Performance of Domestic AC Voltage Stabilizers in Meeting Low Voltage Problems in Nigeria: A Case Study of 12 Different Brands

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ABSTRACT

Every electrical and electronic appliance is designed and manufactured to perform, based on the expectation that the input voltage would be at a certain value. In Nigeria, household electrical and electronic appliances are most times under threat of low voltage supply. This low supply voltage causes these appliances to malfunction or at worse conditions, get damaged. Since the electric power supply/distribution companies are unable to provide the consistent adequate voltage level (220V) demanded by these sensitive appliances, therefore the consumers are ultimately responsible for the safe operation of their appliances, hence the use of automatic voltage stabilizers to improve the situation. This paper describes the line and load regulation tests that were carried out on twelve (12) selected brands of commercially available domestic 1kVA Automatic Voltage Stabilizers used by consumers in Nigeria for the protection of their appliances. The results showed that many of the stabilizers tested are unable to adequately meet the current low voltage situation experienced by consumers of electricity in Nigeria. For line regulation with input voltage range of 100V-250V, Century stabilizer gives an average output voltage of 222.4V and the least standard deviation of 8.5V but Q-Link stabilizer has the highest average output voltage of 224.8V with a standard deviation of 12.2V. PDX stabilizer has the least average voltage of 161V with standard deviation of 22V. For load regulation at output load of 1000W, Concept stabilizer has the minimum load regulation index of 4.52% while Q-Link stabilizer has the highest load regulation index of 9.3%. Variation of load regulation index with load was also considered. Q-Link stabilizer has the highest load regulation index variation with load of 0.0095%/W while Concept stabilizer has the least load regulation index variation with load of 0.0045%/W. Century stabilizer is recommended to be used in areas where there is high degree of line voltage fluctuations and Concept stabilizer is recommended in situations where varying load will be applied to the stabilizer.

Keywords: Automatic Voltage Stabilizer, Line Regulation, Load Regulation, Low Voltage, Regulation Index.

1. INTRODUCTION

The development of any country is largely hinged on the availability of undisturbed and regulated power supply. In Nigeria, electric power is generated from generating stations located at different parts of the country and transmitted in bulk through overhead lines at a high voltage level in a grid system. It is then distributed to various consumers locally through substations’ transformers where it is stepped down to standard low – voltage levels for the different categories of consumers. However, the Nigeria power sector operates well below the installed capacity and estimated consumers demand, with power outage being a frequent everyday occurrence. In 2012, “electricity generation capacity in Nigeria fluctuated between 2.6GW and 3.6GW which is well below consumers demand” (Arobieke et al, 2012), and it has continuously been on the decrease. Many substations and electrical networks in Nigeria were established over 50 years ago, and are still functional today but with poor performance and epileptic power delivery.

Apart from insufficient generation, the supply authority finds it difficult to actively maintain a steady voltage supply between the distribution point and the consumer premises due to the variation of the drop in voltage as the connected loads vary. One of the problems at present is the distribution of the final sub-circuit of 11kV/0.415kV that has proved more challenging. “Almost 35% (if not more) of the power available at this level is lost due to wastage” (Arobieke et al, 2012). Therefore the supply voltage from the supply authority is allowed to fluctuate between ± 6% of the declared nominal voltage if under system stress or following system faults (Nigeria Electricity Regulatory Commission, 2007). Any voltage below or above this is termed under-voltage and over-voltage condition respectively.

Voltage fluctuations can be described as repetitive or random variations of the supply voltage envelope due to sudden changes in the real and reactive power drawn by a load or otherwise. The characteristics of voltage fluctuations depend on the load type, size and the power system capacity. There are two important parameters to voltage fluctuations, the frequency of fluctuation and the magnitude of fluctuation. Both of these components are significant in the adverse effects of voltage fluctuations (Robinson et al, 2003). Frequent fluctuation in the public power supply affects the performance of the various appliances and electrical loads that may be connected.

