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Diagnosis of defects on Medium Voltage Electric Energy Distribution Networks

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ABSTRACT

An analysis of the Medium Voltage (MV) electricity power distribution network in the operated by Cameroon's AES-SONEL company shows that losses are very high due to energy which is produced but not distributed and that the duration of power interruptions as a result of these defects is long due to the time used in searching for the defects. Given that quick detection of defects is a sure means of improving availability and productivity in any company, we hereby propose a system of real-time diagnosis of the defects on AES-SONEL's electric power distribution network. After an inventory of typical defects on electric power networks and the proposal of a tool for their identification, we propose a system for the detection and localization of these various failures. The implementation of the system on a Programmable Logic Controller (PLC) enables the performance of the system to be assessed.

1. Introduction

Electricity supply networks are subject to various disturbances because of the means of production, alongside atmospheric conditions and industrial usage which affect them during transportation and the distribution of the energy produced. The control and management of these shortcomings are of primary importance for reasons of reliability, availability, maintainability and effectiveness of the network, as well as for the safety of persons and property. The transfer of electricity supply in most parts of the developing countries is manual. This system of transferring energy has a high annual rate of energy interruption (more than 10%) as compared to the rate of energy interruption of in developed countries (less than 5%) [1] who use an artificial intelligence based network.

Studies made on the Medium Voltage Electric Power Distribution Networks at the Downstream Network of the AES-SONEL Ngousso Sub-Station [13], show that the company recorded 131,544 kWh of undistributed energy, furthermore it was noticed that the D113 head station at Ngousso recorded for this period 20 activations of its circuit breaker, giving a total duration of 120 h of power cuts, that is to say an average of 6 h per power cut [2]. According to the data experimentally collected by the Network Load-dispatching Centre (NLC), there is typically a time lapse of between 50 min and 2 h from the detection of the defect to the beginning of the search for a solution. In the case of loss of phase, it is usually customers who inform the NLC of the cut [3]. As for the duration of the search for a defect, this depends on the distance from the sub-station to the location of the defect, since the search is done manually. It also depends on the time of day when the fault occurs. To ensure power availability throughout the network and at all times, AES-SONEL should have a reliable system for the control and management of these defects. This availability requires a reliable system of diagnosis which is an important first step to detection and localisation of defects. Such a system will be of paramount importance in contributing to early and rapid detection, improving availability and productivity of the network equipment as well as the profitability of capital invested [4].

The purpose of this research is to design an automatic system for the diagnosis of failures on AES-SONEL's electric power distribution network, using the results of the studies made on the Medium Voltage Electric Power Distribution Networks at the Downstream Network of the AES-SONEL Ngousso Sub-Station. After listing the various potential defects in the electric power network, a tool is proposed for their identification. This is followed by a proposal of an automatic system for the detection and localization of defects as well as the results obtained during system implementation.

2. Types of defects, the characteristic values of the network and identification of defects on electric power network

The various types of defects of the electric power networks are listed and the algorithms for identifying characteristic values have been elaborated.

2.1. Various types of defects

A defect is the difference between the reference characteristics of a device and the characteristics observed on the said device

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Nomenclature

ADSL	Asymetrical Digital Subscriber Line
GPS	Global Positioning System
GSM	Global System Mobile
MODEM	Modulation–Demodulation
MV	Medium Voltage network
NLC	Network Load-dispatching Centre
PLC	Programmable Logic Controller
PMUs	Phasor Measurement Unit

away from the specifications [5]. In this regard, the electrical supply network is mainly a victim of the following defects: short-circuit, high voltage, overload and break in real supply.

Short-circuit is a contact between two live conductors or between a live conductor and the earth conductor. It results in a considerable current increase in a very short time from the source to the point of defect. This current is limited only by the impedance of the line and leads to an overflow of current.

Over voltage is any disturbance superimposed on the nominal voltage of the network and can appear either between phases or between the live phase and earth. The operating mode of the over potential protections gives rise to a high flow of current.

