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Reliability, Dependability And Security Appraisal Of The Protection System Of Captive Generation Electrical Power Supply (A Case Study)

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***Abstract*—The dependability, security and hence, reliability of a of Protection system of an Institution engaged in captive generation of electricity so as to guarantee steady and sustainable power supply for the operation of their concerns was studied to determine it performance over the period of four consecutive years. Data was collected each month of the period with which mathematical analysis and computations were carried out. The result shows a dwindling protection system performance over the years. Thus, indicating a degeneration of the relay system components, sensitivity and selectivity compromise and the need for routine maintenance of the system as well as upgrading of the extant electromagnetic relays in the system systematically with the more-technologically-advanced, all-embracing, more-efficient numerical relays which have the advantages of combining the many functions performed by separate items of hardware in the electromagnetic type being embedded in on single item , high speed, and sensitivity with immense degree of precision in comparison with the electromagnetic type.**

Keywords—Protection System; dependability; sensitivity; selectivity; reliability; numerical relay.

I INTRODUCTION

The reliability, dependability and security of any power supply protection system determines its integrity, and hence, the ability of the system to dynamically reduce the magnitude and duration of power service disturbances and interruptions. Modern life and economic development is clinched by energy availability; which by extension hinges on its reliability. As a matter of fact, the per capita consumption of energy in a country determines the standard of living of the people [1]. Hence, in developing countries where sustainable electricity supply is a tall order, some governmental undertakings and most private investors operating captive generation of electricity so as to guarantee steady and sustainable power supply for the operation of their concerns. In order to ensure the integrity of such energy generating systems, the managers are required to establish/set up procedures to juxtapose the range of susceptibilities that may be antithetical to their objectives; thus making the system reliable, secure and dependable. Concisely, one of the major reasons for embarking on captive generation power supply is to ensure reliability, security and dependability. This is particularly so in industries where variations in voltages, power deficit, blackout and other abnormal conditions are intolerable. To achieve this objective therefore, an indubitable power system protection should be in place. In this paper, the reliability, dependability and security of the power system protection arrangement of the captive power plant of Delta State Polytechnic Ogwashi-uku were appraised in order to ascertain its integrity and hence facilitate management's finest decision making on how to enhance the power supply situation, exploit the dependability and security mutual benefits/ interchange, and accomplish the best results with least cost. There is no doubt that generation is the most expensive part of a plant; and its protective system likened to the brain of the power system, consequently, the reliability of the protective system is a sine qua non to safe operation of the system and of paramount importance with respect to ensuring unhindered electrical power supply in the institution.

II RELIABILITY OF POWER SYSTEM RELAY OR RELAY SYSTEM

The reliability of a power protection system (relay or relay system) is a measure of the extent of certitude that it will function correctly. In other words, reliability stands for the inevitability of accurate operation in concert with guarantee against erroneous and inaccurate operations from all extraneous sources. The goal of any electrical power system protection is to isolate as swiftly as conceivable, the protected circuit, when and if there is any indication of abnormal operating conditions of the system, whether it is deliberate, accidental or naturally occurring faults or system perturbations. While accidental abnormal system conditions could be occasioned by component failure and insulation breakdown/ failure, the naturally prompted failures/faults could come as a result of flash over, or lightning strikes. For a protective system to be considered reliable it must provide its function when require so as to avoid damages to equipment, people and property. Reliability problems arise from inaccurate design, wrong installation/testing and deterioration. Therefore, the examination of the reliability of protective system is imperative particularly, a quantitative understanding of it.

$$\%\ Reliability = \frac{\boldsymbol{Number\ of\ correct\ actuations}}{\boldsymbol{Number\ of\ dessired\ actuations + Number\ of\ incorrect\ actuation}} \times 100 \qquad \text{(i)}$$

A. Dependability and Security

Protection system reliability is made up of two components which are: Dependability and Security.

- **Dependability:** The facet of reliability that relates to the degree of certainty that a relay or relay system will operate correctly [2]. Dependability is therefore the measure of the level of confidence/ assurance that a protective system will operate accurately when the need arises and faster than designed [3]. Dependability becomes applicable when an abnormal current situation occur within the protected zone. A relay system is hence said to be dependable if it actuates only when it is required to do so. This is applicable when the abnormality is in its immediate bailiwick or when it is acting as ancillary. False actuation of protective relay or relay system does not only weaken the system process, but could also cause unwarranted discomposure and nuisances for the power system and or outright loss of service.

$$\%\ Dependability = \frac{\boldsymbol{Number\ of\ correct\ actuations}}{\boldsymbol{Number\ of\ dessired\ actuations}} \times 100 \quad \text{(ii)}$$

Furthermore, dependability can be enhanced by improving the sensitivity of the protective relaying system. Sensitivity is defined as the capacity of the protective system to detect the minutest possible fault/abnormal condition. The smaller the fault signal dictated by a relay, the more its sensitivity.

