International Journal of Energy and Environmental Science
2022; 7(6): 104-108
http://www.sciencepublishinggroup.com/j/ijees
doi: 10.11648/j.ijees.20220706.11
ISSN: 2578-9538 (Print); ISSN: 2578-9546 (Online)

Evaluation of the Maintenance of a Medium Voltage Electricity Distribution Network by the ABC Method: Application in DR Congo

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To cite this article:

Ngosa Kibukila, Muzanga Kakeza, Ilunga Sapembi, Ilunga Lwamba, Ntumba Makenga, Nyembo Wa Sangwa, Mulemba Wa Kabulo, Banza Wa Banza, Kiseya Tshikala. Evaluation of the Maintenance of a Medium Voltage Electricity Distribution Network by the ABC Method: Application in DR Congo. *International Journal of Energy and Environmental Science*. Vol. 7, No. 6, 2022, pp. 104-108.
doi: 10.11648/j.ijees.20220706.11

Received: September 16, 2022; **Accepted**: September 29, 2022; **Published**: December 29, 2022

Abstract: Maintenance is a crucial for a proper functioning of equipment in industrial installations. In this study, we recorded the failures recorded in the medium voltage grid (MVG) of the Gambela I district of the city of Lubumbashi, with aim to adequately address this problem for the proper functioning of the electrical grid. The objective of this study is to prioritize the various causes that disturb the functioning of the power grid and to provide the solutions to make the grid healthy, by using the ABC method translated and interpreted by the Pareto curve. This method is relevant because it allows the investigation of events and the highlighting of important elements of a problem to facilitate choices and priorities. It is a question of identifying failures and detecting their causes and frequencies in order to take appropriate measures for better network performance. Various causes have been recorded in particular causes of electrical origin such as circuits and surcharges; there are also causes due to the upstream network. All these causes are presented in statistical form in the development of our work, and for a period of three months, we noted 83 cuts for a total of 1185 hours of shutdown in supply of electrical energy.

Keywords: Power Grid, Maintenance, ABC Method, Pareto

1. Introduction

At any given moment, the electrical system is subjected to various hazards internal to the network, such as load variations, variations in the capacity of certain means of production or component failures and also external aggression [1]. Thus, disturbances are created which can degrade the state of the grid and eventually lead to a power interruption of certain network loads [2, 3].

However, the distribution system operator must provide the electricity transmission service on the distribution networks at the best quality and at the best cost under optimal safety conditions [4-6]. The maintenance study remains a tool for monitoring, evaluation and control of the network that allows managers to make decisions at appropriate times, in order to make electric service more reliable and efficient. Several methods have been previously used in the search for compliance quality improvement in electricity distribution. Approaches such as Six sigma for quality improvement [7]. Statistical and non-parametric approaches are also applied in asymmetric distributions to observe the voltage level [8, 9], as well as in a distributed generation context [7]. An analysis of process capability is given by G. Arcidiacono and S. Nuzzi [10]. Methods for analyzing power system maintenance based on the comparison of net present values at the organizational level in terms of repair and maintenance are given by R. Gono [11]. The comparison of databases collecting information on power outages in different MV networks is presented by M. Megdiche [1]. The analysis of

MV power system maintenance using the ABC method is so far less elucidated.

The purpose of this work is to prioritize the various causes that disrupt the operation of the network under study and to provide the appropriate solutions to make the network reliable.

This study finds its interest in the fact that it will help us to better control, in practical terms, the causes that affect the network and their priority by ABC method. From a scientific point of view, this study is intended to be an information base for potential researchers who will be studying the maintenance of electrical energy distribution networks.

2. Materials and Methods

2.1. Study Area and Grid Structure

The Gambela I neighbourhood, which constitutes our study area, is one of 8 districts composing the commune of Lubumbashi, before the existence of this district there was only one district which carried the same name. On the expanse of the city of Lubumbashi including the Gambela I district, the transport and distribution network consists of the following voltage levels: high voltage (120kV and 220kV), medium voltage (6.6-15-50kV), and low voltage (0.23-0.5KkV). The reason for these different voltage levels is the need to limit the losses on the network and to allow the distribution of energy. The choice of the voltage level is an optimum between the initial investment cost and the cost of losses in lines throughout the operation.

Power grid supplying Gambela I district is in the looped structure. It is fed from the UNILU station, whose diagram is shown in figure 1.

