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Prototyping a 1 kVA Voltage Regulation Power Stabilizer Using Capacitors Bridge Cascade Model

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Keywords

Capacitor Bridge Cascade Model
Power fluctuation
Voltage regulation

Abstract

Voltage instability in domestic electricity supplies can adversely affect the performance and reliability of household appliances and sensitive electronic equipment. This study presents the design and experimental evaluation of a 1 kVA voltage stabilizer based on a capacitor bridge cascade model (CBCM) for improved household voltage regulation. Questionnaire data collected from Dar es Salaam and Coast regions were analyzed to identify challenges associated with existing voltage stabilizers and inform the design requirements. The proposed CBCM uses 1000 µF, 35 V capacitors arranged in series-parallel bridge configurations to regulate an input voltage range of 160–250 VAC toward a nominal output of 230 VAC. The design was simulated using NI Multisim and implemented as a laboratory prototype at the Power Systems Laboratory, College of Engineering and Technology, University of Dar es Salaam. Experimental validation was conducted under both no-load and varying-load conditions of 250, 500, 750, and 1000 VA, while the input voltage was varied from 160 to 250 VAC at 50 Hz. The results showed that the output voltage decreased gradually from 230.0 VAC at no load to 227.5 VAC at the rated 1 kVA load, corresponding to a maximum load-induced voltage drop of 2.5 VAC and a regulation error of 1.09%. The findings demonstrate that CBCM maintains stable output voltage under varying supply and load conditions, indicating its potential for domestic voltage regulation and appliance protection.

1. Introduction

Voltage instability remains a persistent issue in many developing regions, particularly in residential settings and low-power applications. Despite the availability of various voltage stabilizer technologies, end-users with modest power requirements—typically around 1 kVA—continue to experience significant power fluctuation issues. When these stabilizers fail to maintain a regulated output voltage, connected appliances are exposed to harmful voltage levels, increasing the risk of malfunction or permanent damage [1, 2].

In Tanzania, where grid reliability is frequently compromised, such challenges are well documented. The 2015 National Energy Policy recognizes energy as a critical enabler of socio-economic development and emphasizes the need for affordable, accessible, and reliable electricity services [3]. However, real-world conditions, such as frequent lightning storms, grid switching, and transmission limitations, often cause voltage fluctuations that disrupt supply stability, leading to noticeable power fluctuations [4]. As a result, many households rely on voltage stabilizers to protect sensitive appliances operating at 230 V or 400 V.

Several voltage-stabilization technologies are commercially available, including electromechanical regulators [5], servomotor-based systems, static electronic regulators [6-8]and relay-based switching mechanisms [9-11]. Although these systems can provide effective voltage regulation, those employing moving components may have slower response times, mechanical wear, and higher maintenance requirements [12]. Microcontroller (MCU)-based regulators offer improved control flexibility and regulation accuracy through real-time voltage sensing and programmed switching control [13], [14,15]. However, they require additional components, including sensing circuits, microcontrollers, driver circuits, and switching devices, which increase system complexity, cost, and implementation requirements to consumers [16,17]. In contrast, capacitor-based regulation offers a simpler approach with fewer control requirements and potentially reduced size and cost. However, its regulation capability depends strongly on the capacitor configuration and operating conditions. Therefore, there is a need to investigate a simple and cost-effective capacitor-based voltage-regulation technique for domestic applications. The present study addresses this gap by developing and experimentally evaluating a capacitor bridge cascade model (CBCM) for a 1 kVA domestic voltage stabilizer, with emphasis on voltage regulation under varying input voltage and load conditions [18].

To address these limitations, this study introduces an approach using CBCM for voltage regulation. The CBCM is integrated into the output stage of a 1 kVA stabilizer, where capacitors are arranged in a bridge-cascade configuration to function as reactive energy storage units. This arrangement enables rapid charge-discharge cycles that effectively minimize voltage fluctuations and enhance voltage division. Furthermore, the design eliminates the need for bulky mechanical components, resulting in a compact and reliable stabilizer unit [19].

The proposed system architecture comprises four main components: input power supply ranging from 160 V to 250 V, switching and control circuit for intelligent operation, CBCM for voltage conditioning, inverter circuit [20, 21], and heat sink cooling system to protect the CBCM against overheating (Figure 1). Figure 2 summarizes the overall system configuration and the whole research.