- **Security:** This is defined as the facet of reliability that relates to the degree of certainty that a relay or relay system will not operate correctly [2]. Security is therefore the measure of the degree of confidence that a protection system will not actuate erroneously or above the designed speed [3]. Therefore, security becomes relatable in an event of external faults normal circuit operating conditions. A relay is therefore said to be secure if it does not actuate when it is not require to do so. Hence, the security of a relay is the level of sureness that it will not actuate erroneously.

$$\%\ Security = \frac{\boldsymbol{Number\ of\ correct\ actuations}}{\boldsymbol{Total\ number\ of\ actuations}} \times 100 \quad \text{(iii)}$$

In designing a protection system, balance must be struck between dependability and security as there is always a tradeoff between them. [4] noted that dependability-based protection system failures can produce a long fault rectification; and would involve the isolation of healthy elements in the system, whereas, security-based protection faults can bring about the isolation of healthy elements of the electric system. Thus, protection system should essentially be designed to be mutually dependable and secure since it is well known that components of protective system sometimes fail.

Recent copious protracted research works [6-8] on electrical interruptions and power failures repeatedly portray serious correlation with both dependability and security-based protection system.

A decline in the reliability of the system affects the system's performance; and to maintain appropriate performance for protective system, there are two major constituent dynamics which are directly linked to dependability and security; and they are Sensitivity and Selectivity [3]. Sensitivity refers to the assurance that the relays that are designated to trip for a specified condition exhibit greater tendency to actuate when required than any other back up relay. Thus, sensitivity makes certain that irrespective of the magnitude of the fault, or its location on the protected system elements, the relay whose immediate jurisdiction it is to protect a specified element will sense the fault more intensely and respond accordingly. In other words, the smaller the fault signal that it can detect, the more sensitive it is.

On the other hand, Selectivity, which is sometimes referred to as *timing coordination* expresses the system's ability to discriminate. It is achieved when the least number of devices or elements is cut off from the system when isolating a fault. Hence a system with an innate selectivity should detect a fault as well as be able to decipher whether or not the said fault is in its ambit of operation. Therefore, a system with sound selectivity criterion should limit its operation to faulty elements and isolate it only, thereby averting interruptions and upsets to the entire system.

III Structure of Protection System in Power System

The basic structure of protection system in power system and the interactions of the protection relays is encapsulated in this segment. Figure 1 is the representation of the basic assembly of the protection relay.

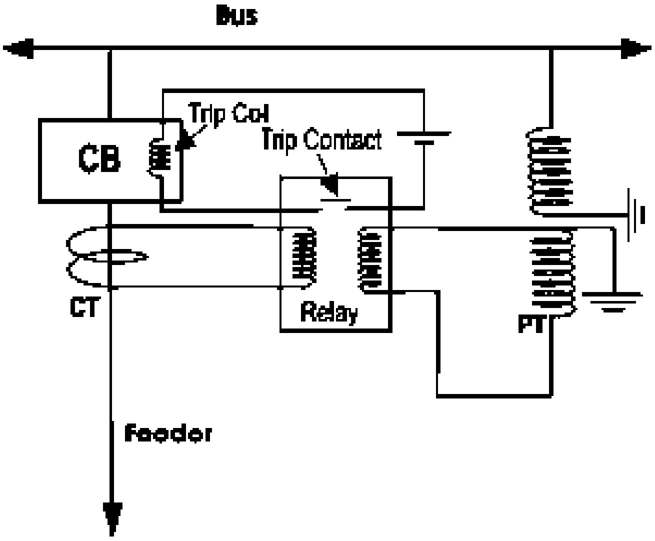

Figure 1. Basic Make up of Protection System

The output of the Current Transformer, CT is connected to the relay current coil, while the output of the Voltage Transformer is connected to the voltage coil of the relay. At the instance of any fault in the feeder circuit, a fraction of output current of the current transformer will pass through the current relay's current coil which in turn builds up the Magnetomotive Force (mmf) of that coil. This mmf build-up appropriately actuates the normally open contact of the relay by closing it. By the closing of this relay contact, the DC trip coil circuit is completed thereby energizing the trip coil. The systematized movement which activates the tripping mechanism of the circuit breaker and the eventual actuation of the circuit breaker to isolate the fault originates from the mmf of the trip coil.

IV MATERIALS AND METHODS

The study was centered on the power system protection system of the 550KVA captive power plant network of *Delta State Polytechnic Ogwashi-uku.* It involves data collection of number of actuations, number of correct actuations, and the number of times the relays fail to actuate when required.