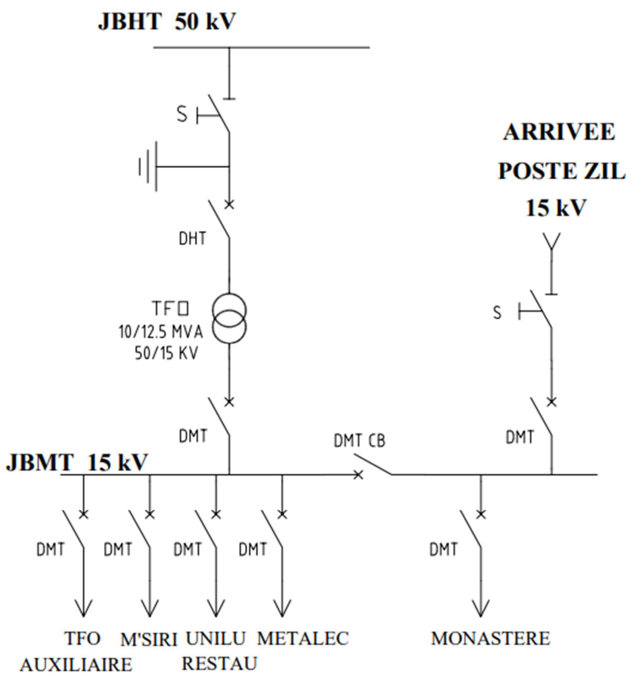

Figure 1. *Single line diagram of the UNILU distribution station (Source: SNEL, 2022).*

2.2. Methodology

2.2.1. The ABC Method

Among the myriad of concerns a maintenance manager faces, is deciding which failures should be investigated and / or improved first. To do this, we must identify those that are the most important and whose resolution or improvement would be the most profitable, especially in terms of unavailability costs. The ABC method provides an answer. It enables investigation that highlights the most important elements of a problem in order to facilitate choices and priorities. The ABC method is an objective and efficient method of choice, based on knowledge of an earlier period. The results are in the form of a curve called "ABC curve" or Pareto diagram. We classify the events (breakdowns for example) in descending order of costs (downtime, financial cost, number, etc.), each event relating to an entity. Then we create a graph match the cumulative cost percentages with the percentages of types of failures or cumulative failures. On the Pareto curve, three zones are observed [12]:

1) Zone A: 20% of breakdowns cause 80% of costs;
2) Zone B: the 30% of additional breakdowns cost only 15% more;
3) Zone C: the remaining 50% of breakdowns concern only 5% of the overall cost.

Hence, it is clear that the preparation of the maintenance work must focus on the breakdowns of Zone A, because they account for the major part of the expenses related to maintenance, ie 80% of the cost.

2.2.2. Determination of Zones

It is a question of delimiting on the curve obtained, zones according to the shape of the curve. In general, the curve has two breaks, which makes it possible to define three zones, namely:

1) The right side of the OM curve determines zone A.
2) The curved part MN determines the zone B.
3) The part assimilated to a line NP determines zone C.

2.2.3. Interpretation of the Curve

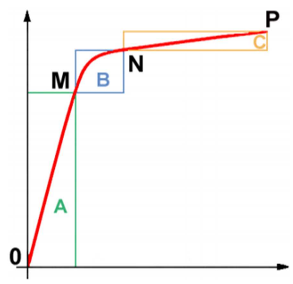

Figure 2. *Representation of the Pareto curve with the three zones.*

The study first focuses on the elements constituting Zone A in priority. If the decisions and modifications made to the elements of zone A are unsatisfactory, the first elements of zone B will be continued until satisfactory. The elements belonging to zone C can be neglected because they have little influence on the criterion studied.

The Pareto analysis is essentially used for the determination of potential solutions among many others [13].

Widely used in economics, the Pareto method is used to analyze warehouse stocks. In technical sciences it is used to analyze the average and marginal impact of parameters A, B and C on a given objective function describing a technical system with several parameters [14].

3. Results and Discussion

Thus, we conducted our study over a three-month period from January to March 2022. During this period, we recorded the cuts made in the network booth and diagnosed the causes that caused these breakdowns. The table 1 represents the causes, the downtime and the number of stops for each cause in the Quartier Gambela I MV distribution grid during this three-month period.

Table 1. *Identified causes, downtimes, and number of stops in the studies power distribution grid.*

Causes	Downtimes (hours)	Number of stops
Electrical cause	238	16
Tansient cause	184	14
Overload cause	196	10
Cause due to upstream power grid	227	21
Unknown cause	220	15
Maintenance cause	120	7

Table 2. *Causes, downtimes, Cumulative sum Percentage in the studies power distribution grid.*

Causes	Downtimes (hours)	Number of stops	Percentage
Electrical cause	238	238	20%
Cause due to upstream power grid	227	465	39%
Unknown cause	220	685	58%
Overload cause	196	881	74%
Transient cause	184	1065	90%
Maintenance cause	120	1185	100%

Figure 3 represents the Pareto curve plotted from the cumulative percentages of downtime based on causes. ZONE A: 20% of the causes (electrical cause, cause due to the upstream network and unknown cause) accumulate 58% of the hours of stop; ZONE B: 30% of the causes (cause of overload, transient cause) cumulate 14% of the hours of stopping, ZONE C: 50% of cause (work orders) accumulates 26% of the hours of stop.

