GLOBAL JOURNAL OF ENGINEERING RESEARCH VOL. 2, NO. 1 & 2, 2003: 49 - 58

PERFORMANCE EVALUATION OF AUTOMATIC VOLTAGE REGULATORS

R. UHUMNWANGHO, J. C. OFODU and A. O.IBE

(Received 17 April 2003; Revision accepted 19 June 2003)

ABSTRACT

Performance of various Automatic Voltage Regulators (AVR's) in Nigeria and the causes of their inability to regulate at their set points have been investigated. The result indicates that the imported AVRs fail to give the 220 volts as displayed on the name plate at the specified low set point (such as 100, 120 volts etc.) on no-load and would expectedly perform worse under load. Many of them regulate to 220 volts only when the input is at 180 volts. Many of them gave higher output when the input is high. At the upper set point, they regulate between 220 and 230 volts as output. The AVR (investigated) manufactured in Nigeria is quite better than the imported ones within the tested range, hence should be encouraged and patronized.

KEYWORDS: AVR, Snap action, Variac.

NOMENCLATURE

AVR	Automatic Voltage Regulator
NM	Nigeria manufactured
SWG	Standard Wire Gauge
A,B, to H	AVRs Available in Nigeria
SON	Standard Organization of Nigeria

INTRODUCTION

In this twenty first century, numerous electronics and electrical items such as; washing machine, vacuum cleaners, refrigerator, television, radio, audio-video players etc. are continuously being used both at home, business and industrial areas. These devices are designed to give their best performance at 220/230V power supply. Hence, variations in the stated values tend to reduce the performance of the user equipment and could even result to entire damage of any equipment connected to it. The fluctuations in the AC mains could vary in both directions, sometimes it may go below the required 220/230V, or go higher. Nationally, the power distribution (in Nigeria) is characterized by high-level fluctuations, ± 35%.

Many areas in Nigeria suffer peculiar problems of their transformer being over loaded, thereby distributing very low voltage which is bound to fluctuation. As a result of this, people resort to the use of Automatic voltage regulators to ensure stable voltage for the proper use of their elec. and electrical gadgets. If the voltage in the AC mains fluctuates, this device AVR should be able to provide a stable voltage to any rated equipment connected to it. Automatic voltage regulator is also known as stabilizer, as it stabilizes the power supply voltage. But its so unfortunate that these AVRs do not function to keep the voltage at 220V.

Different manufacturers of AVR have different designed set points (lower and upper limit). These set points are designed for regulation to occur when the input voltage falls within these set points. All the existing AVRs in Nigeria have the same operating principle, though they posses different operating set points. The readily available AVRs in Nigeria include the following: Super master, Binatone, Samlex, Century, Prestige, PDX, Super Nakai, Tanaka, Crown Star, Nulec, Dakai, Q-link, Nippon America, Power Guard, Chrome, Power-Ware, Lion and Sorex.

Many people purchase different types of automatic voltage regulators with the aim of obtaining a stable voltage of 220V, but the output of these AVRs do not conform with the anticipated outputs as displayed on the name plate. It is in line with these problems that this investigation is carried out to evaluate the performance of various imported and made in Nigeria AVRs with the aim to ascertain the causes of their inability to regulate at their set points. A particular power range of 1kVA is the focus and is limited to single phase AVR.

BASIC OPERATING PRINCIPLES OF VOLTAGE REGULATOR

In common principle, automatic voltage regulator is

R. UHUMNWANGHO, Faculty of Engineering, University of Port Harcourt, Port Harcourt, Nigeria
J. C. OFODU, Faculty of Engineering, University of Port Harcourt, Port Harcourt, Nigeria
A. O. IBE, Faculty of Engineering, University of Port Harcourt, Port Harcourt, Nigeria

