A 1000VA VOLTAGE STABILISER WITH DELAYED-RESTART

By

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ABSTRACT

A domestic voltage stabiliser with delayed re-start capability was designed, implemented and tested. The system was built around an autotransformer having six output tapings. Reliable tap changing for voltage stabilisation was effected using a digital logic controller, interfaced to mechanical relays. Specific features of the stabilser include the ability for the user to program the time that should elapse, after a voltage transient, before the stabiliser can restart; and the over-voltage and under-voltage protection circuits which operate at the extremities of 250V and 140V respectively. Experimentation with the voltage stabilizer showed that, for input voltages in the range 160V - 250V, the output of the stabiliser varied within tolerances recommended by IEE regulations. Furthermore, 'restart' of the stabiliser could be delayed for up to 15 minutes.

1.0 INTRODUCTION

Electrical energy has emerged as a most important source of energy. These days, comfort at home depends largely on the reliable availability of electricity. In third world countries like Nigeria, with high population growth rates and low-level power generation technologies, it often becomes impossible to attain the power supply reliability levels accepted internationally. Literature dealing with the reliability of power generation and supply in Nigeria include [1-3]: in summary, power distribution and generation are well challenged, and of low reliability and quality; voltage profiles are poor and transient dips in the profile of the supply voltage are very common.

To respond to the unsatisfactory voltage profiles delivered to the domestic consumer, the Nigerian local market is well supplied with various brands of stabilisers, capable of improving the voltage profile for domestic appliances. However, what motivated these authors to undertaking this work is the fact that, most of the stabilsers available on the local market do not afford acceptable levels of protection to appliances at home under large transient dips or pikes in the supply voltage. For large transient changes in the mains supply voltage, there results large $\frac{dV}{dt}$ values. For domestic capacitive loads such as radios or musical systems, such values may result in very high transient device current

$i = C\dfrac{dV}{dt}$ (C: effective capacitance of device). In large transient voltage changes, the resulting current flow may exceed the safe current limits for the equipment, resulting in partial or complete failure. In inductive appliances such as fridges, blenders, juice extractors, coffee makers, mixers, etc, a large transient voltage change results in a large "in-rush" of device current given by $\dfrac{d^2i}{dt^2} = \dfrac{1}{L}\dfrac{dV}{dt}$ (L: effective load inductance); If the effect lasts for any significant length of time (especially at slip numbers for a device that has been operating near its rated speed) the current "in-rush" into the device could lead to the failure of the device. From both the experience of the first author at the facilities of the water utility in Katsina State and the subsequent investigations leading up to the design presented in this paper, the above scenario plays out repeatedly, especially for inductive devices. In the light of the proceeding, there exists in Nigeria the need for stabilisers for home appliances with the dual capabilities of voltage regulation and device current disruption after a major voltage transient. Such stabilisers with the dual functions of voltage regulation and current disruption during a large transient are not common on the local market. The current paper reports indigenous effort at realizing this device locally.

2. SYSTEM DESIGN

The stabilizer system is made-up of four sub-units: the autotransformer, the power supply unit, control unit (consisting of the automatic tap selector and timing circuit for restarting the stabiliser after a transient) and the switching circuit. The design procedure, calculations and subsequent implementation of the sub-units of the voltage stabilizer are presented in the sequel.

2.1 Autotransformer design

The autotransformer has six output tapings. See Figure 1. An additional taping used for the supply of the d.c. power unit is not shown in the referred figure. As the mains voltage varies, the load is switched from one tapping of the autotransformer to another so as to maintain the load voltage within the ±6% requirement. The taping to be selected for a corresponding magnitude of the mains voltage can be confirmed from Table 1 [4]. It is important to mention here that the auto-transformer used in this project was designed and produced in the course of the project.

Mains voltage (V)	249-235	234-220	219-205
Transformer tapping selected	6	5	4
Mains voltage (V)	204-190	189-175	174-160
Transformer tapping selected	3	2	1

Table 1: Mains voltage ranges for switching from one transformer taping to another.

2.2 Design of the d.c. power supply unit

Two voltage levels (12V and 5V) were required for the operation of logic circuits and mechanical relays. The system consists of a bridge rectifier, a 3,930μF capacitor for ripple filtering and two voltage regulators ICs (the 7805 for 5 V and the 7812 for 12V), see Figure 2.