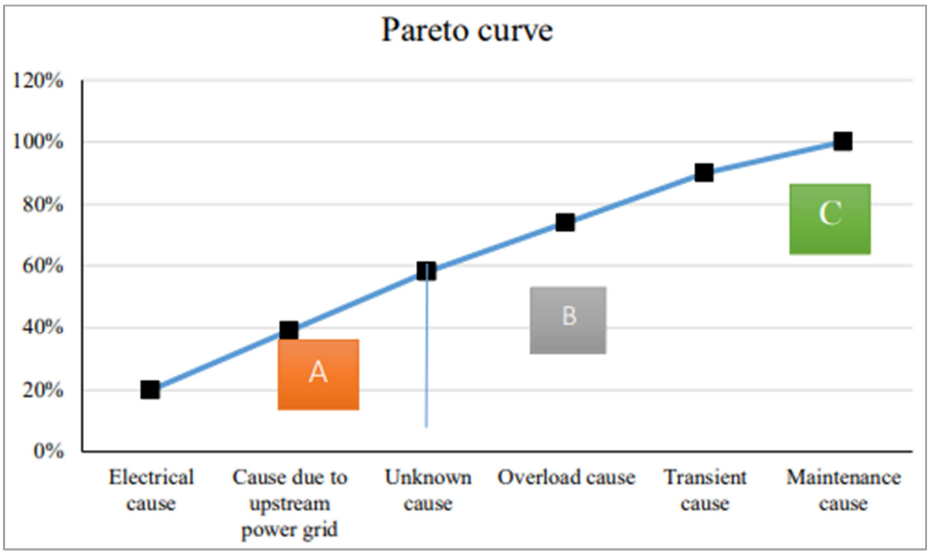

Figure 3. *Pareto curve defining different zones based on downtimes.*

Table 3. *Ranks the data in descending order and calculates the cumulative percentages.*

Causes	Number of stops	Cumulated sum	Cumulated percentage
Cause due to upstream power grid	21	21	25%
Electrical cause	16	37	45%
Unknown cause	15	52	63%
Transient cause	14	66	80%
Overload cause	10	76	92%
Maintenance cause	7	83	100%

Figure 4 below gives the Pareto curve plotted from the cumulative percentages of stop numbers according to causes. ZONE A: 20% of the causes (cause of the upstream network, electrical cause and unknown cause) accumulates 63% of the number of times of stop; ZONE B: 30% of the causes (transient cause and cause of overload) cumulates 17% of the number of stoppages; ZONE C: 50% of the causes (cause of work orders) accumulate 20% of the number of times of stop.

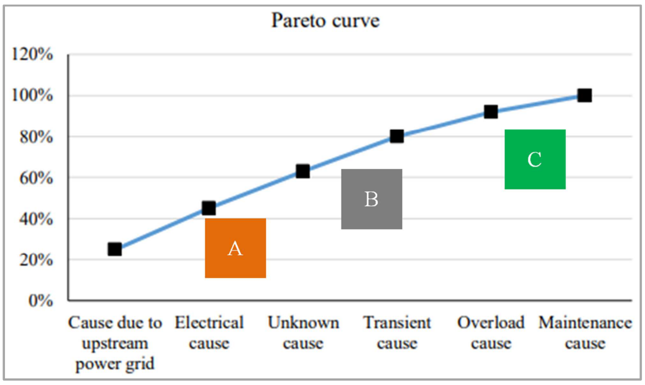

Figure 4. *Pareto curve defining different zones based on numbers of stops.*

We find on the two Pareto curves that the same causes (electrical causes, causes due to upstream networks and unknown causes) are found in zone A. This zone includes the various power outages, which are the most frequent and the most common more expensive. This means that with respect to preventive maintenance, we need to give them more attention and they must be prioritized, by high observation. The failures of zones B and C are also combated by an adequate maintenance policy. In this study it was found that the long duration power outages whose causes were electrical, transient and upstream network. These cuts are mainly due to the obsolescence of the electrical equipment. This finding corroborates with the A. Vinogradov et al. [15] study, which found that the dynamics of power outages were related to the damage of the transformer station equipment. The Gambela I district is part of the original core of the city of Lubumbashi and is one of the old districts of the city. Its electrical network dates from the 1960s, i.e. from the colonial period. This justifies the obsolescence of the electrical equipment. These untimely and unscheduled power cuts explain the poor quality of electrical service observed by Banza Wa Banza [6].

4. Conclusion

The objective of this article was to study the maintenance of a distribution network of electrical energy by the Pareto curve, case of the distribution grid MV of Quartier Gambela I. This work allowed us not only to make an evaluation of the maintenance of the network by ABC method but also to provide an appropriate solution. Thus, we conducted our study over a three-month period from January to March 2022. During this period, we noted various cuts in the supply of electricity. We started to identify the causes of these cuts and found that the causes were electrical, transient and those due to the upstream network. To better carry out our study, we used two methods: The Pareto method that allowed us to prioritize the causes affecting our study network over a period of three months and the statistical method that allowed us to quantify and to present the results of the research in the form of tables and graphs. This leads us to detect 83 cuts that resulted in 1185 hours of stops. After studying and processing the data collected at the SNEL control and coordination office (BCC / SNEL) during the three-month period of the Gambela I district MV distribution network, we found that the network components are in a state obsolete which needs a restructuring that will consist of:

1) Improved production to avoid the power deficit on the upstream network that affects the network to our study.
2) Replacement of equipment in a state of obsolescence whose dielectric strength and insulation resistance have greatly decreased and which cause power outages.
3) Improvement of protections so that we can detect unknown causes and better determines their origins.

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