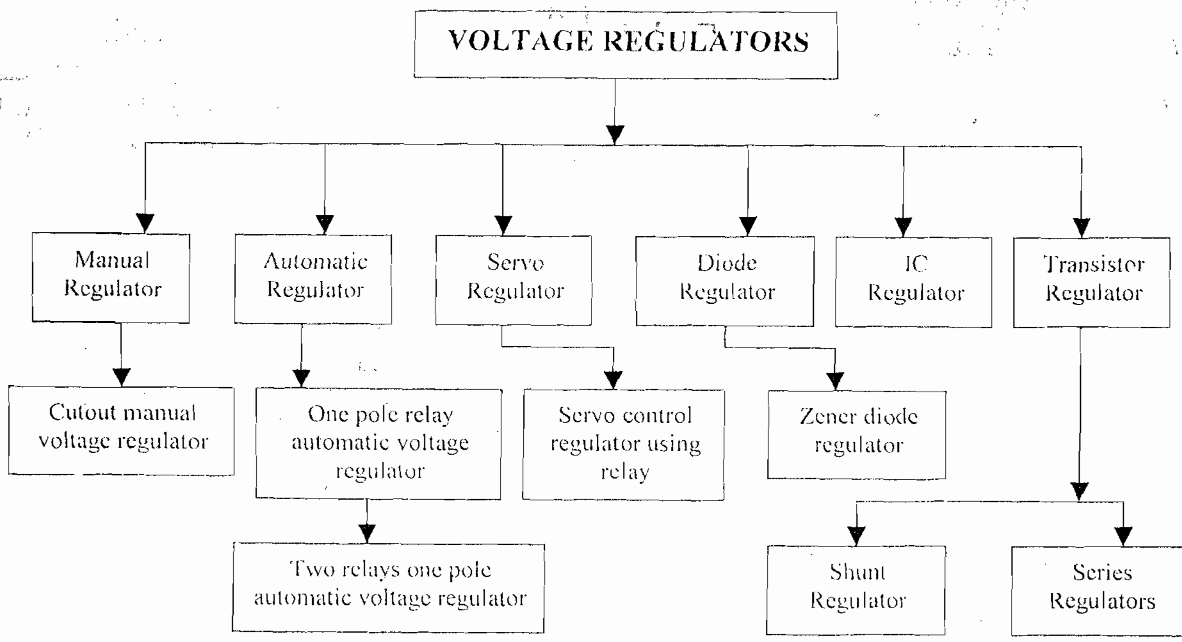

Figure 1: Classifications of Voltage Regulators.

a device used to regulate the input voltage to electrical and electronic appliances so that the user equipment can function effectively without damage. The regulation is done automatically. There exist different types of voltage regulators (VR) and are classified according to their mode of operation ranging from manual, auto-cut to automatic voltage regulators. Others include servor-regulators, shunt VR, integrated circuit voltage regulator (ICVR) etc. Voltage regulator uses various electronic circuits such as comparators, relay drivers or control unit, voltage level sensor, relay chatter control and hysteresis etc, to achieve its function. The various classifications are shown in figure 1. As these electronic circuits operate on low-level dc voltage, a regulated dc supply is also required. Note that the greatest component of the VR remains the autotransformer, (that is, step down and step up wire windings).

METHODOLOGY

As the brand names of the AVRs available in Nigeria differ, so the manufacturers are in different parts of the world. Some are from America, Japan, Korea, China, Taiwan, Malaysia, England, Singapore and Thailand. As a result of this, their degree of performance varies from one manufacturer to the other. In other to properly evaluate the performance of these AVRs (each AVR has been labeled A, B, C, D, E, F, G, or H to protect the manufacturers name) in conjunction with a Nigerian manufactured (NM) one. The values of voltage were varied between 80 – 280 V as input, while observing the output values. To achieve this objective, a device called Variac was used to vary the input voltages. The NM used for this study was originally developed at the Uniport; Science & Engineering workshop in conjunction with Equipment maintenance Centre (The World Bank Project). Other apparatus used are; Voltmeter, Micrometer, Soldering iron, Screw-driver, Lead, Lead sucker, Clamp-on-meter, etc.

A variac is a variable autotransformer, which for any AC supply can give desirable voltage output of up to 300V, depending on the manufacturers design. A Variac is controlled using a knob provided at the top. A dial is used to view the output voltage value. Variac is available in various current ratings such as: 2, 4, 5, 8, 10, 15, 20 Amps etc. The 15 A type was used for the evaluation since the power rating of the AVRs is 1kVA. The output of the Vaviac was connected to the input of the AVR, one at a time, and the output of the AVR was connected to a sensitive digital meter. The Variac voltage served as input into the AVR in question and the corresponding output was monitored with a sensitive meter. To measure the amperage from the AVR, the output cables of the AVR, and the corresponding result is obtained from the dial on the meter.

The next stage involved the measurement of the standard wire gauge (SWG) used in the autotransformer windings. This was achieved by