Overload, generally, is due to an outburst of power which is usually more than load rated beyond the capacities of the line. Overload does not always lead to the implementation of protection operations because certain overloads are tolerated for reasons of exploitation. For the distribution network, the acceptable rate of overload is 140% in 0.3 s. Overload can be detected by the measurement of the forwarded power. Since the voltage is fixed, an overload on the network is equivalent to an overflow of current.

Loss of phase occurs when an active driver (live phase) is broken. If the bit under voltage comes into contact with another live wire or earth, there is a short-circuit.

The identification of these defects dwells on two guiding principles: recording data on the network, analyzing them, and drawing the conclusions thereof on the state of the network.

2.2. Sampling value characteristics of the network

Through the electricity and voltage transformers, samples can be taken in any point of the network at a given frequency. According to of Shannon's theorem, this can be checked for a sampling rate that is at least equal to twice that of the original signal.

2.2.1. Sampling effective U voltage between phases

Effective voltage is obtained by getting the average of the squares of samples taken at regular intervals. Then the square root of this average is calculated. A sample is taken every $\frac{20}{N}$ ms, the square root is calculated and kept in memory. After 20 ms which correspond to the period, the average of these entire samples is calculated then the square root of this average which gives us an approximate value of the effective voltage between phases. For $N = 10$ and $u(t) = 15,000\sqrt{2}\sin 100\pi t$ as shown in Table 1 below.

This is well in the range of variation tolerated by AES SONEL network for voltage at +5%. For a higher degree of accuracy, the sampling interval is fixed at 1 ms is $N = 20$. The algorithm of the calculation of U is established.

2.2.2. Sampling of effective current I by phase

Given that the current signal period is identical to that of the voltage, the methodology is exactly the same one as that of sampling the voltage value. By changing U by I in the calculation algorithm value of U, one obtains the calculation algorithm of the value of I.

2.2.3. Sampling active power P

This is for a signal of 40 ms period. We will make 40 simultaneously samplings of the use of the current and the voltage. The sampling interval is worth 1 ms. The sampling method is that of the two watt meters, as the neutral is not being distributed. An approximate value of the active power phase is given by the average of the products of samples taken. The current is taken on phases 1 and 3. The voltage is taken between phases 1 and 2 then 2 and 3. The P12 power is calculated between phases 1 and 2 then the P23 power between phases 2 and 3. The power $P = P12 + P23$.

The algorithm of the calculation of $P12$ and P are established.

2.2.4. Sampling power-factor cos φ

This arises from three preceding measurements when none of them is not on zero. Because

$$\cos\varphi = \frac{P}{\sqrt{3}UI} \tag{1}$$

The algorithm of the calculation of $\cos\varphi$ is established.

2.2.5. Sampling of power S

This is from measurement of P and $\cos\varphi$

$$S = \frac{P}{\cos\varphi} \tag{2}$$

The algorithm of the calculation of S is established.

Once this data is memorized, it is scanned every 20 ms to detect a possible overflow of the preset thresholds or an abnormal operation of the installation. The above samplings enable us to identify the defects on the electric network of power.

The sampling of voltage and current can be taken in a specific point of the network by the Phasor Measurement Unit (PMUs). The PMUs are the devices capable of measurement synchronous real-time voltage and current phasors in power system [11].

The measurements in real time of the PMUs must be synchronized with the Global Positioning System (GPS). Unfortunately, the use of the GPS is not even current in our country.

Table 1
Evaluation of the effective value of U (T) starting from samples taken every 2 ms.

I	1	2	3	4	5	6	7	8	9	10
U[*i*] (kV)	0	12,469	20,174	20,174	12,469	0	−12,469	−20,174	−20,174	−12,469
Square (*U*[*i*])	0	155,475	406,990	406,990	155,475	0	155,475	406,990	406,990	155,475
Total	224,986									
U (kV)	14,9994									