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Electrical Power Transformer Damage on the Power Grid in Benin: Causes, Consequences and Solution Approaches

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Abstract: The transformer exploits the phenomenon of electromagnetic induction of wound conductors. One of its important properties is that it can act as an impedance matcher. Faults on the electrical network often affect the grounding resistances of power transformers and eventually damage them. Benin's electricity network, like those of other countries in the world, is frequently tested by electrical transformer damage. Through this work, from the static data obtained from the SBEE (Beninese Electric Energy Company), the state of the transformers installed on the electricity network, from 2016 to 2022, is realized. The analysis of their different operating conditions and their installation and protection methods has made it possible to identify the main causes of their damage. Their consequences on the transport and distribution of electrical energy in Benin are highlighted. It appears from this work that most of the faults are due to overvoltage due to discharges, overloads and short circuits. The poles most affected are those on poles (H61) followed by those on frames. Finally, a series of recommendations are proposed to minimize the number of defective transformers.

Keywords: Eelectrical Power Transformers Damage, Benin Power Grid, SBEE

1. Introduction

The transformer makes it possible to transfer electrical energy (in alternating form) from a source to a load, while modifying the value of the voltage. The voltage can be either raised or lowered depending on the intended use. The change from one voltage level to another is done by the effect of a magnetic field. In an electrical network, power transformers are sensitive links located between the production chain and the transmission chain [1]. They are among the most important and expensive equipment used in the transmission and distribution of electrical energy. Generally, when transformers fail, the failure is in the majority of cases due to an insulation fault. These unforeseen failures cause major disruptions to operating systems. [2]. Various factors influence the aging and damage of transformers with oil-cellulose systems and accelerate the aging process. High temperatures and water content have a significant impact on the aging and damage processes of transformers.

The temperature increase of 8°C halves the lifetime of a transformer and the aging process is negligible at temperatures below 50°C [3]. These principles persist to this day, even with the development and use of new materials in transformers in recent years. On the basis of these principles, a generalization allows us to admit that an increase of 10°C halves the service life of a transformer and that monitoring its temperature only makes sense when it is above 50°C. As for water, it can be found in different parts of the insulation system. It can accumulate in solid insulation, be dissolved in oil, or be found as liquid water in the core or bottom of a transformer. It is a threat to the insulation of oil-insulated (or ester-insulated) power transformers. If the water content exceeds the appropriate level, it causes a drop in the breakdown strength of the oil and accelerated aging of the cellulose insulation [4].

SBEE's MV distribution networks are mainly operated at 15kV (Cotonou- Porto-Novo-Natitingou-Calavi), 20kV (Bohicon-Abomey-Ouidah-Parakou-Djougou) and 33kV (N'Dali- Nikki, Ouaké-Kouandé- Kalale). These networks interface with those of distribution through the source substations. The consumers are the LV networks which are connected via the MV/LV transformer stations. Public distribution transformers are therefore of paramount importance in this electrical system. In recent years, their damage has been recurrently recorded on the SBEE networks and the consequences of which are unfortunate for customers. Indeed, for a long time, SBEE has remained out of stock of distribution transformers. Several areas remained without electricity for several months. In order to identify the real causes of these transformer damages and to propose a strategic plan that can counter this avalanche of defects, this work, based on the damage report sheets, aims to make a statistical analysis of the different damage and to identify their causes.

From the analysis of the results, it appears that most of the causes at the origin of these defects are attributed to climatic attacks, uncertainties of consumption (overloads) and short circuits. The life of a transformer is normally thirty years under normal conditions of use. But it is revealed from these analyzes that most of the damaged transformers were installed less than a decade ago.

2. Materials and Methods

2.1. General Information on Transformers

Electrical energy is one of the first lows of today's economy because it is one of the most important needs for man. In order to make it available to the user after it is produced in these power plants far from consumption areas, it is necessary to build networks to transport this energy to urban centers and industrial sites. The transport of this energy can only be done in high voltage, it will therefore be necessary to raise the voltage supplied by the generators of the power stations before transporting it [11]. High voltage is very dangerous and requires exceptional insulation between conductors, so there is no question of supplying a domestic installation with high voltage. It will therefore be necessary to lower the voltage before distributing it. Only processors can carry out these operations in an economical way.

2.1.1. Definition and Role of a Transformer

The transformer is a static electromagnetic induction machine making it possible to transform an electrical current system into one or more other alternating systems, of generally different electrical voltages and intensities, but of identical frequency, with excellent efficiency depending on the number of turns of the primary and secondary coils. These different current systems are electrically separated. It makes it possible to transfer energy (in alternating form) from a source to a load, while modifying the value of the voltage. [12, 15]

All in all, transformers are entirely static electrical machines, this absence of movement is moreover at the origin of their excellent efficiency. Their use is essential for the transport of electrical energy where it is preferred to “transport volts rather than amperes”. They ensure the rise in voltage between the source and the transport network, then allow the lowering of the network voltage towards the user without modifying its frequency. These are devices that can:

1) Transform an alternating voltage from one quantity to another quantity.
2) To transform an alternating current from one quantity to another quantity.
3) To isolate an electrical circuit from a direct current flowing in another electrical circuit.
4) Make an impedance appear to have another value.