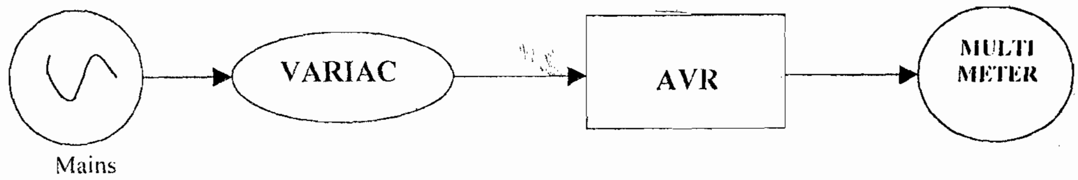

Figure 2: Line diagram of the experimental set up

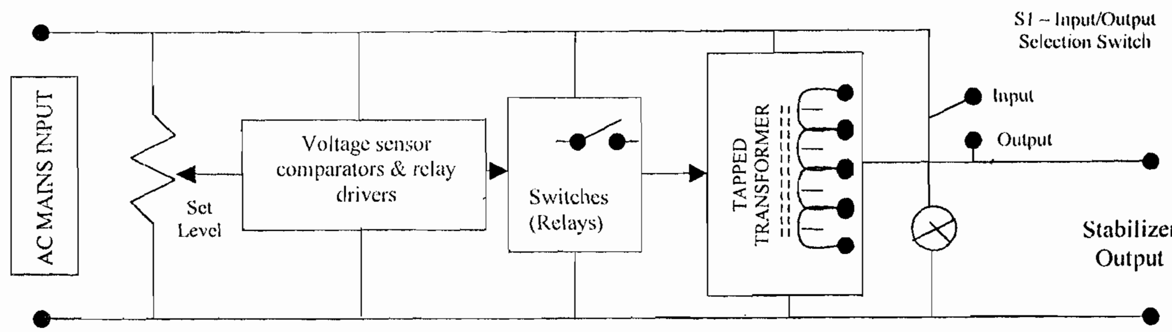

Figure 3: Block diagram of automatic voltage regulator (Source: Slack, 1978).

using soldering iron and lead sucker to desolder the trapping from the circuit. After desoldering, cable stripper was used to strip the coating of the copper wire used for the autotransformer winding. Care was taken not to scrape the copper itself as this may give false result. Then a micrometer gauge was used to determine the diameter of the copper cable used. The gauge number of value obtained was checked in a standard wire gauge table to know the corresponding wire gauge, (Wolf, 1982). Line diagram showing the position of key devices used in the investigation is shown in figure 2, while figure 3 shows the block diagram of an automatic voltage regulator.

CAUSES OF THE FAILURES OF THE IMPORTED AVRs AND THEIR REMEDIES

The major causes of the AVRs not giving their rated output when subjected to this evaluation includes design factor and use of substandard materials. The actual design input voltage differs from the one written on the name plate of the AVRs. Most of them deliver 100 percent power output when the input voltage varies between 180 to 250 volts. The wire gauge for the autotransformer winding is substandard and some of the autotransformers are of lower ratings. Most foreign manufacturers do not take into consideration the fluctuation level of available voltage (± 35%). Above all, the continuos relay chattering when the stabilizer is switched on could be avoided if the rectifier diodes are provided with proper relay driver and chatter with hysteresis.

Finally, to remedy some of the faults, snap action should be incorporated, that is, the design of the transistorized relay driver circuit should be done in a way that whatever be the speed, at which the voltage at the base of the transistor changes, the voltage at the collector of the transistor should always change very rapidly. This keeps the transistor cool and saves it from getting damaged due to overheating.

RESULTS AND DISCUSSION

When the imported AVRs where tested with Variac at different input voltages, the results obtained indicate that they fail to give the output voltage of 220 volts as displayed on the name plate at the specified low set point (such as 100, 120 volts etc.) on no-load. Many of them regulate to 220 volts only when the input is at 180 volts. A lot of them gave higher output when the input is high. At the upper set point (such as 240, 250V), they regulate between 220 and 230 volts as output.

When clamp-on-meter was connected, many did not give the correct current rating which will give their rated values of power. Clamp-on-meter was used to eliminate the problem of power factor from any load that might be used for the evaluation. Tables 1, 2, 3, 4, 5, 6, 7, 8, 9, show the result of the experiment from different AVRs (A, B, C, D, E, F, G, H, and NM) respectively. While table 10 shows the standard wire gauge (swg) for the AVRs.

It was observed that AVR C has three reference

Table 1: AVR (A), Rated power = 1kVA, Rated input voltage = 100 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	10.40	10.20	78.0	78.5	78.25	806.0
100	5.01	4.90	164.0	164.3	164.15	813.3
120	4.6	4.64	180.0	179.5	179.75	830.4
140	4.3	4.28	200.0	201.0	200.50	860.1
160	4.13	4.15	215.0	214.8	214.90	889.7
180	4.08	4.10	220.0	219.5	219.75	898.8
200	3.90	3.90	220.0	220.0	220.00	858.0
220	3.90	3.90	220.0	220.0	220.00	858.0
240	3.72	3.69	228.0	229.4	228.70	847.3
260	3.65	3.65	230.0	230.0	230.00	839.5