Voltage regulation is required for two distinct purposes: under-voltage and over-voltage conditions. Line voltage regulation is the process of maintaining constant output voltage to industrial and domestic users despite a wide variation in input voltage (Standler, 1989). Under-voltage might result into brownout, distortion or permanent damage while overvoltage in the form of spikes and surges could cause distortion, burn-out, melt-down, fire, electro-pulsing and permanent damage. The two distinct reasons of voltage regulation afore mentioned could be caused by abnormal forces of nature, atmospheric conditions, generator power
surge, power grid defects, power distribution imbalance etc. (McGranaghan et al, 1993; Sarmiento et al, 1996).

In Nigeria, household appliances are constantly under threat of fluctuation in voltage level (high or low voltage supply). This sudden increase or decrease in supply voltage causes these appliances to malfunction or at worse conditions, get damaged. Usually, under-voltage conditions are more prevalent than over-voltage conditions in Nigeria. Some of the causes of the extended or perpetual voltage sags are due to use of underrated cables from substations to homes/industries which result in massive voltage drops at every termination to buildings and industries thereby causing unnecessary loss of power/voltage at customers power distribution point. Most substations have underrated transformers that are lower in rating to what they are supposed to be as most of them were installed several years back when the energy demand of that area was still very low. There is continuous increase in load which is not balanced with continuous adequate upgrading of existing facilities or installation of new ones. Current load demand has overshot the load forecast of most substations (Arobieke et al, 2012).

A survey study by Arobieke et al (2012) in a city in South Western Nigeria revealed that voltages in most of the areas surveyed are between 120V and 175V due to overloading and voltage drop along the distribution networks. Voltage drop of more than 40% is common (Arobieke et al, 2012).

A survey of supply voltage by Oluwole et al (2014) in some selected areas of the city where the author resides which is also in South Western Nigeria revealed that about 30% of consumers receive voltages less than 80V while up to 50% receive less than 120V. Their survey also revealed that almost all the substations studied feed (LV distribution) consumers that are many spans from the substation transformer. Some consumers were being supplied electricity at about 4.5km from the substation, with an average distance of 2.5km for most of the selected areas of study. Average typical supply voltage at ends of sampled areas from the respective substation transformer is about 78V at day time and 65V at night (Oluwole et al, 2014).

Due to the small amount of power being generated in the country and distributed, the electricity distribution companies do often engage in load shedding in order to ration the available power. This often results in long hours of blackout in areas where load is being shed, and few hours of supply. During these few hours of supply, there is low voltage problem. Figure 1(a) shows the usual availability of electricity supply at the author’s home terminal (raining season, 2014) when there is no fault or no maintenance operation being carried out. The figure shows the values of voltage supply for a period of 48 hours. Load shedding is being practiced in the region, and the pattern of the load shedding runs over a period of 48 hours repeatedly. In figure 1, the periods of no supply are the periods of load shedding which is somehow regular on 2-day basis. For the periods of supply, variation in the supply voltage with time at the author’s home terminal can be observed.

Figure 1(b) shows the supply in Figure 1(a) but in which the periods of load shedding in each day have been substituted with the corresponding period of supply in the alternate day, thereby showing what the supply would be over a period of a day if there is no load shedding. Morning and evening periods when there is supply are usually characterised with low voltage. In the morning, people begin to use electricity for various purposes for the day. Also, in the evening, there are many users of electricity at homes after returning back from their various places of work. Maximum voltage drop is usually experienced in the evening (peak load periods), while highest voltage supply is usually experienced in the middle of the night (off-peak periods) when there is supply. The figure is not representative of the situation in most parts of the country, because the pattern may vary from area to area, and from season to season. The situation is becoming worse year by year.