2. Methods and Materials

This section presents the materials, design procedure, simulation, prototyping, and experimental methods used to develop and evaluate the proposed CBCM for a 1 kVA domestic voltage stabilizer. The methodology comprised data collection, circuit design, numerical analysis, circuit simulation, printed circuit board (PCB) prototyping, and laboratory testing under controlled input-voltage and load conditions.

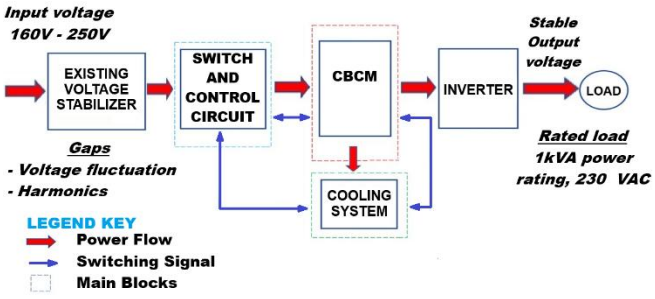


Figure 1. Capacitor bridge cascade model block diagram.

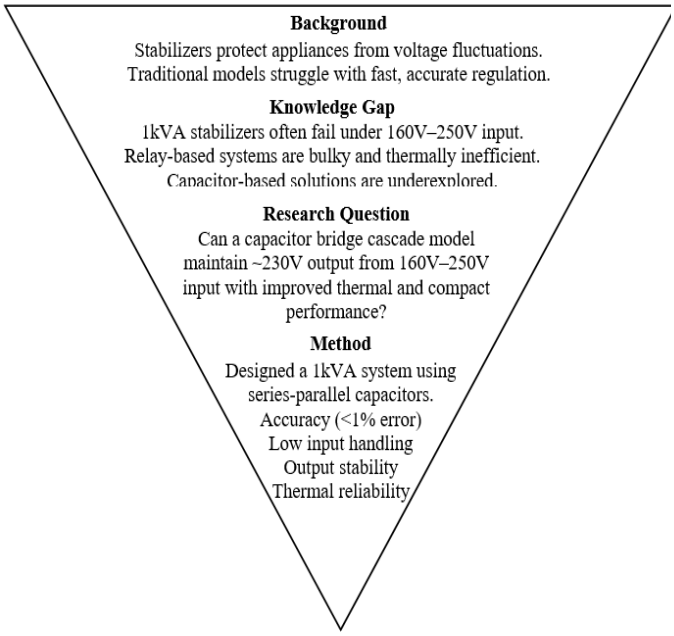


Figure 2. Graphical abstract of the proposed 1 kVA capacitor-based voltage stabilizer design.

2.1. Data Collection

Data were collected from primary and secondary sources to establish the operating requirements and evaluate the proposed CBCM. Primary data were obtained using a structured questionnaire administered to 95 randomly selected respondents comprising voltage-stabilizer retailers and residential users [2223]. The questionnaire collected information on stabilizer ratings, voltage fluctuations, operating problems, and user requirements. Retailers were selected from Kariakoo Market Street in Ilala District, Dar es Salaam, while residential users were selected from Ubungo Municipal Council, Dar es Salaam, and Kisarawe District, Coast Region. Additional primary data were obtained through direct observation, electrical measurements, simulations, and laboratory experiments. Secondary data were obtained from relevant journal articles, books, technical reports, and other published literature on voltage stabilization and capacitor-based voltage regulation. The collected data were organized and analyzed using descriptive statistics, mathematical calculations, and Microsoft Excel to establish the design requirements and evaluate the voltage-regulation and load-handling performance of CBCM.

2.2. Design of the CBCM

The proposed CBCM was designed for a domestic voltage stabilizer with a rated capacity of 1 kVA, nominal output voltage of 230 V, and an input voltage range of 160–250 VAC at 50 Hz. The circuit employed electrolytic capacitors rated at 1000 µF and 35 VDC [8]. The capacitors were connected in series and parallel to obtain the required effective capacitance and voltage characteristics for the CBCM.