Table 2: AVR (B), Rated power = 1kVA, Rated input voltage = 100 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	8.20	8.40	115.00	110.00	112.50	933.8
100	7.90	7.85	120.00	120.80	120.40	948.2
110	6.70	6.50	145.00	146.20	145.60	961.0
120	6.00	6.20	160.00	15.00	159.50	973.0
140	4.80	4.70	195.00	197.00	196.00	931.0
160	4.60	4.50	200.00	201.50	200.50	912.3
180	4.40	4.46	215.00	210.00	212.50	941.4
200	4.30	4.25	219.50	220.00	219.75	939.4
220	4.21	4.21	220.00	220.00	220.00	926.2
240	4.21	4.21	220.00	220.00	220.00	926.2
260	4.15	4.00	222.00	224.00	223.00	908.7

Table 3: AVR (C), Rated power = 1kVA, Rated input voltage = 100 – 280V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	8.40	8.20	110.00	115.00	112.50	933.8
090	6.81	6.86	130.00	129.00	129.50	885.1
100	5.35	5.30	150.00	150.50	150.25	800.1
110	4.50	4.56	180.00	178.00	179.50	813.1
120	4.40	4.38	184.00	185.00	184.50	810.0
130	4.35	4.36	190.00	189.00	189.50	825.3
140	4.27	4.25	198.00	199.00	198.50	845.6
150	4.23	4.23	200.00	200.00	200.00	846.0
160	4.20	4.21	205.00	204.00	204.50	859.9
170	4.10	4.10	210.00	210.00	210.00	861.0
180	4.06	4.02	218.00	219.00	218.50	882.7
190	4.06	4.06	220.00	220.00	220.00	893.2
200	3.90	3.85	220.00	222.00	221.00	856.4
220	3.81	3.81	220.00	220.00	220.00	838.2
260	3.65	3.67	224.00	223.60	223.50	818.0
280	3.56	3.50	230.00	231.00	230.50	813.7

potentiometer for setting the reference voltage and still has two different direct current voltages of 24V dc and 12V dc for relay drivers and comparator circuit, likewise AVRs F and H. AVRs D and H lacked snap action and the relay chatters, and these made the performances fall below expectation.

The over riding results of this investigation are shown in figures 4, 5, 6, 7, 8, 9, 10, 11, 12, that is, plots of the input voltage against the output voltage as obtained from the AVRs. It was also observed that the regulatory set point of the Nigeria manufactured (NM) AVR is lower than the imported ones due to the fact that a fluctuation of ± 35% is taken into consideration.

In Nigeria, the secondary distribution system (i.e. the consumer end) is characterized by low voltage due to overloading of the transformer at the various substations. In most places, the voltage is so low that it cannot power any load or appliance connected to automatic voltage regulator. This is why the manufacturer of the Nigeria made ones emphasize mainly on the lower set point by bringing it down to 80V so as to take care of any low voltage emanating from NEPA distribution. The advantage of the Nigerian product is that it regulates from 80Vto 260V.

Table 4: AVR (D), Rated power = 1kVA, Rated input voltage = 160 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	7.10	7.12	125.00.	120.00	122.50	871.0
090	6.40	6.20	140.00	145.00	142.50	897.8
100	5.60	5.68	160.00	159.00	159.50	899.6
120	4.80	4.72	180.00	182.00	181.00	861.6
130	4.30	4.20	189.00	190.00	189.50	805.4
140	4.00	4.00	201.00	201.00	201.00	804.0
160	3.80	3.85	220.00	218.00	219.00	837.7
180	3.80	3.80	220.00	220.00	220.00	836.0
200	3.80	3.80	220.00	220.00	220.00	836.0
220	3.50	3.46	230.00	232.00	231.00	803.9
240	3.40	3.42	238.00	235.00	236.50	806.5
260	3.20	3.20	240.00	240.00	240.00	768.0

Table 5: AVR (E), Rated power = 1kVA, Rated input voltage = 100 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	7.50	7.42	110.00	115.00	112.50	839.3
100	5.40	5.40	150.00	149.00	149.50	807.3
120	4.60	4.58	190.00	192.00	191.00	876.7
140	4.40	4.40	200.00	200.00	200.00	880.0
160	4.20	4.25	210.00	209.00	209.50	885.1
180	4.00	4.00	220.00	220.00	220.00	880.0
200	4.00	4.91	220.00	221.00	220.50	982.3
240	3.80	3.78	222.00	222.04	222.02	841.5
260	3.70	3.70	225.00	225.00	225.00	832.5