2.3 Automatic tap selector

The circuit for selecting which taping of the autotransformer (the automatic tap selector) to connect to the load uses a Flash ADC, a 3 - line to 8 - line encoder (74138) and Hex inverter. In the design, the monitor voltage is tapped from the psu output of the autotransformer, rectified, and then scaled by a potentiometer (R_1 and R_2). Thus the monitor voltage varies proportionally to the input from the mains. The series of voltage divider networks at the positive inputs of the comparators use the 5V supply to set appropriate reference voltages to the comparators. The values of the reference voltages are set such that a comparator switches state for the following mains voltages: 140V, 1 70V, 1 87V, 2 04V, 2 19V, 2 34V and 260V. The fixed reference voltages from the divider networks, for each of the switching points are shown in Table 2. By sampling the outputs from the comparators, the priority encoder generates a code which the decoder uses to determine which switching circuit must be energized to connect the load to the appropriate transformer tapping for the prevailing level of the mains voltage. The complete design is shown in Figure 3.

Mains Voltage (V)	160	170	187	204	219	234	250
D.C reference voltage (V)	1.92	2.04	2.24	2.45	2.63	2.81	3.0

Table 2: Reference levels for the automatic switching circuit

2.4 Variable 'ON' delay timer

This circuit enables the user to program some delay into the re-starting of the stabilizer after a voltage transient. It disables the tap selector by sending a low level signal to pin 6 of the decoder (74138) for a user-specified period; when the period is over, the transition to high level of the timer output enables the tap selector so that it can select the appropriate output of the stabilizer to be connected to the load, for the prevailing mains voltage level.

Table 3: Performance-characterisation of the d.c. power unit

Regulator Type	No–load voltage (V)	Full – load voltage (V)	Percentage Regulation (%)
7805	4.98	4.978	0.04
7812	11.89	11.888	0.017

2.5 Switching circuit design

The switching circuit is shown in Figure 4; it connects the load to the particular transformer taping which has been selected by the tap selecting circuit. Si of these were used.

2.6 Complete stabiliser circuit

The circuit of the complete stabilizer is shown in Figure 5.

3. RESULTS PRESENTATION AND DISCUSSION

3.1 Load regulation test for the transformer

The load test of the auto-transformer yielded the following performance:

Output regulation = 0.89%

Input regulation = 0.52%

These figures how that the autotransformer has good load regulation.

3.2 D.C power supply test

The voltages of the d.c regulators were measured, both at no - load and then, at full load. The results are shown in Table 3.

3.3 Reference levels for automatic switching circuit

Accurate reference voltages to the switching circuit are necessary for the reliable operation of the tap selector circuit. For several values of the mains voltage, the reference voltages of the tap selector circuit were measured. The results showed that all reference voltages were within 2.6% of designed values. Consequently, the reliable performance of the switching circuit was expected.

3.4 Test of circuit for delaying the re-start of the stabilizer

Using the re-start circuit, it was possible to program delays between 20 seconds and 15 minutes.

3.5 Performance of voltage stabilization function

The results from this test are shown in Figure 6. These results shows that the stabiliser adequately regulates, maintaining its output voltage within the range of 226V to 240V for the mains voltage variation between 160V to 250V. Note from Figure 6, the sharp fall in the output voltage of the stabilizer for input voltages less than 140V as well as for those above 250V. The stabilizer was designed to shut down once the mains voltage variation exceeded these limits. It is thus evident from the results that the "shut-down" function is being properly performed in the circuit. The load voltage regulation achieved by the stabilizer is consistent with levels required by IEE regulations.

4. Conclusion

The design of the stabilizer was implemented and found to work with the following specifications:

Input voltage range, 140V to 250V(ac); Output voltage range, 226 to 240 (ac); Rated output power, 1000VA; Percentage load regulation, 0.89%; Range of programmable delay: 20 sec to 15 minutes.

The design is simple and could be easily reproduced locally. For further development, we intend to fabricate the autotransformer from scrapped compressor parts; a raw material common in most Nigerian cities.

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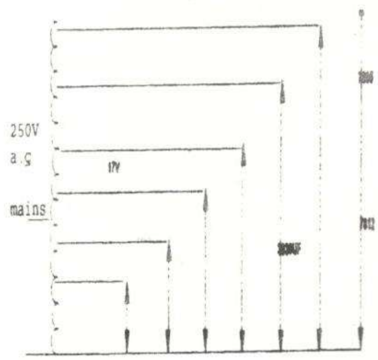

