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Performance Simulation of A 4.0kW Transformerless Stabilizer

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ABSTRACT
Instability in power supply to electrical and electronics appliances at homes and in industries had been an enormous disturbing problem to the effective utilization of electricity. It causes a lot of damage to our equipment and increases the cost of living. These power supply irregularities are caused mostly by voltage fluctuations. To cost-effectively and efficiently arrest the situation, and improved 4.0kW transformer-less voltage stabilizer is projected in this paper. The planned study is meant to find reliable and a lasting solution to the condition of voltage fluctuations across home and industrial equipment. The specific objectives are obtained through sizing and computation of the component values of an improved stabilizer topology and by modelling and simulation of the circuit diagram of the proposed system using the Matlab/Simulink Software.

Keywords-- Current, Converter, Diode, Stabilizer, Transformer-Less

INTRODUCTION

The embedding of microprocessor chip technology and power electronic tools in the design of smart AC voltage stabilizers (or automatic voltage regulators (AVR)) led to the production of a superior and stabilized electric power supply in the event of reasonable and steady aberration of mains voltage [1]. Power instability supply to electrical and electronics appliances at homes and in industries had been an enormous disturbing problem to the effective utilization of electricity. It causes a lot of damage to our equipment and increases the cost of living. These power supply irregularities are caused mostly by voltage fluctuations. In literature, many protective devices had been proposed and implemented to ensure adequate protection of equipment and appliances [1- 6]. The protective relay in [1] demonstrated that if abnormalities in power supply occur, the relay senses them and immediately causes the breaker to open and the facility element is isolated. But since the relay operates mechanically, the parts wear out as the switch contacts become dirty. Besides, it cannot be switched ON and OFF at high speeds to control the rapid transiency of voltage oscillations. Moreover, the fuse is another protective device that makes use of the breaking principle on safeguarding the life span of electrical appliances. But its maintenance time factor when it cuts reduces the efficiency of whatever system it is protecting. Hence, to improve beyond the breaking principles seen infuse and relay, the regulators are used [2] - [4]. The continual power interruptions and drastic variations in electric power lines in Nigeria these days have caused a lot of issues in many places and destructions of lives in different governmental and private hospitals. Various Computers and other sensitive equipment have been damaged due to sudden high voltage and current. Formerly backup generators were suitable to get power should an interruption arise in the utility; yet, a long delay in switching and starting of generators as is presently noticed is insufficient to cope with the instantaneous demands of electrical power in those places [6-7]. Such interruptions unacceptably affect critical loads such as computers, internet providers, telecom service providers, etc. Although the electric utility stakeholder has made remarkable efforts for uninterrupted power line and unembroidered line voltage, inescapably still, there exist issues such as voltage variations and spikes [8] and it will be highly transferrable. The transformer-based stabilizers, even though have the advantages of operational ruggedness and capability in riding out momentary breaks in mains, have the following demerits: large, unbearable audible humming sound, very bulky,

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and difficult to carry about. For higher power quality, and to solve most of the problems created by the transformer-based stabilizer [2], [6]-[8], the transformer-less converters, despite some little harmonic distorting seen in them, have better characteristic performance over the transformer-based converters. The harmonic distortions in transformer-less converters are highly mitigated by filtering and Pulse width modulation, PWM, measures in the power electronic switches such as MOSFETS, thyristors, insulated gate bipolar transistor (IGBT), etc. [9]-[14]. In this work, a PI-controlled transformer-less voltage stabilizer is proposed. The stabilizer's operational principle is based on the output voltage adjustment by the process of pulse–width modulation scheme. At the input and output of this device, there are analog filters meant for active smoothening of the impulsive noises in the circuit. The core merits of this proposed stabilizer are: it is portable, noiseless in operation, takes the operational range of 120-230VAC at 50Hz, less expensive in mass production, occupies little space, and has small power loss. As improvement regarding the traditional relay type voltage stabilizers, contemporary state-of-the-art stabilizers use high performing digital control circuits cum solid-state control circuit arrangement which excludes potentiometer modifications and permits one to set voltage necessities via a keypad, with output begin and stop capability [15-16]. This has also helped to lessen the trip timing or sensitivity of the stabilizers to a very less rate, characteristically less than a few milliseconds. That notwithstanding, it can be attuned with an adjustable setting. Nowadays, stabilizers are considered as improved power solutions to numerous electronic tools that are sensitive to voltage variations as associated with apparatuses like air conditioners, television sets, medical apparatus, computers, telecommunication paraphernalia, and many more.