Since the electric power supply/distribution companies simply cannot provide the consistent and stable power demanded by sensitive electronic equipment, therefore the consumers are ultimately responsible for the wealth and safe

![Figure 1: Availability of electricity at the author’s home terminal (a) over a 2-day period with load shedding (raining season, 2014), (b) what the supply in (a) would be over a period of a day if there is no load shedding.](image-url)
operation of their equipment. The electronic appliances are particularly susceptible to catastrophic damage due to power problems. A device to correct these abnormalities is desirable, hence the use of an automatic voltage stabilizer as a protective device to improve the situation. The purpose of automatic voltage stabilizers is to increase the stability of the available A.C. power supply. The function of every A.C. automatic voltage stabilizer is to convert an input A.C. voltage into a specific, stable, output A.C. voltage and maintain that voltage over a wide range of load current and input voltage conditions.

There has been proliferation of different brands of commercial stabilizers in the Nigeria market with hundreds of thousands of stabilizers being imported into the country every year due to the power problem in Nigeria, with capacity ranges from 500VA to over 10kVA for domestic uses. The Nigeria situation is becoming worse every year, with changes in consumers demand which therefore necessitates these manufactures to continue to work more on the operational features of their stabilizers, as well as introducing other voltage stability appliances to the homes. Many of these stabilizers when use in Nigeria, face situations beyond their design limit or specifications which renders them under utilized in Nigeria homes. In Nigeria domestic homes, the practice is generally to connect each sensitive appliance to a low cost stabilizer of such a rating comparable to the rating of the appliance rather than connecting all the loads in the house to an expensive single high capacity stabilizer. Therefore, loads for lighting, heating, and motoring are not usually supplied with stabilizers, but only sensitive appliances or appliances that their use is very important such as electronic appliances, freezers, refrigerators, low power air conditioners, and other low power loads that cannot work with low voltage.

Although there are many automatic voltage stabilizers in the Nigeria market, within the Nigeria context, some are poor in performance and as such, not durable. This is due to their inability to regulate low voltages, knowing that the major power quality problem experienced in most part of Nigeria is that of brown out and voltage sags. Even though voltage surge and spikes also occur, they are occasional and occur for a very short period of time as compared to brown out and voltage sags. About one and half decade ago, statistical data revealed that 22% of stabilizers purchased by consumers were not performing satisfactorily as a result of very low input supply voltage (Ogunlade, 1999). Thus, many commercial stabilizers regulate input voltage that falls within 160V and 260V which has denied some buyers their adequate utilization. Nigeria’s public power supply availability and network has become extremely worsened, so at present, satisfactory performance of the commercial stabilizers can only be best imagined.

This work aims at assessing the output performance of twelve (12) selected brands of commercially available domestic 1kVA Automatic Voltage Stabilizers common in Nigeria that are used for the protection of electrical and electronic equipment. Electromechanical transformer tap-changing with conventional relays are considered. This type is the most common type for commercial purposes due to its low price and simplicity of its circuitry. The quality of a product is a measure of the degree to which it meets the customer’s requirement (ISO 9000, 2005), and in the case of manufactured devices and equipment, it is a combination of the design and accurate function-ability. It is expedient to note that the quality of a product is not defined by the size, appearance or complexity of structure but by its ability to perform the specific function for which it was manufactured. There are different parameters used to measure the quality of a voltage stabilizer but in this work, the qualities of the automatic voltage stabilizers in terms of the line and load regulation were considered.

2. AUTOMATIC ELECTROMECHANICAL TRANSFORMER TAP-CHANGING AC VOLTAGE STABILIZER

The ideal automatic electromechanical transformer tap-changing A.C. voltage stabilizer is a device which uses a switched autotransformer to maintain an A.C. output that is close to the standard mains voltage as possible under conditions of fluctuations. It uses a servomotor (or relays) through negative feedback, to control the position of the tap or wiper to move in the direction (or switching of relays) that reduces the output voltage towards the standard voltage (Patchet, 1954; Boylestad and Nashelsky, 2007; Oluwole, 2014). Automatic voltage stabilizers consist of two units: the sensing unit and the regulating unit. The sensing unit detects changes in the input or output voltage of the stabilizer and produces a signal which the regulating unit reacts to, and acts in such a manner as to correct the output voltage of the stabilizer to, as near as possible, the standard predetermined value (Patchet, 1954; Oluwole, 2014).

