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A Critical Analysis of the Reliability of Power Holding Company of Nigeria Protection Schemes

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***Abstract*— Power system equipment such as generators, transformers, transmission lines, feeders used by power service providers like the Power Holding Company of Nigeria (PHCN) suffered from disturbances such as over-voltages, sudden connection/disconnection of load, faults, insulation failure, etc. from time to time. To minimize the effect of such disturbances, protection and control actions using protection schemes were required. However, with all the protection schemes in place, system failure due to the above mentioned disturbances were still common phenomena. Thus this study critically analysed the protection schemes used in PHCN. Direct method of information gathering involving the use of observation and review of site logbook were used to obtain relevant information for the research work. Several visits were also made to each of the substations under PHCN Abule – Egba Business Unit in Lagos State, Nigeria. The fault data from site logbook for a period of three consecutive years (2009-2011) were used to estimate the failure rate and the reliability of the PHCN Protection Schemes. The result of the analysis showed that the reliability of all the substations ranges between 98 to 100 percent. The average reliability was determined to be 99.25%. Conclusively the substations showed a very high reliability and consequently very low failures rates hence PHCN Protection Schemes are reliable.**

***Index Terms*— Failure rate, Protection Schemes, PHCN**

I. INTRODUCTION

A great demand for electrical energy is notable feature of modern civilization. Most of this energy is needed for lighting, domestic appliances, industrial electrical machinery and electric traction. The importance of electrical power in everyday life has reached a certain stage that it is desirable to protect the power system from harm during fault conditions and to ensure maximum continuity of supply.

Whenever fault occurs at a particular point in a power system, its effects start from the point where it occurs before spreading to other parts of the system. As such means must be devised to rapidly isolate the faulty part from the healthy part using some protection schemes [5]. In view of the above, protection systems are designed to detect abnormal system conditions and take predetermined, corrective actions (other than the isolation of faulted elements) to preserve as far as possible system integrity and regain acceptable system performance

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[2].To achieve the aim of protection by the protection systems, certain devices are arranged into special schemes known as protection schemes. These devices include: Circuit Breakers, Relays, Current transformers, Voltage Transformers, and Dc Source. Power system protection schemes are designed to detect abnormal system conditions, take predetermined corrective actions, and disconnect a faulty circuit element rapidly and also ensuring discrimination with other relays. Thereby preventing injury to personnel and damage to equipment, as well as to improve customer service [1]. This research work deals with the schemes of protection in recent Nigeria practice in Power Holding Company of Nigeria.

Protection schemes studies have become imperative areas of intense research. The reason being that without protection schemes, generation, transmission and distribution would have been impossible in power holding Company of Nigeria and in effect a standard of service to the consumers would not be achieved. It is impractical to design and build equipment or networks so as to completely eliminate the possibility of faults. As such, in electrical power systems, faults are bound to occur. What matters most is the ability of a given protection scheme to operate as required, whenever fault occurs in the system so as to isolate the faulty part from the rest of the system [4]. However, with protection schemes in place in PHCN, cases of system breakdowns, blackouts, burnt transformers etc. are still recorded. This has greatly affected the technological and industrial development of the country since no country can undergo the said developments without a stable power supply. Hence it is expedient to undertake a critical analysis of the reliability of PHCN power protection schemes.

Power system equipment (e.g. generators, transformers, transmission lines, feeders etc.) used by power service providers like the PHCN suffer from disturbances such as over-voltages caused by lightning surges, sudden connection/disconnection of load, faults, insulation failure, etc. from time to time. Under severe disturbances the system equipment are damaged or degraded. The damages or degradations caused by such disturbances may result to a short term or long term power outage depending on the severity of the damage. To minimize the effect of such disturbances, protection and control actions are required. In view of this, certain protection schemes are used by the PHCN. However, with all the protection schemes in place, system failure due to the above mentioned disturbances are still common phenomena. Thus this study seeks to analyse the reliability of the protection schemes used in the Power Holding Company of Nigeria (PHCN), Abule-Egba Business unit under Ikeja Distribution zone having nine injection substations of 33/11kV transformers, with 32 outgoing feeders.