The fluctuating input voltage is regulated by the voltage stabilizer before it is fed to the load (or instrument that is sensitive to voltage variations). The voltage (output) from the stabilizer will be in the range of 220V or 230V for the single-phase supply case and 380V or 400V for the three-phase supply case, around the given changing range of input voltage. This regulation is achieved by buck and boost processes and actions made by internal circuitry. There exist enormous types of automatic voltage regulators found in the present-day market. They are always single or three-phase units as needed by the application type and capacity (KVA) expected. Two versions in the form of balanced load models and unbalanced load models are the major presentations of the three-phase stabilizers. From the other perspective, they can be either analog or digital type stabilizer units. In a voltage stabilizer, voltage amendment from over and under-voltage situations is achieved using two important schemes, the boost, and the buck approaches. These approaches can physically be achieved using switches or automatically via electronic circuitry. In a time of under-voltage condition, the boost process raises the voltage to a rated level while the bucking process brings down the voltage level in the time of overvoltage condition. The change of the voltage to and from the mains supply involves the stabilization concept. For such tasks to be performed, the stabilizer makes use of a transformer connected in diverse formations with switching relays. While some stabilizers use transformers having taps on winding to provide varied voltage corrections, servo stabilizers make do with an autotransformer to have an extensive range of corrections. The voltage of electricity supplied stays within the definite range as long as the operation of sensitive electronic devices goes on efficiently. Accompanying their operations are very many types of voltage oscillations including but then not limited to voltage surge, sag, spikes, harmonic distortion, and momentary interruptions. Voltage sag appears to be the most significant power quality problem in large industries as well in domestic operations. As the sensitive electronics loads are on the increase, the problem of voltage sag cannot be ignored. Hence there is every need to pay adequate attention to this issue since they may cause significant loss in production and also financial loss in the industry. Apart from loss in production, voltage sags do also cause damage to equipment and as such reduce their efficiency, which results in a lower quality product and reduced customer satisfaction. Storms are the main cause of external voltage sag. Many power quality problems arise from heavy storms striking the power line. The internal source of sag making is domiciled mostly within the facility. A sudden increase in load is also one

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serious cause of voltage sag, motor starting event, heaters being turned, etc. are other internal sources of voltage sag production. The majority of sags are generated within an edifice. For example, in residential wiring, the most common cause of voltage sags is the starting current drawn by refrigerator and air conditioning motors. Many customer power devices to mitigate the voltage sag are introduced. The inverter-based regulators and ac-ac converters are the universal groupings of voltage sag regulators. The series-connected device is a sample of inverter-based regulator topology. To eradicate this problematic issue a transformer less dynamic sag corrector topology has been employed. This paper hence rides on with a brief hint on the operating modes of the planned topology and its working principle, and then followed by simulation, analysis, and results.

METHODOLOGY

Fig. 1 shows the circuit proposed for the stabilization system. The boosting and the bucking processes are well depicted.

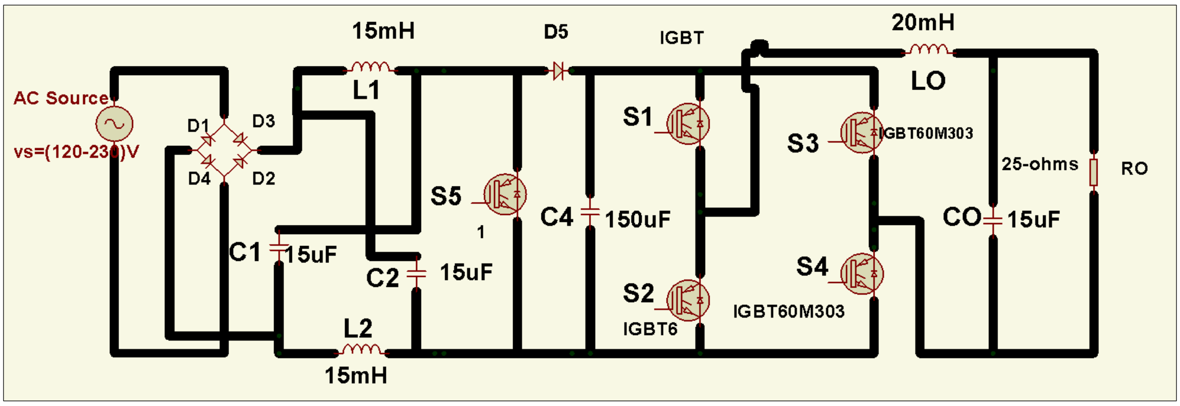

Figure 1: *Circuit topology of the proposed improved system.*

Fig. 1 represents the circuit diagram of an improved voltage stabilizer. It boosts and bucks twice to regulate the output voltage across the loads.