2.1.2. Transformer Installation and Temperature

During the conversion of voltage and current by a transformer, losses (losses in the core, losses in the conductors and losses by eddy currents) are translated into heat. It is then possible to feel heat near the transformer. The transformer case temperature can reach a maximum rise of 65°C. Combined with a maximum ambient temperature of 40°C, the case can reach a temperature of 105°C on the surface [5, 16]. Internally, this temperature can reach 180°C at the hot spot when the transformer is operating at full load. It is important to note that the case core and top cover can reach temperature levels near design limits even with no load powered. This completely normal situation is explained by the losses in the core, due to the magnetic field present in it as soon as the transformer is energized. Good ventilation is therefore necessary to keep the transformer at a suitable temperature. If installed in a confined space, sufficient ventilation must be provided to maintain adequate ambient temperature. At all times, the average ambient temperature over a 24-hour period must be below 30°C and never exceed 40°C. The area required for the ventilation openings of the enclosure depends on the transformer power in kVA, the losses in the form of heat in KW, the difference in height between the ventilation openings at the input and output and the difference temperature between inlet air and outlet air. This surface has been designed to allow adequate ventilation of the transformer and should never be obstructed. No surrounding objects should interfere with the ventilation surface.

2.1.3. Electrical Transformer Failures: Causes and Manifestations

The transformer is an electrical device that has a lifespan of several decades. However depending on its use, its maintenance, its load, the disturbances it undergoes, it can be the seat of more or less important failures of which here are some. [6, 14]

1) Oil leak: The transformer has many rubber seals, typically at the bottom of the tank, at the base of the

terminals, at the refrigeration fittings, etc. Over time these seals can degrade, harden, causing oil leaks.

2) Tap changer hot spot: When the tap changers, whether loaded or unloaded, are not handled for years, they can form hot spots at their internal connections. These current-seeing contacts may heat up abnormally. As a result the oil can decompose and form solid carbon spots around the defect. In some cases the contact may even be soldered.
3) Electrodynamic type fault: In the event of a short-circuit, internal or external to the transformer, the currents within the windings are very high and can cause them to move mechanically.
4) Dielectric type fault: During overvoltage on the network, lightning strikes or operation of circuit breakers, etc., the insulating paper of the windings can allow ignition between turns or in the tank. If the oil is too acidic or the transformer has suffered many short circuits in its life then these insulating papers can be damaged. As soon as too much electrical stress can exceed the dielectric strength of these papers at critical locations, then a flashover will form at this location.

2.1.4. Origins and Causes of Transformer Damage

To ensure reliable operation of a transformer, it must be well protected against all types of constraints, namely: Internal and external overcurrents and overvoltage. Overvoltage are at the origin of the creation of transient problems with very steep fronts which can generate troublesome stresses on the operation of the various network devices, in particular the transformer. The most dangerous are overvoltage from lightning strikes. Lightning striking a line wire produces voltage waves over time at the point of impact. These waves propagate on either side of the point of impact with a speed close to that of light and with a certain deformation. When the overvoltage wave arrives at a point of connection of elements of the network, such as the point of connection of a transformer with the overhead line for example, its amplitude increases and continues to propagate in the winding of the transformer. This situation can cause flashovers in the transformer, possibly fires and even accidents to people at the station. Electrical networks are subject to both internal and external overvoltage and transformers are the most affected elements [7, 13]. Table 1 below summarizes the stresses causing damage, the probable damage suffered by the transformer and the observable manifestations on the operation of the latter [8, 10].

Table 1. *Origins and Causes of Transformer Damage.*

Constraints (Causes)	Probable harm	Observable manifestations
Surges (Close Lightning Strike, Network Maneuvers)	Breakdowns between MV turns, Possible evolution on land	Release of gas or smoke, Low phase current increase, ground current
Low overcurrent (Overload, impedance fault on LV network)	Destruction of the windings at the hottest points with short-circuiting of turns	Release of gas or smoke, Low phase current rise
Violent overcurrent (BT fault close)	Destruction of windings at the hottest points with short-circuiting of turns and displacement of coils	Rapid and random evolution towards a winding fault
Aging (Cumulative previous constraints)	Breakdowns between MV turns, Possible evolution on land	Release of gas or smoke, Low phase current rise