The functional block diagram of a stabilizer utilizing electromechanical transformer tap-changing with relays is shown in Figure 2. It makes use of relays connected in series with autotransformer taps.
The function of the autotransformer is to produce the required output voltage with the help of the control unit (Gupta and Lyman, 1980). The voltage variations are accomplished by changing the ratio of transformation automatically (Pansini, 1983). The transformer turns ratio is accordingly varied by selecting one of a fixed number of taps using relays. An accuracy of ±10% can be achieved.

2.1 Line Regulation

One important characterization of an automatic voltage stabilizer is how well it holds the output voltage constant in the face of changing input voltage. This is called the line regulation. Line regulation is characterized by the change in output voltage which results from a change in input voltage from the source of supply divided by the change in input voltage. It is expressed as a percentage.

\[
\text{Line_{reg}} = \frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}} \times 100\%,
\]

(1)

The line regulation error of an ideal automatic voltage stabilizer is 0%. It is expected that an automatic voltage stabilizer will keep the output voltage within a specified minimum.

2.2 Load Regulation

Load regulation is the change in output voltage for a given change in load current. Good load regulation means that the output voltage does not change much with changing load resistance. To characterize the load regulation of a stabilizer, different amount of loads are connected to the stabilizer, and the variation of output voltage is measured. These loads provide the needed resistance to formulate the stabilizer’s load regulation. The load regulation is also expressed as a percentage. The load regulation at a specific load is expressed (in %) as

\[
\text{Load}_{\text{reg}} = \frac{V_{\text{NL}} - V_{\text{L}}}{V_{\text{L}}} \times 100\%,
\]

(2)

where \( V_{\text{NL}} \) is the output voltage with no load, and \( V_{\text{L}} \) is the output voltage with load.

3. MATERIALS AND METHODS

3.1 Materials Used

In the course of carrying out test for the performance of the different brands of the 1kVA automatic voltage stabilizers, several steps were taken as well as precautions in order to increase the accuracy of test results obtained. The materials utilized in the course of carrying out the test are outlined below:

- AC Voltmeters.
- 3kVA Variac.
- Twelve different brands of automatic transformer tap-changing voltage stabilizers.
- 10A (Clamp-on) AC Ammeter.
- Single Phase Wattmeter.
- Load. This consists of five sockets properly assembled on a board and prepared to be connected to a source of electric supply. Connected to each socket is a heating element. Several combinations of heating elements of different wattage were used depending on the load desired.
- 5A AC Switches.
- Wires for connection.
- Testers and Screw drivers.

The various brands of automatic voltage stabilizer tested with their model numbers are arranged in the order shown in Table 1.

### Table 1: Tested Stabilizer Brands

<table>
<thead>
<tr>
<th>S/N</th>
<th>Brands</th>
<th>Model Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Century</td>
<td>CVR-TUB 1000VA</td>
</tr>
<tr>
<td>2</td>
<td>V Masters</td>
<td>AVR-1000VA</td>
</tr>
<tr>
<td>3</td>
<td>Concept</td>
<td>AVR-1000VA</td>
</tr>
<tr>
<td>4</td>
<td>Q-Link</td>
<td>AVR-PRO 1000VA</td>
</tr>
<tr>
<td>5</td>
<td>Binatone</td>
<td>BVR-1000</td>
</tr>
<tr>
<td>6</td>
<td>Moder Gold</td>
<td>MVR-1000</td>
</tr>
<tr>
<td>7</td>
<td>Super Masters</td>
<td>SMR 1098-1000VA</td>
</tr>
<tr>
<td>8</td>
<td>African Masters</td>
<td>SMS-1077</td>
</tr>
<tr>
<td>9</td>
<td>Dura</td>
<td>DV-1000</td>
</tr>
<tr>
<td>10</td>
<td>Volt Plus</td>
<td>PG-5012</td>
</tr>
<tr>
<td>11</td>
<td>Star Lite</td>
<td>AVR-1000VA</td>
</tr>
<tr>
<td>12</td>
<td>PDX</td>
<td>OKS-TUB 1000VA</td>
</tr>
</tbody>
</table>