Boost Converter

Boost converter (also called a step-up converter) is a DC to DC converter circuit that is fashioned to change an input DC signal into an output DC signal yielding a voltage level likely much greater than the input voltage level. The boost converter (step-up converter) is a DC-to-DC power booster that steps up voltage (while lowering down current) from its input (supply) to its output (load). Suitable DC sources, such as batteries, solar panels, rectifiers, and DC generators are good channels where the power for the boost converter can come from. An operation that converts one DC voltage to another DC voltage is better called DC to DC conversion. The boost converter is a DC to DC converter having an output voltage higher than the voltage of the source. The boost converter is usually called a step-up converter since it "raises" the voltage of the source. As power (P=VI); conservation has to be achieved, the output current should therefore be lower than the current of the source.

Buck Converters

Buck converters (step-down converters) are DC-to-DC power converters that cut down voltage (while utilizing less average current) from their input (supply) to their output (load). This is made of a switched-mode power supply classically containing not less than two semiconductors (a diode and a transistor, although current buck converters most times change the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two together. To lessen voltage ripple, filters of capacitor make (likely joined with inductors) are usually joined to such a converter's output (load-side filter) and input (supply-side filter). Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat but do not step up

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output current. Buck converters can be exceedingly effective (most times above 90%), hence very efficient for tackling issues like changing a computer's core (bulk) supply voltage (often 12 V) down to lower voltages desirable for USB and the CPU.

Simulink Model

The Simulink model for the proposed circuit is as shown in Fig. 2.

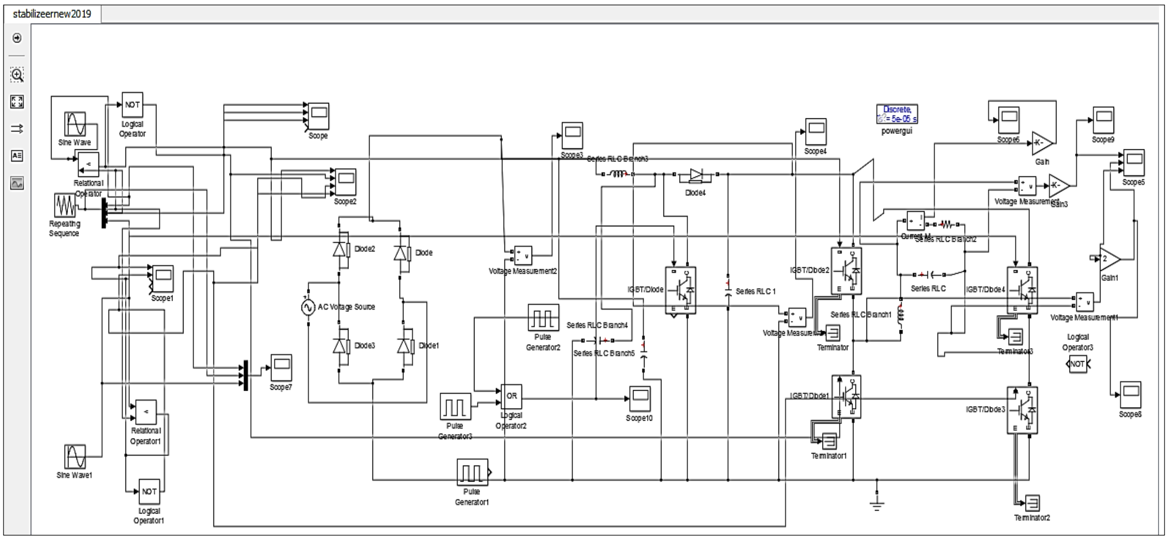

Figure 2: *Simulink Model of the proposed system.*

SIMULATION AND ANALYSIS OF RESULTS

The following are the results from the Matlab simulations. The modeling and simulation of this work are achieved in Matlab/Simulink environment and it's for validation of the proposed system's aim anchoring on using Thin Film solar panel properties. The Simulink model is shown in Fig. 2, while the simulation results of an improved 4.0kW Stabilizer are as shown in Fig. 4 and 5. The DC-DC voltage is as shown in Fig. 3.