V MEASUREMENT OF NUMBER OF ACTUATIONS OF RELAYS IN RESPONSE TO FAULTS OR ABNORMAL CIRCUIT CONDITIONS AND FAILURE TO ACTUATE WHEN REQUIRED

The number of operations of the relays and failures to operate when required were recorded each month for a period of four years. The purpose of this is to be able to compute the dependability, security and reliability of the relay system over the period of four years. The concerned relays are the entire generator protective relay system which include: Instrument Transformer, Protective relays and Circuit Breakers.

Table 1 : Number of Operation in the year 2013

Nature of Actuations	Number of Operation in 2013												
Month	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT	OCT	NOV	DEC.	Total
No of Actuations	-	2	1	1	1	2	2	1	2	2	-	-	14
No of correct Actuations	1	-	1	1	1	1	2	1	2	1	1		12
Failure to actuate	-	-	1	-	1	-	-	-	1	-	-	-	3

Table 2 : Number of Operation in the year 2014

Nature of Actuations	Number of Operation in 2014												
Month	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT	OCT	NOV	DEC.	Total
No of Actuations	1	-	1	1	2	1	2	1	2	2	1	1	15
No of correct Actuations	1	1	1	1	-	1	2	1	1	1	1	-	11
Failure to actuate	-	-	1	-	-	-	1	-	1	-	-	-	3

Table 3 : Number of Operation in the year 2015

Nature of Actuations	Number of Operation in 2015												
Month	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT	OCT	NOV	DEC.	Total
No of Actuations	1	1	2	1	2	1	1	1	2	1	-	1	14
No of correct Actuations	1	1	1	2	1	1	1	1	2	1	1	-	13
Failure to actuate	-	-	1	-	1	-	-	-	1	-	1	1	5

Table 4 : Number of Operation in the year 2016

Nature of Actuations	Number of Operation in 2016												
Month	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT	OCT	NOV	DEC.	Total
No of Actuations	1	2	2	2	2	3	2	1	3	2	1	2	23
No of correct Actuations	1	1	1	1	2	1	2	1	2	1	1	2	16
Failure to actuate	-	1	1	-	1	2	-	-	1	-	1	-	7

VI RESULTS AND DISCUSSION

Applying equations (i), (ii) and (iii) to the data in Tables 1-5, the results are as shown in Table 6

Table 6: Tabulated Results of the computation of Reliability, Dependability and Security

Year	2013	2014	2015	2016
% Dependability	80	78.57	72.22	69.57
% Security	85.71	73.33	92.85	69.57
% Reliability	70.59	61.11	56.52	53.33

The expected overall effect of every protection system is guaranteed reliability; and reliability does not stand alone. It is a result of the mutual interactive outcome of Dependability and Security of the system.

It can be seen that in the years 2013, 2014, and 2015, dependability and security were high, but the overall reliability for those years were relatively poorer. Also, in the year 2016, the computed values of dependability and security are of the same. This, however brought the reliability value to middling value of 55.33%.

A close examination depicts that failure to actuate increased for the year 2015 and 2016. This is obviously an issue of compromised sensitivity and selectivity which are by extension determinants of dependability and security respectively. Consequent upon this, the reliability of the system portrays a declining trend by the year. This is an obvious indication of deterioration of the protection system quality, which by implication could be occasioned by the depreciation of the relays, circuit elements and devices.

VII RECOMMENDATION AND CONCLUSION

To improve the reliability of the protection system under study, adequate redundancy of equipment and functional adaptability has to be introduced into the protection system. This will minimize the single component failures which has affected the system hitherto. In this context of redundancy, two locally independent protection system that have no common single points of failure are incorporated into the system. This provides high-speed isolation of fault, and as well, forestall false tripping.

Until there is a fault or other forms of circuit abnormality, protective relays do not exhibit their function. And as stated earlier, the failure of the protection system results to myriads of encumbrances to the system, the users and the managers of the system alike. Above all, poor system reliability is the bottom line. For the reliability all of its components with respect to the system under study to be ameliorated, well mapped out routine maintenance or testing program is a sure bet. With such program in place, any form of depreciating relay or other circuit elements can be easily identified and immediate appropriate remedial actions initiated. Furthermore, the extant electromagnetic relays in the system comprising switches, springs and linkages are susceptible to frailties, and other intramural defects which are capable of instigating false tripping and the attendant degraded reliability. These contrivances should be systematically replaced with the more-technologically- advanced, all-embracing more-efficient numerical relays. They have the advantage of combining the many functions performed by separate items of hardware in the electromagnetic type being embedded in on single item [9]. These relays have high speed, and sensitivity with immense degree of precision in comparison with the electromagnetic type.

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