For capacitors (C_1, C_2, C_3, …, C_n) connected in series, the equivalent capacitance (C_{eff}) was determined using Equation (1), while for capacitors connected in parallel, the equivalent capacitance was determined using Equation (2). A single CBCM arm was then formed by combining the series and parallel capacitor configurations (Figure 5). Three identical arms were connected in parallel to form the complete CBCM configuration. The complete arrangement, including the source transformer (T1), switching and control circuit, was determined using Equation (3). Figure 6 presents a single-line diagram of an inverter, secondary/load transformer (T2), and load.

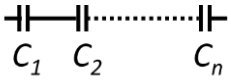


Figure 3. Series connection of capacitors.

$$C_{eff} = \frac{1}{\sum_{i=1}^{n} \frac{1}{C_i}} \quad (1)$$

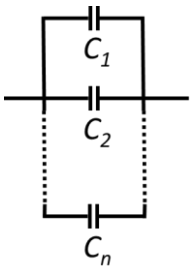


Figure 4. Parallel connection of capacitors.

$$C_{eff} = \sum_{i=1}^{n} C_i \quad (2)$$

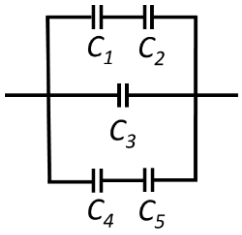


Figure 5. One arm of the CBCM.

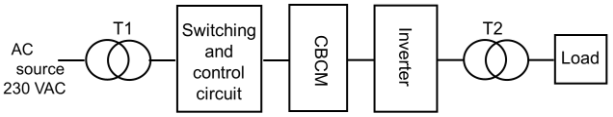


Figure 6. Single-line diagram of the CBCM with source, switching and control circuit, inverter and load.

$$C_{CBCM} = \sum_{i=1}^{2} \frac{1}{C_i} + C_3 + \sum_{i=4}^{5} \frac{1}{C_i} \quad (3)$$

2.3. Component Specifications

The main components used in the CBCM prototype were selected according to the required 1 kVA operating capacity and the specified input-voltage range. The principal component specifications are summarized in Table 1.

Table 1. Main component specifications of the CBCM.

Component	Specification	Quantity	Function
Capacitor	Electrolytic, 1000 µF, 35 VDC	15	Capacitive voltage compensation
Inverter	1.875 kVA	1	Power conversion
Input/source transformer (T1)	According to design	1	Input-voltage transformation
Secondary/load transformer (T2)	According to design	1	Load-side voltage delivery

Component	Specification	Quantity	Function
Switching circuit	Comparator-based	1	Switching and control
Load	Up to 1 kVA	Variable	Load testing

2.4. Simulation

The complete CBCM circuit was developed and simulated using NI Multisim. The simulation was conducted over an input voltage range of 160–250 VAC at 50 Hz while the load was maintained [18] at the rated 1 kVA [18]. The 1000 µF, 35 VDC electrolytic capacitors were configured according to the proposed CBCM topology, and the switching operation was controlled using a comparator-based control circuit. The inverter was rated at 1.875 kVA to provide adequate capacity above the 1 kVA rated load [18]. For each input voltage condition, the input and output voltages were recorded and compared with the nominal output voltage of 230 VAC. The simulation results were used to verify the ability of the proposed configuration to regulate the output voltage before hardware implementation.

2.5. Prototyping

Following simulation verification, the CBCM was prepared for hardware implementation. The PCB layout for prototyping the proposed CBCM was designed using Proteus Design Suite 8.17 SP2. The PCB design incorporated the electrical connections and component arrangement obtained from the validated circuit design. The fabricated PCB was then assembled using the specified components and inspected for correct component placement, electrical continuity, and consistency with the simulated circuit before laboratory testing.

2.6. Cost Analysis

A cost analysis was conducted to determine the resources required to fabricate the proposed CBCM prototype, considering the electronic components, power devices, magnetic components, control and protection devices, and other materials used in assembling the prototype. The cost of each component was determined based on its quantity and corresponding acquisition cost, with the costs of multiple units calculated by multiplying the quantity by the unit acquisition cost. The individual component costs were then summed to obtain the total prototype fabrication cost. The resulting bill of materials (BOM), presented in Table 2, provides the component categories, specifications, quantities, and associated costs, thereby establishing a transparent basis for estimating the resources required to reproduce the developed prototype. For economic benchmarking, the total fabrication cost of the CBCM was compared separately with the acquisition cost of a commercially available 1000 VA automatic voltage regulator (AVR), allowing the economic characteristics of the two voltage-regulation approaches to be assessed independently from their electrical performance.