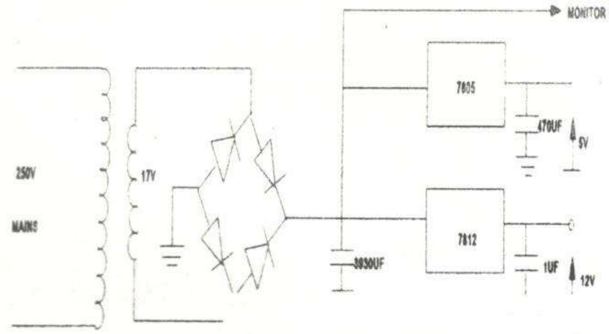

Figure1 : Auto-transformer circuit

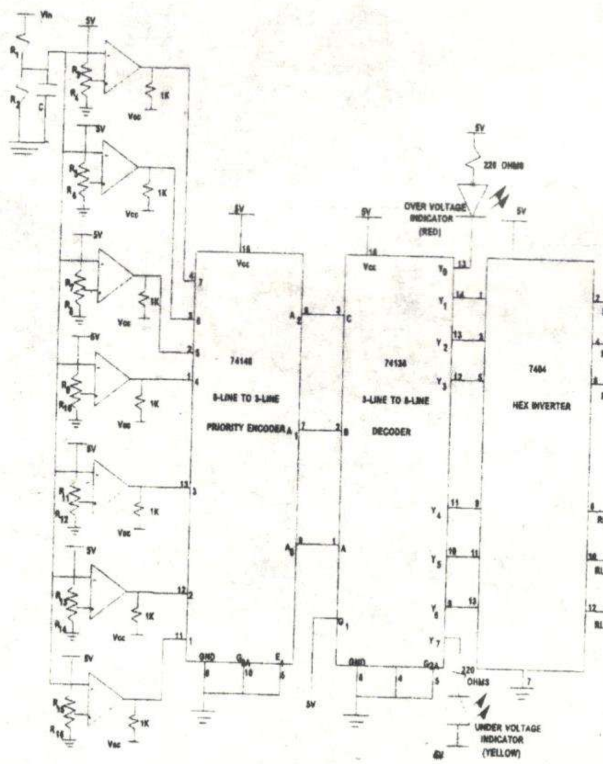

Figure 3: Automatic tap selector circuit

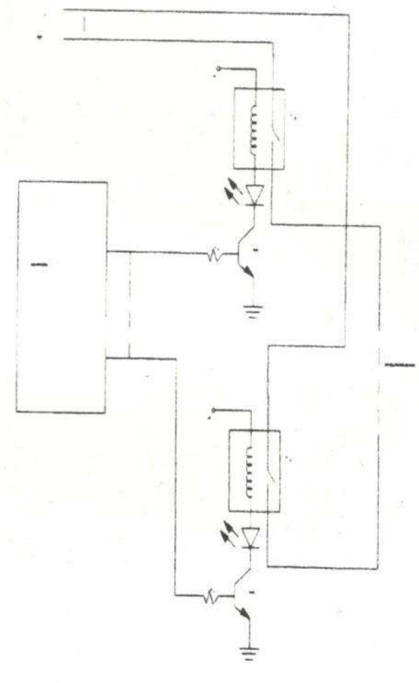

Figure 4: Switching circuit