Table 6: AVR (F), Rated power = 1kVA, Rated input voltage = 100 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	7.80	7.70	120.00	119.00	119.50	926.1
100	6.00	6.10	150.00	149.00	149.50	904.5
120	5.10	5.10	190.00	190.00	190.00	969.0
140	4.80	4.75	200.00	201.00	200.50	957.4
160	4.50	4.48	210.00	211.00	210.50	945.1
180	4.30	4.30	220.00	220.00	220.00	946.0
200	4.30	4.30	220.00	220.00	220.00	946.0
220	4.30	4.35	220.00	221.00	220.50	953.7
240	4.10	4.15	224.00	223.00	223.50	921.9
260	4.05	4.00	229.00	230.00	229.50	923.7

Table 7: AVR (G), Rated power = 1kVA, Rated input voltage = 100 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	9.84	9.82	110.00	111.00	110.50	1086.2
100	9.43	9.44	150.00	149.00	149.50	1410.5
120	4.61	4.60	180.00	181.00	180.50	831.2
140	4.56	4.56	189.00	189.00	189.00	861.8
160	4.30	4.20	195.00	196.00	195.50	830.9
180	4.06	4.08	205.00	204.00	204.50	832.3
200	4.00	4.00	220.00	220.00	220.00	880.0
220	4.00	4.00	220.00	220.00	220.00	880.0
240	3.90	3.80	228.00	230.00	229.00	881.7
260	3.75	3.70	235.00	236.00	235.50	877.2

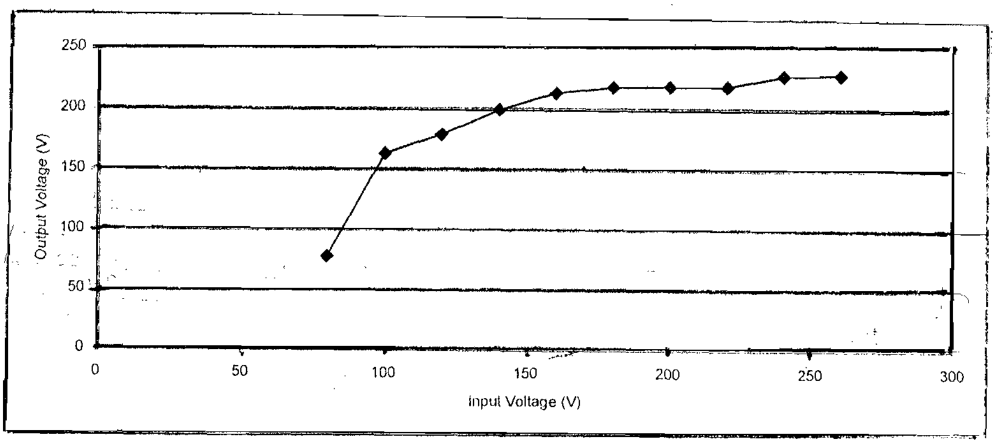

Figure 4: Plots of input against output voltages of the AVR (A) at no load condition

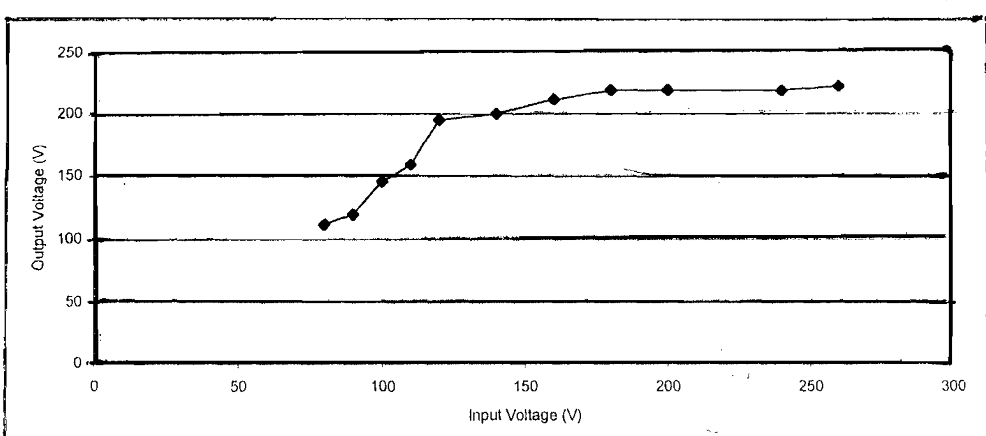

Figure 5: Plots of input against output voltages of the AVR (B) at no load condition

It can be seen from the plot that the NM AVR gave a straight line graph between 110 and 260V showing that the output is a constant value unlike the imported ones. The most important aspect of the Nigeria produced AVR is the exact standard wire gauge (swg) used in the transformer winding. The wire diameter used (from micrometer) is 1.6256mm which corresponds to a 16 SWG. This type of wire can withstand any load in the range of 1kVA(1000VA) and the transformer will not experience overheating. Values of the actual power (average) feasible with the AVRs are shown in a bar chart of figure 13 as against the rated values. Also more tapings were made so as to have wider range of voltage regulation.