II. Mathematical Equation for Reliability and Failure Rate

Reliability (R_t) is the measure or the probability that a product or service will perform properly under normal operating condition for a specified period of time. It is used as a measure of the system's success in providing its function properly.

The failure rate (f_t), is calculated as: [3]

$$f_t = \frac{n_f}{n_o} = \lambda \tag{1}$$

Where:

n_f = number of failures per year

n_o = total numbers of observation per year

The failure rate for n consecutive number of years is expressed as;

$$\lambda = \lambda_1 + \lambda_2 + \cdots + \lambda_n \tag{2}$$

Where n= total number of years

$$Reliability, R_t = e^{-\lambda t} \tag{3}$$

For this research work, a protection scheme with reliability of 95 % and above is assumed to be reliable.

Conclusively, the data collected using the site logbook and observation will be analysed using Eq. (1) to (3) before conclusion could be drawn about the state of the PHCN protection schemes.

III. Sample Case Study

Abule-Egba 33/11kV Business Unit

Station Location: Ikeja district, Lagos State, Nigeria.

A. Fault Data and Reliability Analysis of the Injection Substations under Abule-Egba 33/11kV Business Unit (2009-2010)

This analysis majorly treats relay which is the main protective device in any power system protection scheme with Abule-Egba 33/11kV Business Unit PHCN Substation as a case study. The failure rate of each substation was analysed to determine the reliability of the protection schemes in each substation. Tables 1- 9 show the failure detail for each injection substation. The failure detail of the nine injection substations of table 1-9 was presented in a chart of figure 1.

Table 1: Failure details from site logbook for Ekoro injection substation.

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	1	0
June	0	0	0
July	0	1	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	1
December	0	0	0
Total number of failure per year	0	2	1

Table 2: Failure Details from Site Logbook for Agege Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	1	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	1
December	0	0	0
Total number of failure per year	1	0	1

Table 3: Failure Details from Site Logbook for Ijaiye Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total number of failure per year	0	0	0

Table 4: Failure Details from Site Logbook for Abesan Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	1	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total number of failure per year	0	1	0

Table 5: Failure Details from Site Logbook for Yidi Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	1
November	0	0	0
December	0	0	0
Total number of failure per year	0	0	1

Table 6: failure Details from Site Logbook for Iju Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	2
December	0	0	0
Total number of failure per year	0	0	2

Table 7: Failure Details from Site Logbook for Ayobo Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total number of failure per year	0	0	0

Table 8: Failure Details from Site Logbook for Yusuf Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	1
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total number of failure per year	0	0	1

Table 9: Failure Details from Site Logbook for Abule/Iroko Injection Substation

Months of the year	Number of relay failure per month for the year 2009	Number of relay failure per month for the year 2010	Number of relay failure per month for the year 2011
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	1	0	0
November	0	0	0
December	0	0	0
Total number of failure per year	1	0	0

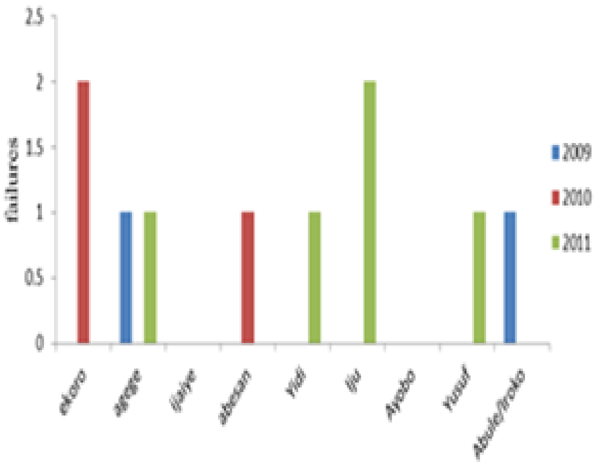

Figure 1: Chart Showing the Failure Details for the nine Injection Substation

COMPARISON BETWEEN THE RELIABILITY AND THE FAILURE RATE

Using Eq. (1) to calculate the failure rate (λ) and subsequently using Eq. (3) to calculate the reliability (R_t), the following results were obtained for the substations analysed as shown in table 10.

