.95	Needed

N_L = 135; N_T = 3; N_S = 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
15.	electric shock victims.	3.69	4.00	4.83	3.74	0.93	Needed
16.	Keep a record of tasks	4.08	3.67	4.67	4.10	0.48	Needed
17.	Locate and operate primary and secondary disconnecting switches during service.	4.37	3.67	4.67	4.37	0.80	Needed
18.	Lock out the transformer when de-energised	4.01	4.00	4.17	4.01	0.20	Needed
19.	Lock up switches so that unauthorised persons cannot put them on.	3.64	3.67	4.33	3.67	0.99	Needed
20.	Observe the safety aspect of each task	3.90	4.00	3.83	3.90	0.53	Needed
21.	Observe sources of accidents and remove them.	4.90	4.33	3.83	4.85	0.51	Needed
22.	Select the right size and shape of earthing conductor for grounding the casing.	4.96	4.33	4.17	4.91	0.31	Needed
23.	Test the effectiveness of the earthing connection.	4.90	4.33	4.17	4.86	0.48	Needed
24.	Use a hot stick and other voltage testers to determine voltage before maintenance.	4.17	4.00	4.17	4.17	0.39	Needed
25.	Use of personal protective equipment.	4.11	3.67	4.50	4.12	1.13	Needed
26.	Use appropriately rated equipment to carry out tests.	3.75	3.67	4.33	3.77	0.97	Needed
27.	Use red and orange lock-out tags at disconnection points to block unauthorised operations.	3.69	4.33	3.83	3.71	0.92	Needed
	Work calmly without pressure and hurry.						
	Grand Mean			4.15			Needed

$\bar{x}_L$ = 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.

D. 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 fault diagnosis (troubleshooting) skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

TABLE IV
ANOVA ON THE FAULT DIAGNOSIS (TROUBLESHOOTING) SKILLS NEEDED IN POWER DISTRIBUTION TRANSFORMERS BY ELECTRICAL ENGINEERING STUDENTS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.076	2	.038	.348	.707
Within Groups	15.488	141	.110		
Total	15.564	143			

Table 4 shows no statistically significant difference between groups as determined by one-way ANOVA $F(2,141) = 0.348$, $p = 0.707$). The F-value of 0.348 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.

E. 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 ICT skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

TABLE V
ANOVA ON THE SKILLS IN ICT NEEDED IN POWER DISTRIBUTION TRANSFORMERS BY ELECTRICAL ENGINEERING STUDENTS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.018	2	.009	.130	.878
Within Groups	9.958	141	.071		
Total	9.976	143			

Table 5 shows no statistically significant difference between groups as determined by one-way ANOVA $F(2,141) = 0.130$, $p = 0.878$). The F-values of 0.130 of the analysis are greater than the α -value of 0.05 significant level at 141 degrees of freedom (df). Therefore, the null hypothesis is accepted.

F. 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-based supervisors on the safety skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

TABLE VI
ANOVA ON THE SAFETY SKILLS NEEDED IN POWER DISTRIBUTION TRANSFORMERS BY ELECTRICAL ENGINEERING STUDENTS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.065	2	.032	.550	.578
Within Groups	8.280	141	.059		
Total	8.344	143			

Table 6 shows no statistically significant difference between

groups as determined by one-way ANOVA $F(2,141) = 0.550$, $p = 0.578$). The F-values of 0.550 of the analysis are greater than the α -value of 0.05 significant level at 141 degrees of freedom (df). Therefore, the null hypothesis is accepted.

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 fault diagnosis (troubleshooting) skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. 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 ICT skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. 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 safety skills needed to maintain power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria.

IV. DISCUSSION

The study's findings revealed that students of Electrical Engineering in Polytechnics in North-East Nigeria needed 19 fault diagnosis (troubleshooting) skills to maintain power distribution transformers. The supporting hypothesis told 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 fault diagnosis (troubleshooting) skills needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The findings agree with Ref. [14] and Ref. [15], who mentioned that fault diagnosis is essential in maintenance activities. Faults must be diagnosed before the required repairs and maintenance activities occur. The workman has to ensure that they possess adequate knowledge of the maintenance. Ref. [16] concluded that fault diagnosis is an essential skill that all technicians need to know where the fault of a broken down machine or equipment (transformer) lies.

The study's findings revealed that students of Electrical Engineering in Polytechnics in North-East Nigeria needed 12 ICT skills to maintain power distribution transformers. The complementing hypothesis showed 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 skills in ICT needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The findings agree with Ref. [17],[18] who, in their separate submission, reported that ICT is revolutionising the entire electrical

engineering industry and is one of the essential skills needed in ICT proficiency. ICT has made the world a global village, and everything in it is interconnected. The more a craftsman or technician acquires ICT skills, the more relevant they become in the industry. Against this background, the students of Electrical Engineering in Polytechnics in North-East Nigeria required more ICT skills to be acquainted with power transformer fault diagnosis.

The study's findings revealed that students of Electrical Engineering in Polytechnics in North-East Nigeria needed 27 safety skills to maintain power distribution transformers. In the same vein, the accompanying 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 safety skills needed for the maintenance of power distribution transformers by Electrical Engineering Students of Polytechnics in North-East Nigeria. The findings are in agreement with Ref. [15],[19],[20], who acknowledged that the safety of both humans and materials is sacrosanct in any engineering world. As power transformers utilise higher voltages and current for effective functioning, it is expedient that the students who wish to acquire the skill in transformer troubleshooting should be safety conscious. Ref. [21] states that an attempt without safety consciousness may devastate the craftsman. Still, when equipped with all safety consciousness and the consequences of letting off the safety skills, the craftsman will eventually be safe in all the activities.

V. CONCLUSIONS

The study concluded that the knowledge of troubleshooting power transformers is online and offline. The online troubleshooting skills in this study are referred to as the ICT skills, which have been adjudged as needed by the students of Electrical Engineering in Polytechnics in North-East Nigeria. It was also concluded that students of Electrical Engineering in Polytechnics in North-East Nigeria require safety skills in power transformers as this will help them become good troubleshooters of power transformers.

Based on the findings of the study, there are some recommendations. The Department of Electrical Engineering Technology in all polytechnics should endeavour to expose students to faulting-finding activities so that students of Electrical Engineering will acquire fault diagnosis (troubleshooting) skills for maintaining power distribution transformers. ICT skills should be made mandatory for all students of Electrical Engineering in Polytechnics to get acquainted with the needed skills and utilise them when needed. Students of Electrical Engineering in Polytechnics should be constantly exposed to videos showing the danger of lacking safety skills and consciousness when maintaining power distribution transformers. This will help to improve the student's safety skills and consciousness.

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