Table 2. Bill of materials used for the capacitor bridge cascade module (CBCM) prototype.

No.	Component	Specification	Quantity
1	Bridge rectifier	Whinstone bridge rectifier	1
2	CD4047 IC	Monostable	1
3	Diode	1N4007, 1000 V, 1.0 A	1
4	Electrolytic capacitors	35 V/47 µF	5
5	Electrolytic capacitors	35 V/1000 µF	16
6	Electrolytic capacitors	35 V/330 µF	2

No.	Component	Specification	Quantity
7	Existing stabilizer	230 V, 100 VA–1 kVA	1
8	IRF250 MOSFETs	Power MOSFET	2
9	IRF540 MOSFETs	Power MOSFET	2
10	Green LED	Low-current LED	1
11	Red LED	Low-current LED	1
12	LM2596 module	DC–DC buck converter, 5 A, 1.23–40 V	1
13	Load	230 V lamp/domestic appliance, up to 1 kVA	1
14	Motor fan	12 VDC	1
15	Non-electrolytic capacitors	100 nF	2
16	Operational amplifier	LM324 IC	1
17	Polarized capacitor	100 nF	1
18	Potentiometers	1 kΩ	2
19	Potentiometer	10 kΩ	1
20	Potentiometers	22 kΩ	2
21	Transformer T1	220/240 VAC to 12/24 VAC, 3000 mA, centre-tapped	1
22	Transformer T2	220/240 VAC to 12/24 VAC, 5000 mA, centre-tapped	1
23	PTC switch	Positive temperature coefficient thermistor	1
24	Relay	12 VDC	1
25	Resistor	220 Ω	1
26	Resistors	1 kΩ	3
27	Resistor	2.2 kΩ	1
28	Resistors	3.3 kΩ	2
29	Resistors	10 kΩ	5
30	Silicon PNP power transistor	250 W, 175 °C	1
31	Silicon NPN low-power transistor	625 mW, 150 °C	1
32	Voltage regulator	LM7815	1
33	Zener diodes	6.2 V, 500 mW	4

3. Experiments

The assembled CBCM prototype was experimentally evaluated at the Power Systems Laboratory, College of Engineering and Technology, University of Dar es Salaam. The experimental setup was configured for a nominal supply frequency of 50 Hz, with the input voltage varied from 160 to 250 VAC and the output voltage maintained at a nominal value of 230 VAC. The prototype was tested under both no-load and load operating conditions to evaluate its voltage-regulation performance and load-handling capability.

The load was varied in five steps: 0 VA (no-load), 250 VA (25% load), 500 VA (50% load), 750 VA (75% load), and 1000 VA (full load). From 160 to 250 VAC input voltage and load condition, the input voltage and output voltage were measured

and recorded using the calibrated AC electrical measuring instruments. The measurements were repeated over the specified range of input voltage to characterize the response of the CBCM under different operating conditions. The recorded data were subsequently used to determine deviation of the output-voltage, voltage drop, percentage voltage drop, and voltage-regulation error.

To assess the practical operating performance of the CBCM, additional tests were conducted by simultaneously varying the input voltage and load. These tests were intended to determine the ability of the prototype to maintain a stable output voltage under combined supply and loading disturbances. The experimental arrangement and test sequence were kept consistent throughout the measurements to ensure comparability between operating conditions.

For benchmarking, the same input voltage and load conditions were applied to a commercially available 1000 VA AVR. The measured results from the CBCM and the commercial AVR were compared in terms of output voltage stability, voltage-regulation accuracy, response to input voltage variations, and load-handling capability. The experimental procedures and operating conditions were maintained consistently for both devices to provide a meaningful comparative assessment [24-29].

4. Results

The CBCM voltage stabilizer was evaluated under varying input voltage and load conditions. The input voltage was varied from 160 to 250 VAC, while the load was varied from no-load condition to the rated 1 kVA capacity [18]. The results include the output voltage response, percentage error, voltage drop under load, and combined input voltage and load response.