2.1.5. Remedies and Sealants Against High Water Content

If the water content exceeds the appropriate level, the cellulose must be dried. There are different drying methods. The simplest and least problematic method is to use bypass systems. These systems extract water from the operating transformer by flowing it through the oil passage. It is not recommended to use oil treatment plants, as these plants only dry the oil and cannot extract more than 1% of the water from the transformer. The sealing of the transformer must be a priority, in order to prevent the ingress of humidity and water. The use of technologies specifically designed for transformer sealing guarantees the long-term performance of the transformer. When it comes to choosing sealing products for transformers, the key factors are:

1) high adhesion of the sealant to the various components inside the transformer;
2) high breakdown voltage to avoid partial discharge;
3) compatibility with mineral and ester insulation fluids;
4) ability to bond to a variety of materials such as copper, brass, steel and rubber.

2.2. Benin Power Grid

2.2.1. Description of the Electrical Network

Benin's electricity network is subdivided into a transmission network (from 330 kV to 161 kV) and a distribution network (63 kV, 33 kV, 20 kV, 15 kV and 11 kV for medium voltage and 220 V for low voltage The Beninese Electric Energy Company (SBEE), which is the national electricity distribution company, owns and operates the network for voltages ranging from 63 kV to 15 kV for medium voltage and 220 V for low voltage It imports electricity from the Electric Community of Benin (CEB) from distribution centers and has power plants connected to the SBEE network. The CEB is the bi-national company (Benin and Togo) responsible for the production of energy, its import and transmission. It is the main partner of SBEE. It imports most of its electricity from the Volta River Authority (VRA), through the GRIDCo Power Network at 161 kV in Lomé Aflao in Ghana and from the Transmission Company of Nigeria (TCN) at 330 kV at Sakété in Nigeria. The two networks are interconnected, but they currently operate as two asynchronous control zones.

Distribution networks are affected by different types of disturbances. [9]. These disturbances can affect them permanently (harmonics, flicker, etc.) or only occasionally following events. This second category of disturbances is linked either to the operation of the network in the presence of faults, or to normal operation. Among the most common events are load shedding, work causing shutdown, outgoing start-ups, blackouts, short-circuits, connections of loads or decentralized productions, motor start-ups, etc. In this work, we will focus more on the first four types of events because of their frequency of appearance on MV networks.

The objective of the work is to identify the factors leading to the failure of power transformers on the distribution network on the one hand, to analyze their consequences and to recommend means that can help to mitigate these factors. To achieve this, starting from the data collected at the level of the SBEE, the state of the installed transformers will be elaborated, the census of those defective and the causes of their damage will be summarized.

2.2.2. Status of Installed Transformers

MV/LV distribution transformers with power ranging from 50kVA to 1600kVA are installed on SBEE's distribution networks and are used to supply domestic and industrial end customers.

The number and geographical distribution of these transformer stations depend on the density of consumption. Thus, in densely populated areas, cabin substations (H59) equipped with high-power transformers predominate, and in rural areas pole-mounted transformers (H61) offer less expensive solutions than other substations.

Table 2. *Point of installed transformers by region.*

STATE OF POWER TRANSFORMERS IN BENIN AT THE END OF JANUARY 2022						
POSTS	**TRANSFORMERS**	**Power (MVA)**		**Max Power 2021**	**Max Power 2022**	**COMMENTS**
CVE	T3 161/63kV	40		0	0	RAS
	T3 161/15kV	15		13.8	13	
	T5 161 / 63 kV	80		70	63	
	T6 161 /15kV	40		36.1	24.7	
CTMG	T1 (TAG) 161/11kV	35		23.19	21.16	RAS
	T2 161 /15kV	19		15.7	15.35	Dilapidation of the transformer; oil leak from the tank; one faulty fan motor out of six.
	T3 161 /15kV	50		19.18	11.92	
	BAT10 161/ 15kV	122		-	-	RAS
	BAT20 161 / 15kV	122		-	-	
AVAKPA	T1 161 / 20 kV	25		14.62	8.06	Fault on the spring charging mechanism of the circuit breaker supplying the transformer: The circuit breaker is bridged
LOKOSSA	T1 63 / 20 kV	16.6		0	11.07	The dielectric breakdown tests show a very low value, hence the need to replace the dielectric.
	T11 63/20kV	16.6		11.26	-	The transformer T11 has an oil leak at the diaphragm of the on-load tap changer
SAKETE	ATR1 330 / 161 kV	200		130	137	Self-transforming fire protection system (SCHUBB) Defective and out of service
	ATR2 330 / 161 kV	200		130	137	Self-transforming fire protection system (SCHUBB) Defective and out of service
	T3 161 / 20 kV	12.5		1.2	1	RAS
TANZOUN	T1 161 / 63 kV	50	80	31.3	25.2	RAS
	T1 161 / 15 kV	30		7.8	7.1	
	T2 161 / 63 kV	50	80	37.4	26	
	T2 161 / 15 kV	30		0	0	
ONIGBOLO	T1 161 / 20 kV	35		13	13.1	RAS
	T2 161 / 20 kV	35		12.4	12.4	
	T3 161 / 63kV	50		0	0	
PARAKOU	T1 161 / 20 kV	16	20	9.4	-	"Low level" transformer oil following the operation of the fire protection during the tests of the Dispatching project by INEO. Awaiting topping up with dielectric oil. Fault on the closing command of the 161 kV circuit breaker of transformer T1 (bridged circuit breaker)
	T1 161 / 33 kV	7		0	0	
	T2 161 / 20 kV	16	20	13.7	11.14	RAS
	T2 161 / 34.5 kV	7		0	0	
DJOUGOU	T1 161 / 20 kV	16	20	4,816	3.64	RAS
	T1 161 / 33 kV	7		6.57	6.27	
BOHICON	T1 161 / 20 kV	20		14.3	14.8	RAS
	T2 161 / 63/ 20 kV	20		6.8	6.4	
BEMBEREKE	T1 161 / 34.5 kV	20		5	4.5	RAS
	T2 161 / 34.5 kV	20		0	0	
KANDI	T1 161 / 34.5 kV	20		4.3	2.7	RAS
	T2 161 / 34.5 kV	20		0	0	
MALANVILLE	T1 161 / 34.5 kV	20		0	0	The Post has not supplied the SBEE since its commissioning
TOTAL		1.493				