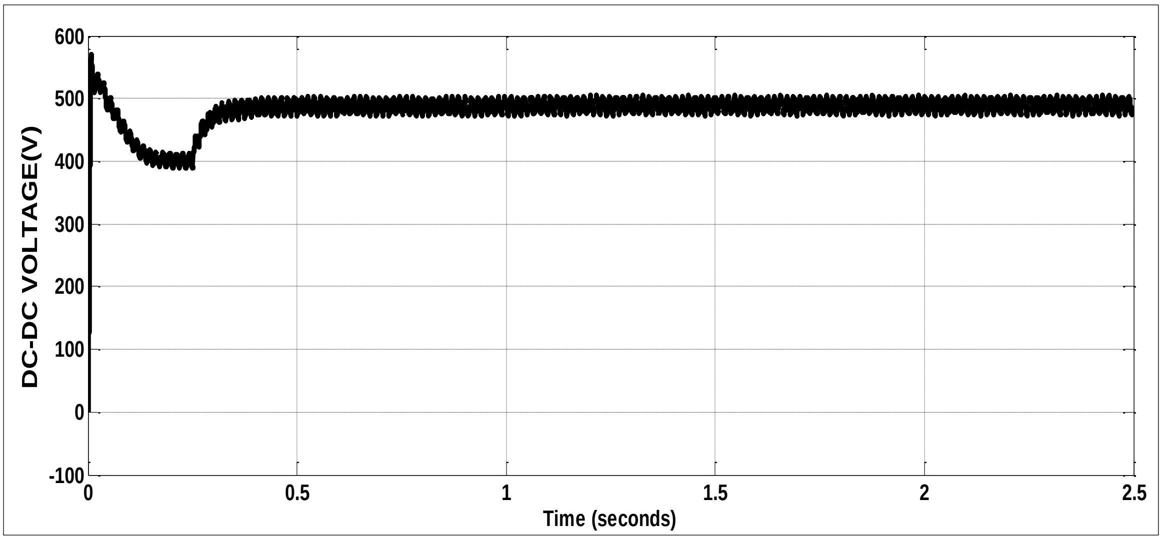

Figure 3: *Waveforms of the input voltage and the boosted voltage of DC-DC converter.*

An input voltage of 230VAC is rectified to 311V in Fig. 1. It is noticed that at $0 \leq t \leq 0.30$ seconds, the output voltage of DC-DC transiently rises from 0V to 580V, bucks to 400VDC, and then stabilizes at 500VDC at a time interval of $0.38 \leq t \leq 2.5$ seconds.

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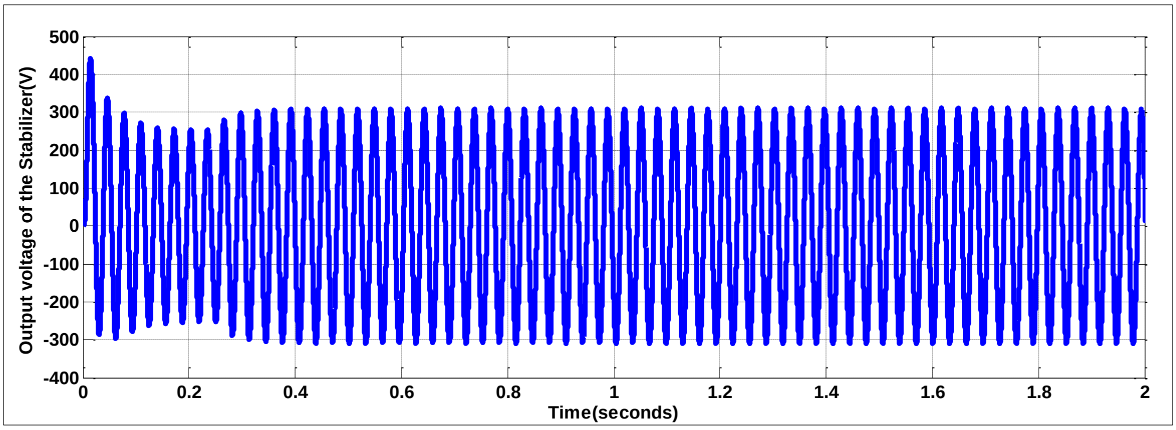

Figure 4: *Waveform of the Output voltage of the proposed system.*

It is noticed that at 0 ≤ t ≤ 0.30 seconds, the voltage output of the stabilizer transiently rises from 0V to 400VAC, bucks to 230VAC peak, and then stabilizes at 320VAC peak voltage at an interval of 0.38 ≤ t ≤ 2.5 seconds.