4.1. Output Voltage Response to InputVoltage Variation

The existing SWR-1000VA stabilizer was initially evaluated through simulation over an input voltage range of 160–250 VAC. The simulation circuit and corresponding output waveform are presented in Figures 7 and 8.

The CBCM prototype was subsequently tested at the Power Systems Laboratory of the College of Engineering and Technology, University of Dar es Salaam (Figure 9).

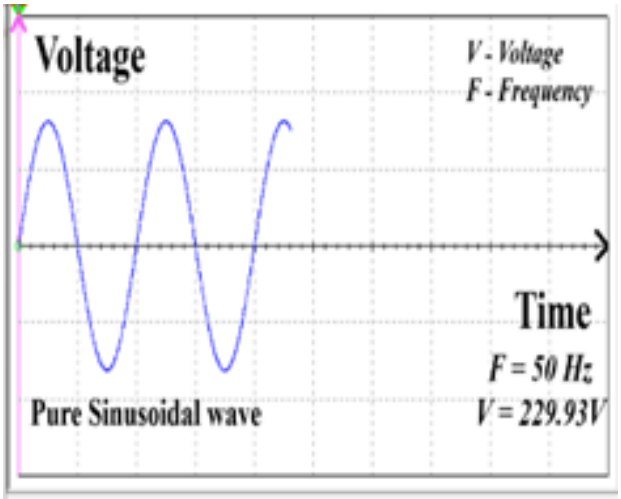


Figure 7. Simulation of existing SWR-1000 VA stabilizer.

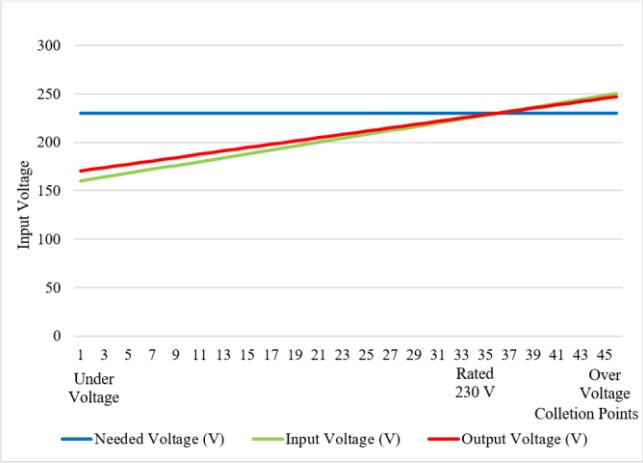


Figure 8. Simulation results of output waveform of existing SWR-1000 VA stabilizer.



Figure 9. Experimental testing of the CBCM prototype at the Power Systems Laboratory of the College of Engineering and Technology, University of Dar es Salaam.

The measured output-voltage profiles of the CBCM and the existing SWR-1000VA stabilizer are presented in Figure 10.

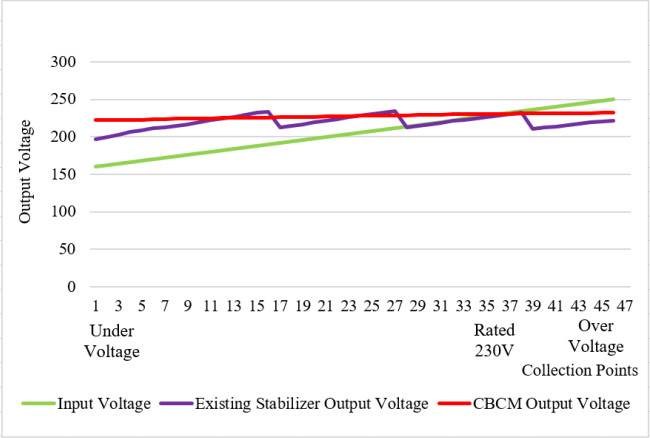


Figure 10. Experimental output-voltage profiles of the SWR-1000VA stabilizer and CBCM.

The CBCM output voltage ranged from 222.9 to 232.5 VAC over the investigated range of the input voltage, while the existing SWR-1000VA stabilizer produced an output voltage range of 197.7–234.3 VAC. At the lowest input voltage of 160 VAC, the measured outputs were 222.9 VAC for the CBCM and 197.7 VAC for the existing stabilizer. At the upper end of the input range, the corresponding output voltages were approximately 232.5 VAC and 234.3 VAC, respectively.