2.2.3. Census of Defective Transformers from 2016 Until January 2022

In 2016, an analysis of the data sheets revealed 113 damaged transformers, i.e. 5.2% of the 2,175 installed. From 2015 to January 2022, there were 552 damaged transformers, i.e. 16.36% of the 3790 installed. This shows a strong increase in the damage rate in five years. The damaged transformers are of different brands and of all power ratings. Their statistics according to the year and each region are presented in table 3.

Table 3. *Damaged transformers by year and by region of installation from 2016 to 2022.*

Region/ Year	DRL1	DRL2	DRA	DRBA	DROPS	DRATAD	DRZC	DRCC	Total/Year	%/Year
2016	5	7	44	8	9	6	12	22	113	26.65
2017	8	6	17	7	8	14	14	8	82	15.71
2018	8	7	23	16	9	7	17	19	106	20.31
2019	7	4	12	31	13	6	14	7	94	18.01
2020	3	0	10	5	0	8	9	1	36	6.90
2021	4	7	15	23	13	4	10	6	82	15.71
January 2022	0	1	0	0	4	1	2	1	9	1.72
Total /Region	35	32	121	90	56	46	78	64	522	
%/Region	6.70	6.13	23.18	17.24	10.73	8.81	14.94	12.26		100

2.2.4. Causes of Transformer Damage

Following some difficulties in collecting information from 2018 to 2021, table 4 presents by region and by year, the number of causes of damage to transformers from 2016 to 2017. As for tables 5 and 6, they show the proportions defective transformers according to their support on the one hand and whether they are protected or not on the other hand.

Table 4. *Causes of transformer damage by region and by power.*

Powerful/ Region	50 kVA	63 kVA	65 kVA	100 kVA	160 kVA	250 kVA	400 kVA	630 kVA	800 kVA	1600 kVA	Total / Region	%/Region
DRL1	0	0	0	1	1	5	3	3	0	0	13	6.80
DRL2	0	0	0	1	6	2	2	1	0	1	13	6.80
DRA	3	0	0	15	15	12	13	2	1	0	61	31.94
DRBA	1	0	0	9	4	1	0	0	0	0	15	7.85
DROPS	2	0	1	9	8	8	1	0	0	0	29	15.18
DRATAD	4	0	0	2	1	0	0	0	0	0	7	3.66
DRZC	2	1	0	11	9	0	0	0	0	0	23	12.04
DRCC	3	0	0	16	8	3	0	0	0	0	30	15.71
Total/Power	15	1	1	64	52	31	19	6	1	1	191	
% Powerful	7.85	0.52	0.52	33.51	27.22	16.23	9.95	3.14	052	0.52		100

Table 5. *Proportion of defective transformers according to their type of substation.*

Type of position	In Cabin	H59 (On chassis)	H61 (on electric pole)
Proportion of processors defective (%)	11.50	17.3	71.2

Table 6. *Proportion of defective transformers protected or unprotected.*

Faulty transformers	Without protection	With protection
Proportion (%)	12	88

From these different statistical tables, different diagrams will be produced, analyzed and then interpreted in order to highlight the major causes of damage to these transformers. After evaluating their consequences on the electrical network, possible solutions will be proposed in order to considerably reduce the number of defective transformers.