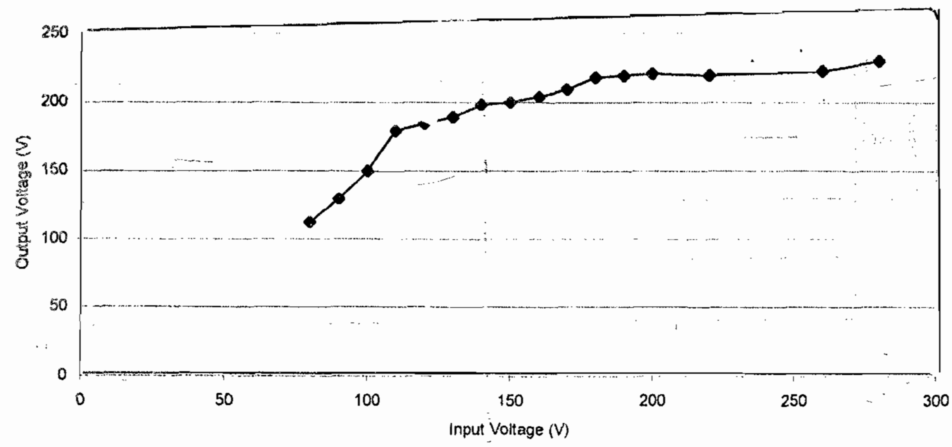

Figure 6: Plots of input against output voltages of the AVR (C) at no load condition

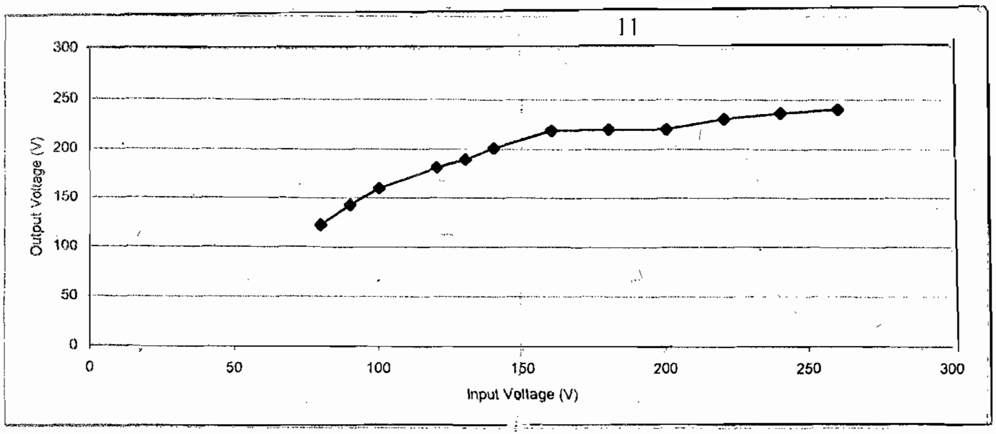

Figure 7: Plots of input against output voltages of the AVR (D) at no load condition

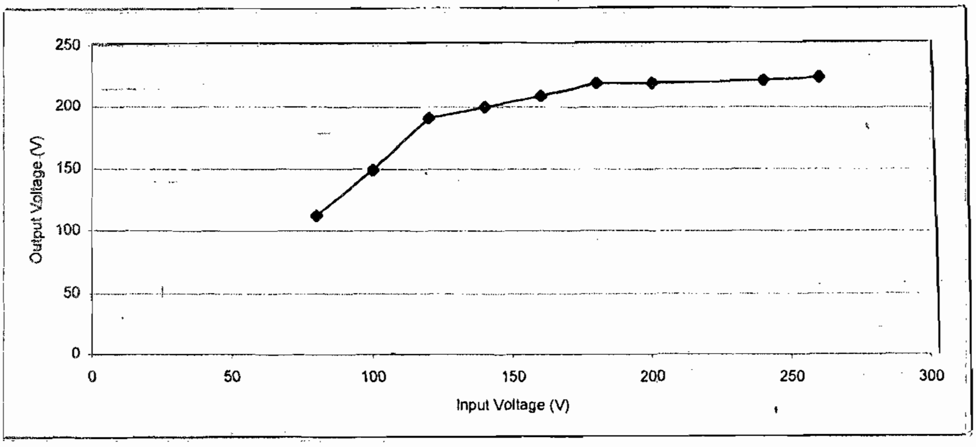

Figure 8: Plots of input against output voltages of the AVR (E) at no load condition