The corresponding output-voltage errors relative to the nominal 230 VAC are presented in Figure 11.

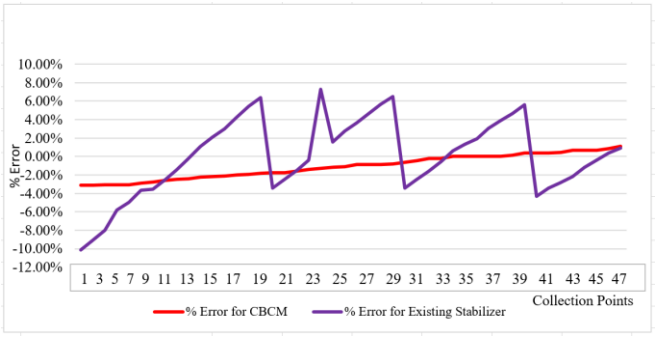


Figure 11. Experimental output-voltage percentage error profiles of the SWR-1000VA stabilizer and CBCM.

At 160 VAC input, the CBCM recorded an output voltage error of −3.09%, compared with −10.14% for the existing stabilizer. At 230 VAC input, the CBCM output was approximately 230 VAC, corresponding to approximately 0% error. Across the investigated input voltage range, the CBCM output voltage error remained within approximately ±3.1% of the rated output voltage, whereas the existing stabilizer exhibited a maximum output voltage error of approximately ±10.14% before resetting or returning to its rated output voltage.

4.2. Load-Test Results

The CBCM was tested at five loading levels corresponding to 0%, 25%, 50%, 75%, and 100% of its rated 1 kVA capacity. The measured output voltage, voltage drop, voltage-drop percentage, and performance error are presented in Table 3.

The output voltage decreased from 230.0 VAC at no-load to 227.5 VAC at full load. The corresponding voltage drop increased from 0.0 to 2.5 VAC, while the voltage-drop percentage increased from 0.00% to 1.09%. The maximum

Table 3. CBCM voltage regulation measurements under different load conditions.

Load condition	Applied load (VA)	Output voltage (VAC)	Voltage drop (VAC)	Voltage drop (%)	Error (%)
No load	0	230.0	0.0	0.00	0.00
25% load	250	229.5	0.5	0.22	0.22
50% load	500	228.8	1.2	0.52	0.52
75% load	750	227.9	2.1	0.91	0.91
Full load	1000	227.5	2.5	1.09	1.09

measured performance error was 1.09% at the rated 1 kVA load.

4.3. Output Voltage under Combined Input-Voltage and Load Variation

The CBCM was further evaluated under simultaneous variation of input voltage and load. The input voltage was varied from 160 to 250 VAC, while the applied load was varied from 0 to 1000 VA. The measured output voltages are presented in Table 4.

Table 4. CBCM output voltage under varying input voltage and load conditions.

Input voltage (VAC)	No load (VAC)	250 VA (VAC)	500 VA (VAC)	750 VA (VAC)	1 kVA (VAC)
160	223.0	222.5	221.8	221.2	220.5
170	223.5	223.0	222.3	221.7	221.0
180	224.5	224.0	223.3	222.5	222.0
190	225.5	225.0	224.3	223.5	223.0
200	227.0	226.5	225.8	225.0	224.5
210	228.0	227.5	226.8	226.0	225.5
220	229.5	229.0	228.3	227.5	227.0
230	230.0	229.5	228.8	227.9	227.5
240	231.0	230.5	229.8	228.9	228.5
250	232.0	231.5	230.8	229.9	229.5

At 160 VAC input, the CBCM output ranged from 223.0 VAC at no-load to 220.5 VAC at 1 kVA. At 230 VAC input, the output ranged from 230.0 to 227.5 VAC across the same loading range. At 250 VAC input, the output ranged from 232.0 VAC at no-load to 229.5 VAC at full load.

Across all tested conditions, the highest measured output voltage was 232.0 VAC, recorded at 250 VAC input under no-load, while the lowest was 220.5 VAC, recorded at 160 VAC input under 1 kVA load.