3. Results, Analysis and Discussion

3.1. Points of Transformers Installed

Thus it is noted that the DRL1 (22.11%) and the DRA (19.9%) are the regions in which there are more transformers installed with regard to the density of consumption. DRL1 is H59 dominant because it is a high load area. On the other hand, the DRA, despite the fact that it is now a peripheral zone of Cotonou (high concentration of population) therefore with high load, most of the substations are in H61 and the operators resort to makeshift solutions by putting certain transformers (250 to 630kVA) on chassis in order to solve the problems of load growth with which they are often confronted. This region has a network structure that is no longer suitable for the distribution of the loads that are developing there, hence the need to reconfigure and modernize it, which can take into account the constant evolution of consumptions.

3.2. Inventory of Defective Transformers from 2016 to 2022

Figure 1 below, presents the number of damaged transformers by region and by year from 2016 to 2022. As for Figures 2 and 3, they show the different proportions of defective transformers by region on the one hand and by year on the other hand.

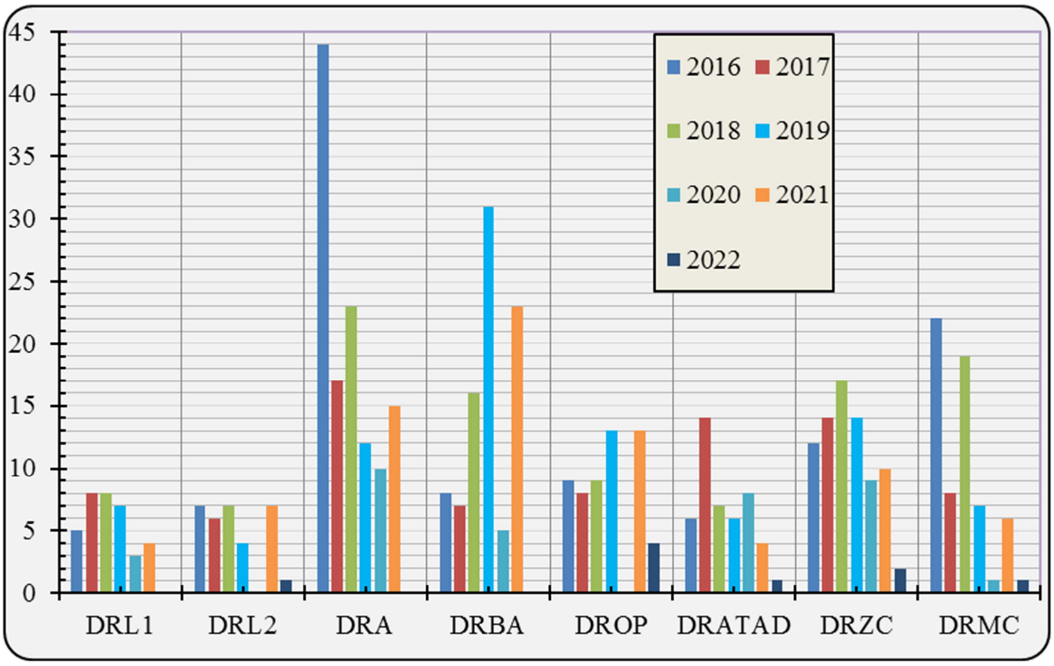

Figure 1. *Point of defective transformers by region and by year.*

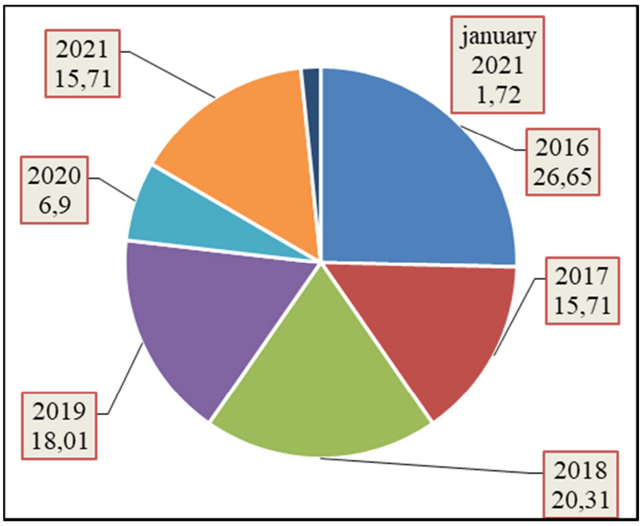

Figure 2. *Proportions of defective transformers by year.*

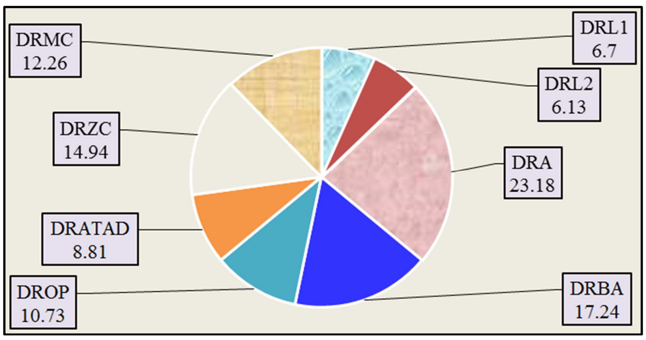

Figure 3. *Proportions (in %) of defective transformers by region.*

The diagram in figure 2 reveals that the transformer damage rate decreases from 2016 to 2020 and goes from 20.31 to 6.9%. But in 2021, we are witnessing a significant increase in this rate. This observation is justified by the fact that during this year, apart from atmospheric and anthropological disturbances, there is an increase in the connection of users to the electricity grid.

From 2016 to January 2022, the evolution of the diagrams in Figures 1 and 2 show that the DRA is the region which recorded the highest rate of damage with 21.18% compared to the total number of damage on the electricity network. of Benin, followed respectively by the DRBA (17.24%), the DRZC (14.94%), the DRMC (12.26%) and the DROP with a rate of 10.73%. These regions are globally high charge density regions As for the rest of the regions, areas with low load density, they recorded a damage rate of less than 10%. From the above, the high density of charges is therefore a limiting factor for the normal operation of transformers and contributes significantly to their defect.

3.3. Causes of Damage to Transformers in Benin

The diagram in Figure 4 shows the proportions of causes of damage to transformers in the years 2016 and 2017.

From the analysis of the damage sheets, it emerged that most defects are due to overvoltage from discharges (46.15%), overloads (19.49%) and short circuits (29.23%) (Figure 4). In fact, overvoltage subject the insulators to stresses that exceed the insulation voltage of the transformers. Nowadays, keraunic levels are very high and atmospheric discharges are therefore very severe on electrical installations. Appropriate measures must then be taken to protect them effectively against this phenomenon. Also the earth circuits of some transformers have been vandalized by social divorcees. Very high discharge currents are not efficiently drained to the ground and thus create floating potentials which are very dangerous for equipment and third parties. The regional authorities will then have to identify all these scenarios and rehabilitate them with 95mm² Almelec Alu cable that can efficiently carry currents of 100kA to the ground.