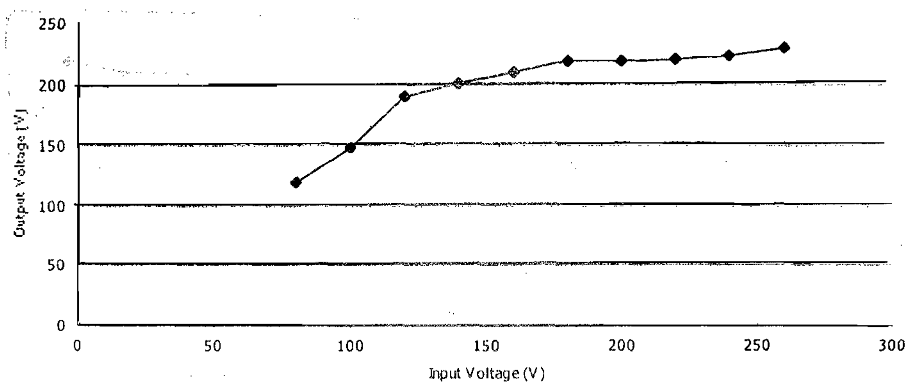

Figure 9: Plots of input against output voltages of the AVR (F) at no load condition

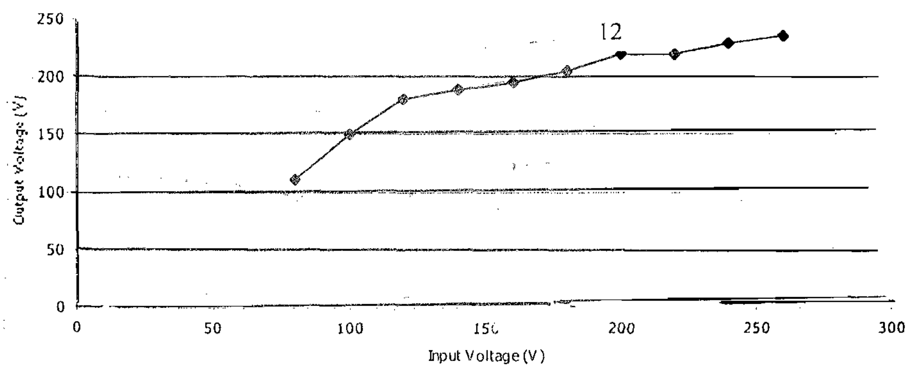

Figure 10: Plots of input against output voltages of the AVR (G) at no load condition

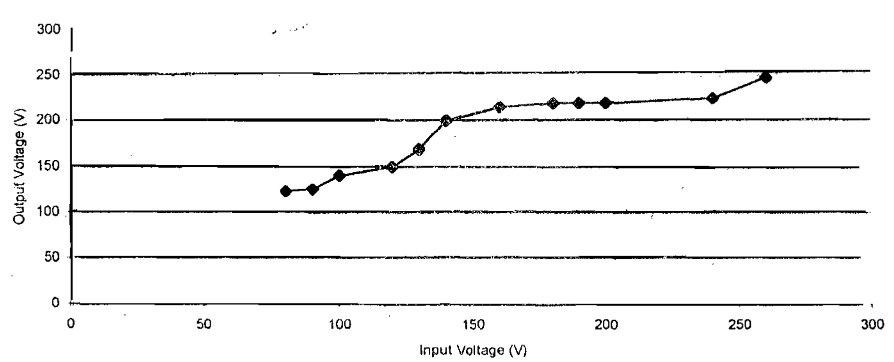

Figure 11: Plots of input against output voltages of the AVR (H) at no load condition

CONCLUSION AND RECOMMENDATION

From the experiment and analysis made, it can be seen that almost all the foreign Automatic voltage regulators posses the same low performance curve. The problem is as a result of over zealousness of the importers to make huge profit to the detriment of the end users. The manufacturers having known that Nigeria is a developing country, have the misconception that Nigerians will not be able to analyze their product if it actually suits the type of fluctuation in Nigeria, so as a result, they tend not to worry about output result of their product.