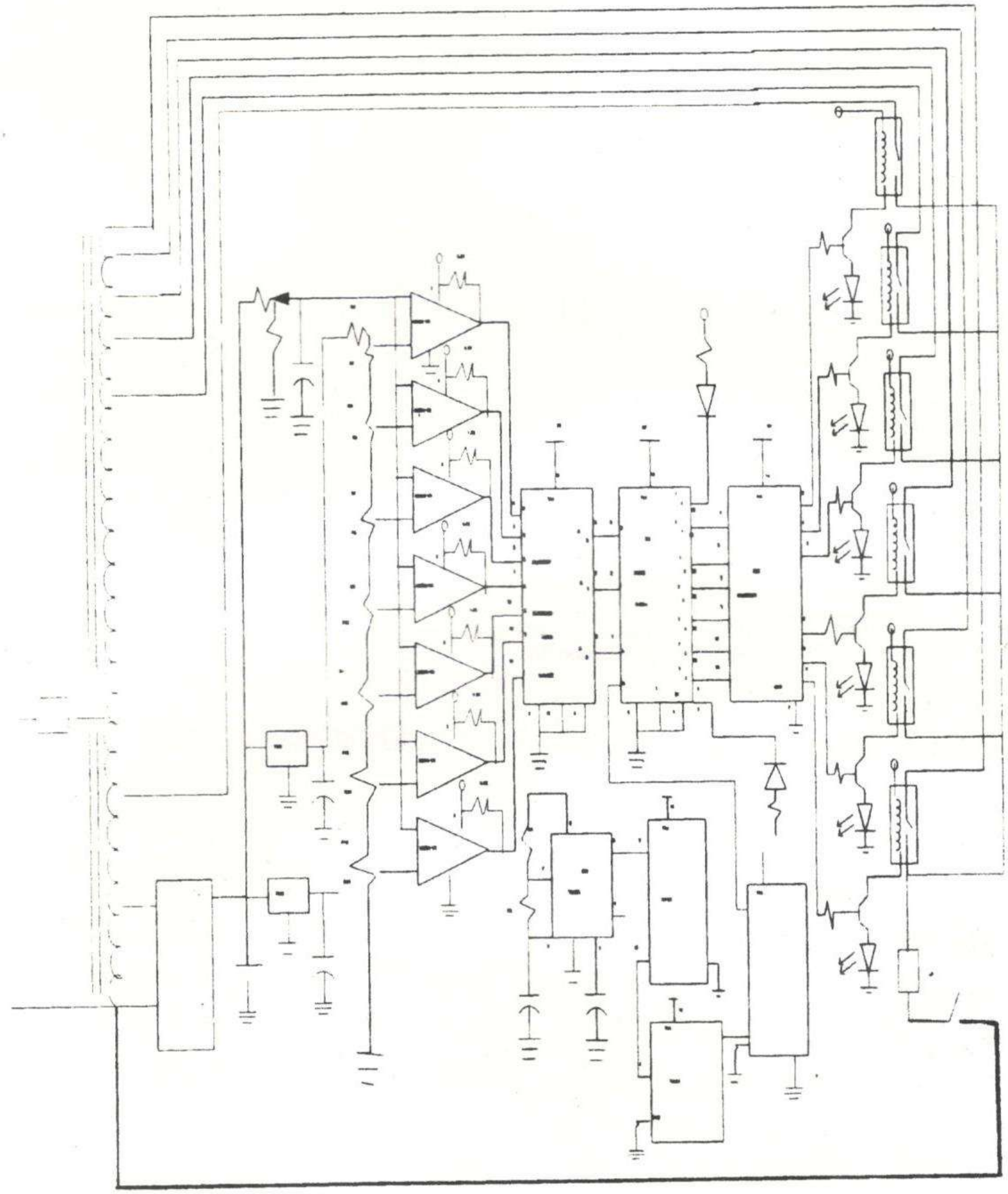

Figure 5: **Complete stabiliser circuit**

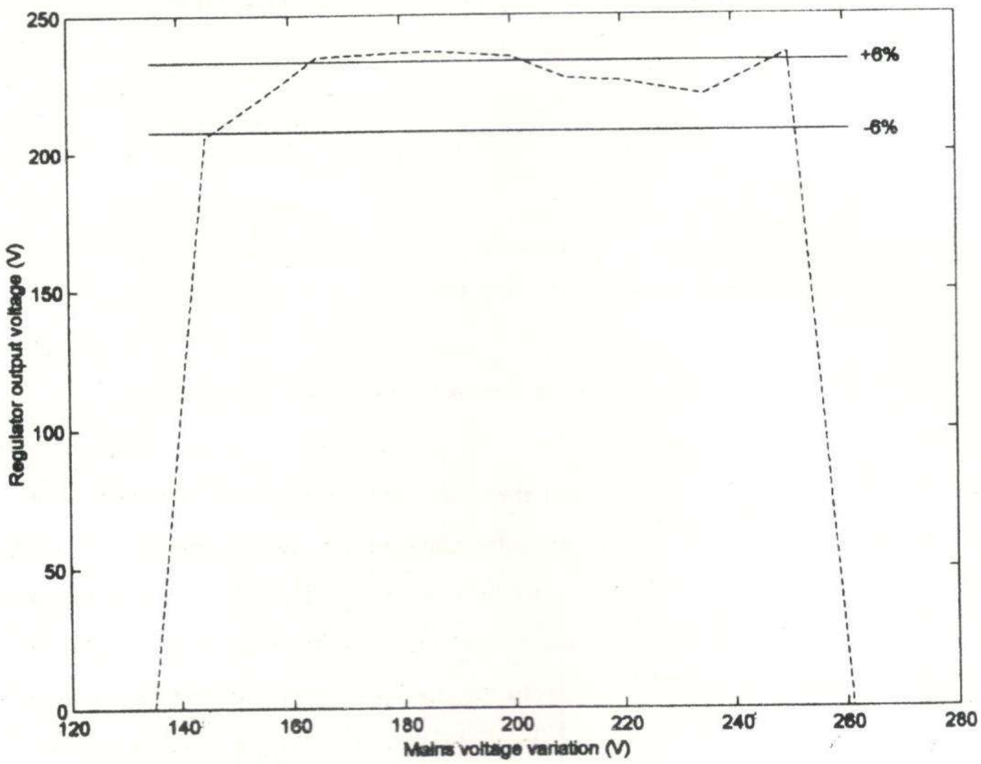

Figure 6: **Load voltage regulation as a function of mains voltage variation**