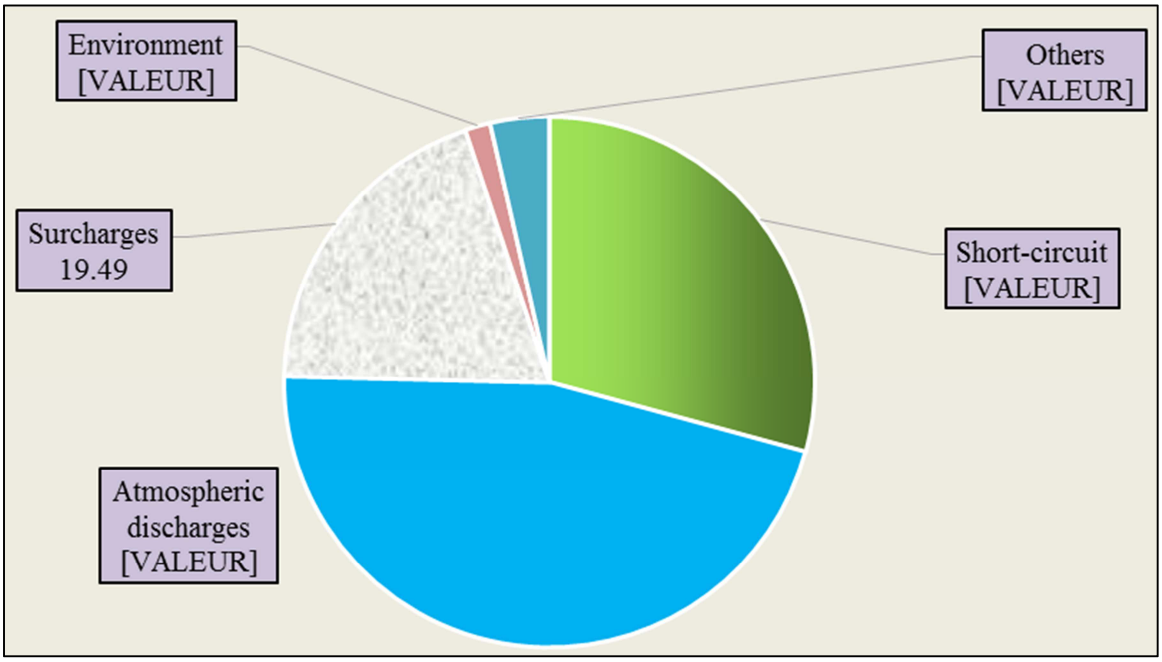

Figure 4. *Causes of damage to transformers in 2016 and 2017.*

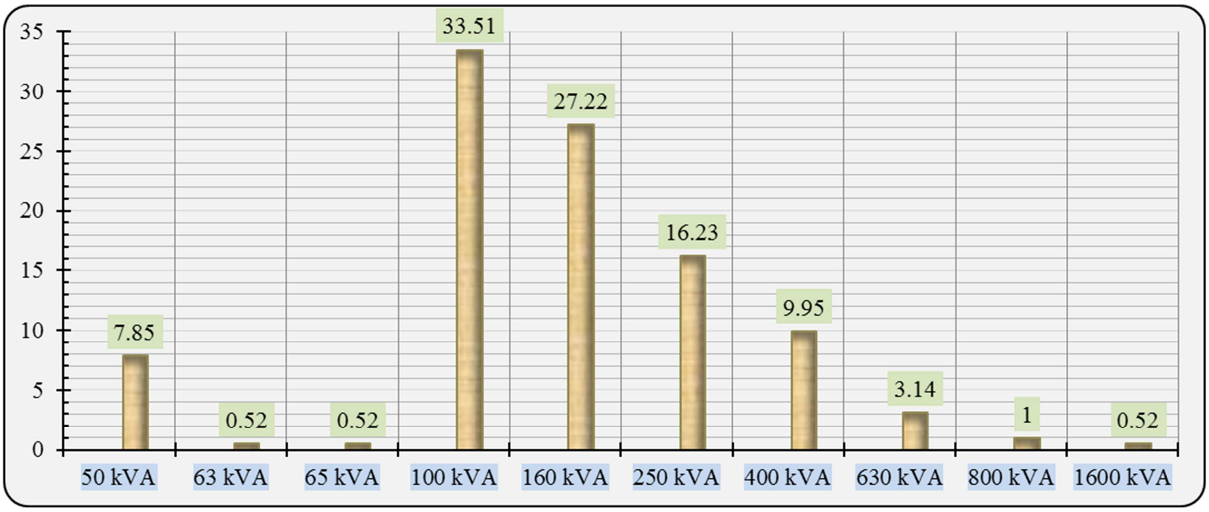

Figure 5. *Defect rate by transformer power.*

The posts most affected are those on poles (H61) with a rate of 71.2% and then posts on frames with a proportion of 17.3%. The PMD ends often used on networks and which equip frame-mounted transformers are exposed to bad weather and over time water infiltrates them: they do not have the characteristics corresponding to this mode of operation. This constitutes a weak point on chassis-mounted substations and can contribute to their failure.

H61 transformers are exposed to atmospheric, electrostatic and sometimes switching overvoltage. Lightning generates currents of up to several kA. Spark gaps and surge arresters are devices used to clip and limit high amplitude overvoltage. These devices are complementary and separable. They are chosen according to the level of protection desired. It is noted that some of the damaged transformers are without these devices which should limit overvoltage to a value compatible with the required insulation levels of the equipment.