#### 3.2 Line Regulation

The schematic of the set up for the line regulation test is shown in Figure 3. The terminals of the Variac were connected to the plug of the stabilizer. After the connections had been made, the Variac was plugged in to the source of ac mains supply after which the stabilizer was switched ‘on’ and the readings were taken. The output voltage from the Variac which is the input voltage to the stabilizer was varied and the output voltage from the stabilizer was noted. Measurements were made at input intervals of 5V.

![Figure 3: Schematic of the set up for the Line Regulation Test.](image)

![Figure 4: (a) The Variac that was used (b) Century stabilizer under test.](image)
3.3 Load Regulation

The schematic of the set up for the load regulation test is shown in Figure 5. The plug of the board containing the load was plugged in to the stabilizer through a wattmeter and a clamp ammeter, after which the stabilizer was connected to the source of ac mains supply. Next, the heating elements of different wattage in different combinations depending on the load desired were fixed and the results were noted. The no-load voltage, output voltage of the stabilizer and the power consumed was noted for each load that was connected.

The readings of the output voltage, the input voltage and the power consumed were taken simultaneously. The input mains voltage was not constant throughout the load regulation test for all the stabilizer brands, nevertheless, the no-load voltage, the load voltage and current readings with power consumed were taken concurrently as fast as possible for each load.

4. RESULTS AND DISCUSSION

4.1 Line Regulation

The line regulation of the tested different brands of stabilizers is shown in Figure 6 (a) and (b). Figure 6(a) shows the output voltage against input voltage for Century, V Masters, Concept, Q-link, Binatone and Moder Gold stabilizers, while Figure 6(b) shows the output voltage against input voltage for Super Masters, African Masters, Dura, Volt Plus, Star Lite and PDX stabilizers.

Figure 5: Schematic of the set up for the Load Regulation Test.

Figure 6: (a) Output Voltage against Input Voltage for Century, V Masters, Concept, Q-Link, Binatone and Moder Gold stabilizers.
Figure 6: (b) Output Voltage against Input Voltage for Super Masters, African Masters, Dura, Volt Plus, Star Lite and PDX stabilizers.

It can be observed that some of the brands shut down with input voltage less than 100V, so the average of the output voltage for input voltage range of 100V to 250V was calculated for each brand of stabilizer.

\[ V_{\text{out(average)}} = \frac{V_{100} + V_{105} + V_{110} + \ldots + V_{250}}{31} \]

The average output voltages of the tested brands with their respective standard deviations (S.D) are shown in Figure 7. Super Master stabilizer has the highest S.D followed by PDX stabilizer which has the least average output voltage, while Century stabilizer has the least S.D.

Figure 7: Average output voltage and standard deviation for input voltage range from 100-250V. 1: Century; 2: V Masters; 3: Concept; 4: Q-Link; 5: Binatone; 6: Moder Gold; 7: Super Masters; 8: African Masters; 9: Dura; 10: Volt Plus; 11: Star Lite; 12: PDX.
As indicated that some of the stabilizer brands shut down with input voltage less than 100V; and the voltage at the terminals of many consumers in the country are below 100V throughout the day due to low voltage problems; therefore, Table 2 presents the performance of the stabilizers to input voltage range within 0V and 100V.