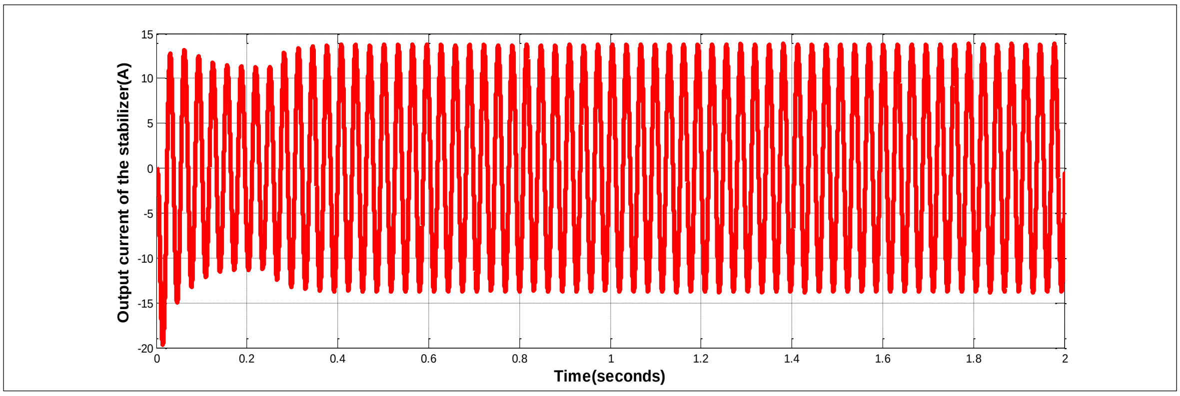

Figure 5: *Waveform of current through the load.*

It is also observed that at 0 ≤ t ≤ 0.30 seconds, the output current of the stabilizer transiently increases from 0A to 13A, bucks to 12A peak, and then stabilizes at 14A peak current at the interval, 0.38 ≤ t ≤ 2.5 seconds. When the output of voltage and current are multiplied, a 4000W power rating is obtained.

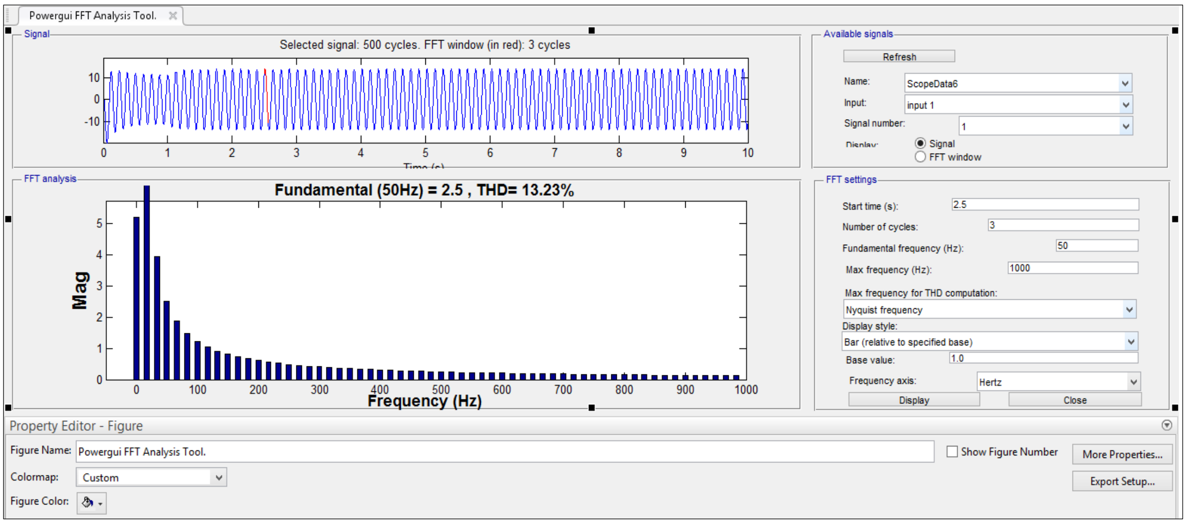

Figure 6: *The Current Spectral examination of the harmonic distortion.*

Fig. 6 shows the result due to the Current Spectral investigation of the harmonic distortion. It is noticed from Fig. 6 that the projected system keeps total harmonics distortion THD, of 13.23% at a current amplitude of 14.05A (12.5A-RMS) considering 3cycles and at t=2.5 seconds.

CONCLUSION

An Improved 4.0kW Transformer-less voltage Stabilizer was analyzed, modeled, and simulated by a combination of Z- Converter, boost converter, H-bridge Inverter, and feedback system. From the spectral analysis, it is shown to have a relatively better performance at that level of operation.

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