4.4. CBCM Load-Test Results

The principal measured parameters of the CBCM load test are summarized in Table 5.

Table 5. CBCM load-test performance summary.

Parameter	Measured value
Rated output voltage	230 VAC
Rated load capacity	1 kVA
Full-load current	≈ 4.35 A
No-load output voltage	230 VAC
Full-load output voltage	227.5 VAC
Maximum voltage drop	2.5 VAC
Maximum voltage-drop percentage	1.09%
Full-load performance error	1.09%
Adopted maximum voltage-drop criterion	≤3%

The maximum voltage drop measured during the dedicated load test was 2.5 VAC, corresponding to 1.09%, at the rated 1 kVA load. The corresponding full-load output voltage was 227.5 VAC.

5. Discussions

This study investigated the voltage-regulation performance of CBCM for a 230 VAC, 1 kVA

voltage stabilizer. The study was guided by four research questions: (i) Can the CBCM maintain a stable output voltage when the input voltage varies from 160 to 250 VAC? (ii) Does the CBCM provide improved voltage regulation compared with the existing SWR-1000VA stabilizer? (iii) How does increasing the load from no-load to 1 kVA affect the CBCM output voltage? and, (iv) Can the CBCM maintain acceptable regulation when both input voltage and load vary?

The study found that the CBCM provided improved voltage regulation compared with the existing SWR-1000 VA stabilizer. At an input voltage of 160 VAC, the CBCM produced 222.9 VAC, corresponding to an error of −3.09%, whereas the existing stabilizer produced 197.7 VAC, corresponding to −10.14% error. The lower error demonstrates improved compensation of severe input undervoltage. Over the tested input-voltage range, the CBCM maintained an output of approximately 222.9–232.5 VAC, compared with 197.7–234.3 VAC for the existing stabilizer. These results answer the first two research questions by demonstrating that the CBCM reduced output-voltage variation and provided better under-voltage compensation than the existing stabilizer under the tested conditions.

The study also found that the CBCM maintained acceptable regulation as the load increased to its rated 1 kVA capacity. The output voltage decreased from 230.0 VAC at no-load to 227.5 VAC at full load**,** giving a maximum voltage drop of 2.5 VAC**,** or 1.09%**.** This value is below the adopted 3% voltage-regulation criterion**,** equivalent to 6.9 VAC for a 230 VAC system. The relatively small voltage reduction indicates that the increase in load produced only a limited effect on the regulated output. This finding answers the third research question and confirms that the prototype maintained acceptable voltage regulation at its rated load**.**

The combined input voltage and load tests further showed that the CBCM maintained regulated output under simultaneous changes in supply voltage and load. At 160 VAC input, the output decreased from 223.0 VAC at no-load to 220.5 VAC at full load, while at 230 VAC input it decreased from 230.0 VAC to 227.5 VAC. At 250 VAC input, the corresponding output values were 232.0 VAC and 229.5 VAC. These results answer the fourth research question by demonstrating that the CBCM can provide voltage regulation when both supply voltage and connected load vary. However, the output deviation becomes more noticeable at extreme input conditions, particularly under full-load undervoltage operation.

The results are significant because voltage fluctuations can affect the operation and reliability of electrical and electronic equipment connected to low-voltage distribution systems [9]. The improved performance observed at 160 VAC input indicates that CBCM can reduce the effect of severe supply undervoltage compared with the existing stabilizer. The 1.09% full-load voltage deviation also demonstrates that the proposed topology can maintain relatively stable output while supplying its rated load. Thus, the proposed system has potential for applications where both supply-voltage variation and changing electrical demand are present.

The main novelty of this study is the experimental evaluation of the CBCM under both wide input-voltage variation and progressive loading using a 1 kVA prototype, together with direct comparison with an existing SWR-1000VA

stabilizer. Rather than evaluating voltage compensation under only one operating condition, the study considers the combined effects of input voltage and load on the output. This provides a more practical assessment of the proposed topology and contributes experimental evidence to the development of alternative voltage-stabilization approaches.

A major strength of the study is the use of an experimentally tested prototype under controlled laboratory conditions. The evaluation covered an input range of 160–250 VAC and loading from 0 to 1 kVA, allowing the voltage-regulation behaviour to be quantified using output voltage, voltage drop, and percentage error. The use of a predefined 3% regulation criterion also provides a clear basis for judging the full-load performance.