### Table 2: Performance within input voltage range of 0V and 100V

<table>
<thead>
<tr>
<th>S/N</th>
<th>Brand</th>
<th>Input Voltage Range (V)</th>
<th>Output Voltage Range (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Century</td>
<td>0 – 30</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30 – 100</td>
<td>60 – 200</td>
</tr>
<tr>
<td>2</td>
<td>V Masters</td>
<td>0 – 100</td>
<td>0 – 213</td>
</tr>
<tr>
<td>3</td>
<td>Concept</td>
<td>0 – 100</td>
<td>0 – 211</td>
</tr>
<tr>
<td>4</td>
<td>Q-Link</td>
<td>0 – 100</td>
<td>0 – 212</td>
</tr>
<tr>
<td>5</td>
<td>Binatone</td>
<td>0 – 85</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85 – 100</td>
<td>168 – 197</td>
</tr>
<tr>
<td>6</td>
<td>Moder Gold</td>
<td>0 – 90</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90 – 100</td>
<td>138 – 153</td>
</tr>
<tr>
<td>7</td>
<td>Super Masters</td>
<td>0 – 100</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>African Masters</td>
<td>0 – 80</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80 – 100</td>
<td>149 – 185</td>
</tr>
<tr>
<td>9</td>
<td>Dura</td>
<td>0 – 75</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75 – 100</td>
<td>150 – 199</td>
</tr>
<tr>
<td>10</td>
<td>Volt Plus</td>
<td>0 – 75</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75 – 100</td>
<td>140 – 186</td>
</tr>
<tr>
<td>11</td>
<td>Star Lite</td>
<td>0 – 95</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95 – 100</td>
<td>146 – 154</td>
</tr>
<tr>
<td>12</td>
<td>PDX</td>
<td>0 – 55</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55 – 95</td>
<td>89 – 150</td>
</tr>
</tbody>
</table>

Table 2 shows that for input voltage less than 100V, the output of many of the stabilizer brands cannot adequately meet the current worsened low voltage situation experienced by many consumers of electricity in Nigeria.

#### 4.2 Load Regulation

The load regulation (in %) was calculated for all the stabilizers when connected to different amount of loads. The bar chart showing the % load regulation of the tested brands of stabilizers at various loads is shown in Figure 8. At output load of 1000W, Concept stabilizer has the minimum load regulation index of 4.52% while Q-Link stabilizer has the highest load regulation index of 9.3%.

![Figure 8: % Load regulation at various loads](image)
Since the load regulation varies at different loads, the rate of increase in load regulation index with load was computed for the stabilizers. Figure 9 shows the variation of load regulation index with load for the selected stabilizers. Figure 9(a) shows the variation for Century, V Masters, Concept, Q-Link, Binatone and Moder Gold stabilizers, while Figure 9(b) shows the variation for Super Masters, African Masters, Dura, Volt Plus, Star Lite and PDX stabilizers.

Within the load range of 200W to 1000W, the load regulation increase per unit load (%/W) for the stabilizers are shown in Figure 10. Q-Link stabilizer has the highest load regulation increase per unit load of 0.0095%/W while Concept stabilizer has the least load regulation increase per unit load of 0.0045%/W.

5. CONCLUSION

‘Quality is better than quantity’ as is generally accepted. The essence of this work is not to tarnish the image of any manufacturer of stabilizer, but rather is to give an assessment of how these stabilizers are able to meet ever-changing operational-features’ demand due to the worsening situation of the country’s power sector every day. In this paper, this was done by carrying out tests for the output performance quality of selected twelve (12) commercial different brands of 1kVA automatic A.C. voltage stabilizers available in the Nigeria market. As a result of the tests and analysis carried out, many of the stabilizers are unable to adequately meet the current worsened low voltage situation experienced by consumers of electricity in Nigeria. Century stabilizer is
recommended to be used in areas where there is high degree of line voltage fluctuations and Concept stabilizer is recommended in situations where varying load will be applied to the stabilizer. Some stabilizer producing companies are beginning to produce specifically for Nigeria those that can regulate input voltage that falls within 90V - 280V, with output voltage range between 180V-250V e.g. TEC Stabilizer by Thermocool Engineering Company.

REFERENCES