From the analysis of the causes of damage, it is noted that some transformers are not protected against the effects of lightning. These are equipped with no earth circuit, spark gap or surge arrester in defiance of the recommended standard.

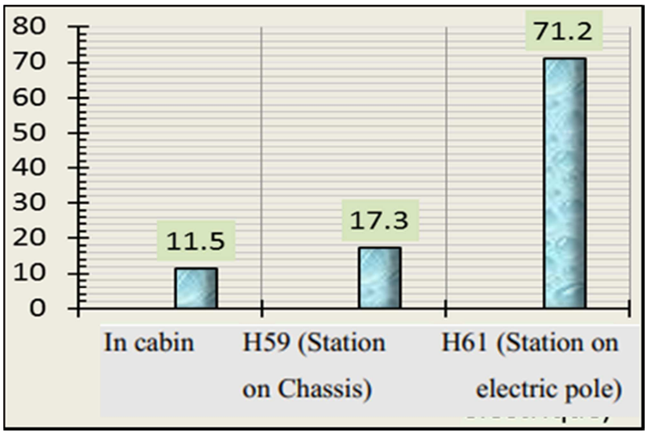

Figure 6. *Rate of employment varies by type of post.*

3.4. Results Interpretation

From the analysis of the damage sheets, it appears that most of the defects are due to short circuits, overvoltage from atmospheric discharges and overloads.

The current protection system consists of 29 mm² or 25 mm² earth copper cables which are used to make the mass and neutral earth connections on the distribution stations. Given that several tens of amperes must be passed to the ground under a high frequency, these sections of conductor seem to be insufficient to effectively conduct the discharges to the ground.

