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Diagnosis of defects on medium voltage electric energy distribution networks: The case of rural zone's supply

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ABSTRACT

An analysis carried out on the High Voltage A (HVA) electricity power distribution network run 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 the defects is long due to the time used in searching for these defects, particularly in rural zone's supply. 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 a rural network's supply of AES-SONEL's electric power distribution network, the case of. 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 power network supervision and control in most developing countries is manual. This method of management has a high annual rate of energy interruption (more than 10%) as compared to the rate of energy interruption in developed countries (less than 5%) [2] who use an artificial intelligence based network.

Studies made on the AES-SONEL electric power distribution network, with focus on the lower network of the Ngousso station (Yaounde Cameroun) during the period from June 2005 to April 2006 [1], show that the company recorded 1.315.144 kWh of undistributed energy; furthermore it was noticed that the D31 circuit breaker (supply of Monatélé) tripped 54 times for this period, this led to 398 hours of power cuts, an average of 7 hours per power cut [3]. According to the experimental data collected by the Network Load-dispatching Centre (NLC), there is a typically a time lapse of between 50 minutes and 2 hours from the detection of the defect to the beginning of the search for the solution. In the case of loss of phase, it is usually consumers who inform the NLC of the cut [4]. As for the duration of the search for a defect, this depends on the distance from the sub-station to the location of the fault, since the search is done manually. It also depends on the type of network (urban or rural) and 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 [5].

The purpose of this research is to design an automatic system for the diagnosis of defects on the supply's network of Monatélé. 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 common in electric power networks are listed and the algorithms for the monitoring of characteristic network parameter are explained.

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2.1. Various types of defects

A defect occurs when there is a discrepancy between the reference value and the measured value for any given network parameter [6,7]. In this regard, the electric power network is subjected to four main types of faults: short-circuits, over voltages, overloads and line ruptures (loss-of-phase).

2.2. Collecting characteristics parameters of the network

With the help of current and voltage transformers, samples are taken at a specific point of the network, at predetermined intervals. According to Shannon's theorem, a sampling rate that is at least equal to twice the frequency of the original signal is good enough.

The voltage between phases is sampled as follows: 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 all the samples taken is calculated, then the square root of this average gives us an approximate value of the effective phase-to-phase. For $N = 10$ and $u(t) = 15,000\sqrt{2}\sin 100\pi t$, Table 1 can be obtained.

This is within the 5% tolerance rating stipulated by AES SONEL. For a higher degree of accuracy, the sampling interval is fixed at 1 ms ($N = 20$). The algorithm for the calculation of phase-to-phase voltage is established.

2.2.1. Sampling of phase current I

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

2.2.2. Sampling of active power P

This is a signal with a period of 40 ms. This requires 40 samples of the current and the voltage to be obtained simultaneously. The sampling interval is therefore 1 ms. The sampling method is that of two wattmeters, since the neutral is not being distributed. An approximate value of the active power 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 power P12 is calculated between phases 1 and 2 and then the power P23 between phases 2 and 3. The power P = P12 + P23.

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

2.2.3. Sampling power-factor cos φ

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

$$\cos\varphi = P/\sqrt{3}UI \quad (1)$$

The algorithm of the calculation of cos φ is established.

2.2.4. Sampling of power S

This follows from the measurement of P and cos φ

$$S = P/\cos\varphi \quad (2)$$

The algorithm of the calculation of S is established.

Once kept in memorized, this data is scrutinized 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 [12].

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

2.3. Identification of defects on electric power network

This identification shall involve defects on overload, homopolar current and the loss of phase.

2.3.1. Identifying line overload defects

We must define the various thresholds of current intensity and times at the end of which a defect indication must be issued. We have three thresholds of overload. The first corresponds to operating current higher than 140% of the nominal intensity during 500 ms; the second is that in which the current is higher than 180% the nominal intensity during 100 ms; the third corresponds to the current of minimal short-circuit during an instantaneous time. The calculation algorithm for the identification of an overload defect is shown in Fig. 1.

2.3.2. Identifying homopolar current defects

Homopolar current is the algebraic sum from the instantaneous values of electrical currents on the three phases. The threshold of the homopolar current is selected between 130% from I_0 and 10% the nominal intensity. I_0 is the value of the current due to the ground-phase capacities at the upper level of the network. The calculation algorithm for the identification of homopolar current defect is shown in Fig. 2.

2.3.3. Identifying loss- of- phase defects

There is loss of phase when at the upper level the three phases are live, whereas two phases only are having current. The calculation algorithm for the identification of loss-of-phase defect is shown in Fig. 3.

The measurements of PMUs [13], Artificial Neural network (ANN) [14] and the complex space-phasor and Hilbert–Huang transform [15] can be used to identify the various types of defects.

3. Proposing a system for the detection and localization of defects on an electric energy network

To identify any defect, the processing unit needs to have all the characteristics of the network in real time. These characteristics are furnished to the treatment unit by detection modules placed in a specific point of the network and which must fulfil the following requirements:

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									