A critical look at the graph of the locally made one shows that its performance is quite better than the imported ones. But because the local manufacturers are not being encouraged by the government and not patronized by Nigerians, they

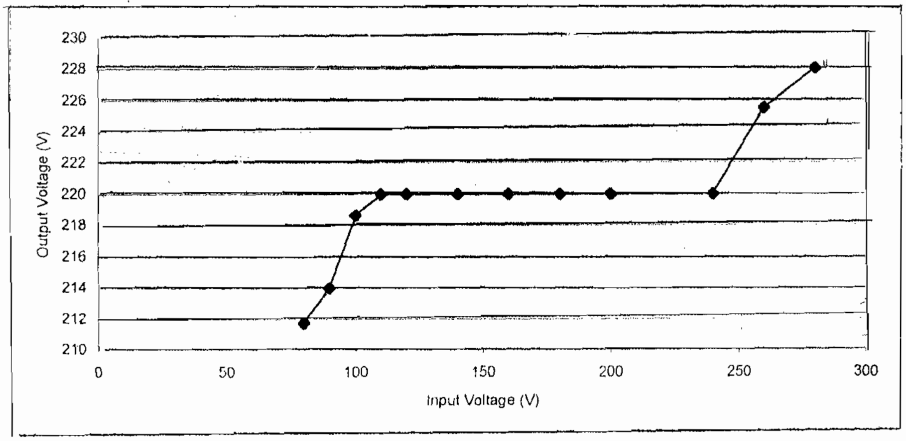

Figure 12: Plots of input against output voltages of the AVR (NM) at no load condition

Table 8: AVR (H), Rated power = 1kVA, Rated input voltage = 140 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	7.40	7.48	125.00	122.00	123.50	925.0
090	6.91	6.91	126.00	126.00	126.00	870.7
100	6.35	6.30	140.00	141.00	140.50	888.7
120	5.80	5.78	150.00	150.50	150.25	869.9
130	5.18	5.20	170.00	169.00	169.50	879.7
140	4.30	4.28	200.00	201.00	200.50	860.1
160	4.08	4.06	215.00	216.00	215.50	877.1
180	3.94	3.94	220.00	220.00	220.00	866.8
190	3.94	3.94	220.00	220.00	220.00	866.8
200	3.94	3.94	220.00	220.00	220.00	866.8
240	3.76	3.70	225.00	226.00	225.50	841.1
260	3.63	3.65	250.00	248.00	249.00	906.4

Table 9: AVR (NM), Rated power = 1kVA, Rated input voltage = 80 – 260V, Rated output voltage = 220V

Input voltage (V)	Clamp-on meter reading (Amp)		Output voltage (V)		Average output voltage (V)	Power (VA)
	1st Run	2nd Run	1st Run	2nd Run		
080	4.69	4.68	211.50	212.00	211.75	992.0
090	4.65	4.65	214.00	214.00	214.00	995.1
100	4.58	4.60	218.80	218.50	218.65	1003.6
110	4.50	4.50	220.00	220.00	220.00	990.0
120	4.50	4.50	220.00	220.00	220.00	990.0
140	4.50	4.50	220.00	220.00	220.00	990.0
160	4.50	4.50	220.00	220.00	220.00	990.0
180	4.50	4.50	220.00	220.00	220.00	990.0
200	4.50	4.50	220.00	220.00	220.00	990.0
240	4.50	4.50	220.00	220.00	220.00	990.0
260	4.38	4.36	225.00	226.00	225.50	985.4
280	4.35	4.35	228.00	228.00	228.00	991.8

Table 10: The Standard wire gauge of the AVRs 13

S/N	AVRs	DIAMETER (MM)	SWG
1	A	0.052	17. ½
2	B	0.9659	19. ½
3	C	1.2192	18
4	D	0.9144	20
5	E	0.8636	20. ½
6	F	1.2192	18

tend to relax in their effort. Also, there is the habit among consumers once a product is written made in Nigeria, it will not perform well compared with foreign ones. Because of this attitude, local manufacturers are discouraged.

I recommend that Government should set up technical body whose sole aim will be to make sure that the gadgets imported into the country are tested and conform to technical standards. This technical body will liaise with the Standards Organization of Nigeria (SON), on an advisory capacity. This should apply not only to regulators but also to other items in general. Also, importers of AVRs should give their foreign manufacturers a clear picture of the level of fluctuation in Nigeria so that the designs will satisfy local requirements They should ensure that the manufacturers give the exact rating of their designs.

ACKNOWLEDGEMENT

The authors acknowledge the help rendered by the Staff of Exclusive Technology for the opportunity to carry out the experiment in their workshop and various suggestions and inputs made by some members of the academic staff of Faculty of Engineering, University of Port Harcourt.

REFERENCES

Olubiwe, M., 2002. Performance Evaluation of Different types of Automatic Voltage Regulators In Nigeria. A University of Port Harcourt M.Eng Report, Department of Electrical and Electronics Engineering. Nigeria.

Slack, W. F., 1978. Design and implementation of Automatic Voltage Regulators, fourth edition, Reinhold, New York.

Wolf. S., 1982. Electronic Measurements and Laboratory Practice, Fourth Edition, Prentice-Hall Electrical Engineering Series