In fact, for some time now, faced with the frequent breaking of LV circuit breakers, operators have been striving to build bridges on the LV circuit breakers fitted to H61 substations. This practice is not likely to protect the transformers against overloads, since it is very difficult to size the bridge according to the IMAP current of the transformers. The oil and other insulators of the transformer will undergo thermal stresses which may bring them to the point of breakdown.

In some areas of high load concentration, the transformers are overloaded and it is very difficult to find others to do the reinforcement because of the shortage of stock. We have noticed that several transformers are leaking oil in operation. Most of the pole-mounted transformers installed on the SBEE networks are not equipped with any device that can enable operators to monitor the loads. Indeed those equipped with D265T or D165T type circuit breakers at the bottom of the pole are well monitored since they have load indicators. It will therefore be wise to gradually replace the compacts protecting the H61s with pole-mounted circuit breakers with a view to effectively monitoring their load. A permanent overload of 10% reduces the service life of the transformer from 30 years to 6 years. On most transformers, especially on poles, the control of loads is uncertain in view of the growth in consumption, hence the need for automatic monitoring.

Short circuits have electrodynamics' effects on transformer windings. In fact, some circuit breaker boxes are open and exposed to the weather.

Since the upstream terminals are unprotected, it often happens that they are shorted by reptiles and the like. The secondary windings are then directly short-circuited and deteriorate.

Frame-mounted transformers (250-630kVA) are not protected by fuses against short circuits at the primary, as recommended by the NFC 13-100 standard. They then receive directly all disturbances that may occur on the lines without any protection system being able to operate. We will have to make technical choices in the direction of adopting transformers with integrated protection in the form of fuses.

In addition, there are a myriad of brands of transformers installed on the networks. In the series of Damaged Transformers, we no longer find the Transfix brands, followed by the Nexans brand, then by Matelec: there is then a problem of standardization. It will then be necessary to review the technical specifications of the equipment taking into account the normative references.

All in all, the failures of power transformers on this electrical network are due to overloads, aging, poor maintenance, poor security or internal faults.

3.5. Proposal of Areas for Improvement and Recommendations

The causes being clearly identified, all that remains is to implement a well-adapted action plan to ensure better operation and good protection of the power transformers. Thus for a good installation of a transformer, it is necessary to:

1) place the transformer away from heat sources
2) provide a well-ventilated location
3) comply with the clearances required by the electrical code and applicable standards
4) make sure that the power supply and load cables do not obstruct the ventilation grilles of the case
5) ensure that the average ambient temperature is below 30°C, over a 24 hour period and never exceeds 40°C when the transformer is in operation
6) carry out periodic maintenance to ensure that the ventilation openings and the transformer are free from dust

To effectively contribute to the proper functioning of installed transformers and ensure their lifespan, it is necessary to:

1) update and review technical specifications of transformers
2) check the conformity of all surge arresters installed on the transformers and replace them if necessary
3) replace all spark gaps with lightning arresters, especially in lightning strike areas
4) check and replace vandalized earth circuits with aluminum cables with a section well suited to the discharge current
5) carry out regular measurement campaigns on all distribution stations
6) transfer workstations to chassis in cabin
7) take back boxes of compact circuit breakers by metal boxes padlock sand
8) resume transformer ground earth circuits and improve if

necessary
9) carry out measurement campaigns of ground earth and neutral values
10) periodically evaluate actions and measure the performance achieved

4. Conclusion

Ultimately, it appears from this work that most defects are due to overvoltage from discharges, overloads and short circuits. The posts most affected are those on poles (H61) followed by those on frames. Similarly, some of the damaged transformers are without protective devices which should limit overvoltage to a value compatible with the required insulation levels of the equipment. All in all, the failures of power transformers on this electrical network are due to overloads, aging, poor maintenance, poor safety or internal faults.

Abbreviation's List

SBEE: Beninese Electricity Company
LV: Low voltage
kV: kilovolt
kA: kilo Ampere
kVA: kilo Volt – Ampere
MV: High voltage category A
H59: MV/LV substation on chassis
H61: MV/LV substation on electric pole
DD: Distribution Department
DRL1: Regional Directorate of Littoral 1
DRL2: Regional Directorate of Littoral 2
DRA: Atlantic Regional Branch
DROP: Regional Directorate of Ouémé – Plateau
DRZC: Regional Directorate of Zou – Hills
DRMC: Mono-Couffo Regional Directorate
DRBA: Regional Directorate of Borgou – Alibori
DRATAD: Regional Directorate of Atacora – Donga
DPGS: Department of Heritage and Inventory Management
IMAP: Maximum admissible current at all times

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