Table 10 failure rate (λ) and reliability (R_t)

Substations	failure rate (λ)	reliability (R_t) %
Ekoro Injection Substation	**5.48x10^{-3}**	**98.37**
Agege Injection Substation	**5.94x10^{-3}**	**98.23**
Ijaiye Injection Substation	**0**	**100**
Abesan Injection Substation	**2.28 x10^{-3}**	**99.31**
Yidi Injection Substation	**9.13 x10^{-4}**	**99.72**
Iju Injection Substation	**1.83 x10^{-3}**	**99.4**
Ayobo Injection Substation	**0**	**100**
Yusuf Injection Substation	**9.13 x10^{-4}**	**99.72**
Abule/Iroko Injection	**5.02 x10^{-3}**	**98.50**

The result in table 10 showed that Ekoro, Agege, Abesan, Yidi, Iju, Yusuf and Abule-Iroko substations had 98.37, 98.23, 99.31, 99.72, 99.4, 99.72, 98.50 reliability respectively with 5.48x10^{-3}, 5.94x10^{-3} , 2.28 x10^{-3}, 9.13 x10^{-4}, 1.83 x10^{-3}, 9.13 x10^{-4} , 5.02 x10^{-3} failure rate respectively over the period of survey while Ijaiye and Ayobo substations had 100 percent reliability respectively each with 0 failure rate respectively

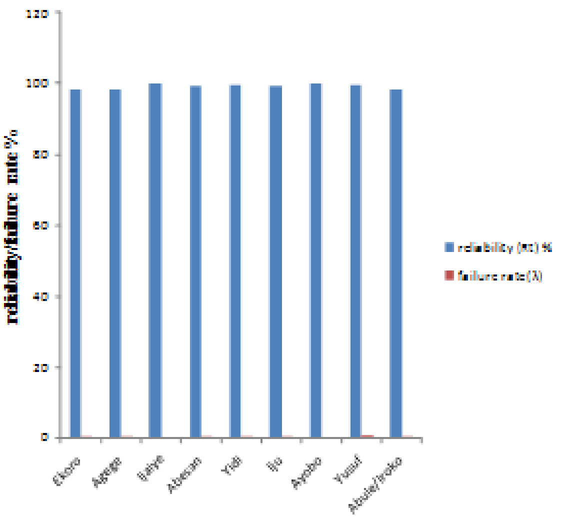

Figure 2: Chart Showing the Failure/Reliability rates for the nine Injection Substation for three consecutive years.

The result from the analysis revealed that Ijaiye and Ayobo substations had the best reliability while Agege injection substation had the least reliability. Since on the average the reliability exceeds 95 percent, this implies that the protection schemes in use in PHCN over the period of the research are reliable.

IV. CONCLUSIONS

Power system protection is very important in the planning and operation of power systems. Each element of the system is provided with its own protection devices arranged into a protection scheme. Each protection scheme operates as appropriate to prevent the protected element from being damaged in the event of fault. The effectiveness of any given protection scheme is measured by its reliability which can be estimated from the number of times the scheme fails and the resulting fault.

In view of this, reliability analysis was carried out for the nine substations in Abule-Egba 33/11kV Business unit; the result of the analysis showed that on the average, the Abule-Egba 33/11kV Business unit has a reliability of 99.25%%. Thus a general conclusion can be drawn that the PHCN protection schemes are reliable.

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