However, the study has specific limitations that should be considered when interpreting the findings. The investigation was limited to a 1 kVA**,** 230 VAC CBCM prototype and an input-voltage range of 160–250 VAC. Therefore, the measured performance cannot be directly generalized to higher power ratings or wider voltage ranges without redesign and further testing. In particular, capacitor ratings and values and those of other circuit components may need to be changed when the topology is scaled to different power levels because current, voltage stress, and component operating conditions will also change.

The study did not extensively investigate long-term capacitor aging, thermal effects, environmental conditions, highly dynamic loads, or nonlinear loads [18]. These factors may influence the voltage-regulation performance and reliability of the CBCM during extended practical operation. Furthermore, the experiments were conducted under controlled laboratory conditions rather than in actual domestic installations. Consequently, the reported results establish the performance of the tested prototype but do not yet establish its long-term behaviour under varied real-world operating conditions.

Another important limitation is the remaining output voltage deviation under severe undervoltage conditions [18]. At 160 VAC input and full load, the CBCM produced 220.5 VAC in the combined test. Although this represents substantial regulation compared with the unregulated input condition and demonstrates the compensation capability of the topology, it is below the nominal 230 VAC output. Therefore, applications requiring very tight output regulation during severe undervoltage may require further improvement of the compensation mechanism.

The practical implication of these findings is that the CBCM could provide a useful approach for voltage stabilization in electrical systems experiencing supply-voltage fluctuations. Its relatively small load-induced voltage drop suggests that the topology can supply loads up to its rated 1 kVA capacity without exceeding the adopted voltage-regulation criterion. This may be relevant to domestic and small commercial applications where maintaining a stable supply voltage is important for equipment operation.

Future research should therefore focus on improving CBCM performance under extreme undervoltage and higher loading conditions. Further studies should evaluate efficiency, transient response, thermal performance, power quality, component aging, and long-duration reliability [18]. Testing with dynamic and nonlinear loads would also provide a better representation of actual

domestic and commercial operating conditions. In addition, CBCM prototypes with higher power ratings should be developed to determine how component scaling affects voltage regulation and system reliability. Comparative testing against recent voltage-stabilization technologies using the same input voltage, load, and performance criteria would also provide stronger evidence of the relative advantages of the proposed topology.

Overall, the study found that the CBCM achieved lower voltage error, improved under-voltage compensation, and acceptable full-load voltage regulation compared with the existing SWR-1000VA stabilizer. The measured 2.5 VAC full-load voltage drop and 1.09% regulation error demonstrate satisfactory performance for the tested 1 kVA prototype. These findings support the CBCM as a promising approach for 230 VAC voltage stabilization, while the identified limitations define the additional testing and development required before the technology can be generalized to wider operating conditions and higher power ratings.

6. Conclusion

This study introduces a significant advancement in voltage stabilization technology through the implementation of the CBCM, which enhances voltage regulation and power quality in a 1 kVA rated stabilizer. By integrating bridge-connected capacitors in parallel with the voltage regulation circuit, the CBCM effectively minimizes voltage fluctuations and ensures a highly stable output, maintaining 229.99 V to 230 V across a wide input range of 160 V to 250 V. The results show that the CBCM consistently operates within a ±3.1% margin, far surpassing SWR-1000VA stabilizer that allows deviations up to ±10%. These results demonstrate that CBCM stands out as a reliable, efficient, and compact voltage regulation solution. Its performance advantages make it highly suitable for use in residential settings and for protecting sensitive electronics in regions with unstable grid conditions.

DISCLAIMER

The comparison presented in this paper is conducted strictly for academic and research purposes to evaluate voltage regulation techniques. It focuses on the differences between the proposed CBCM and the SWR-1000VA stabilizer under the tested conditions, particularly regarding voltage regulation performance, compensation capability, and design approach. The findings are limited to these conditions and should not be interpreted as a general assessment of the product's reliability, commercial performance, or market position.

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CONTRIBUTIONS OF CO-AUTHORS

Reginald Beda Matola	ORCID: 0009-0007-8086-2506	Conceived the idea, collected data, and conducted the experiments and wrote the paper
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