Trapezoidal Power Supply System Based on Fluctuating Input Voltage Method

Abdulkadir Iyyaka Audu¹, Jibril Danladi Jiya²
¹Department of Computer Engineering, University of Maiduguri
²Department of Mechatronic Engineering, Abubakar Tafawa Balewa University, Bauchi, Nigeria

Abstract—Performance aspect of trapezoidal uninterruptible power supply system based on fluctuating input voltage method is presented. Trapezoidal shaped alternating current (ac) voltage load waveform has remained potentially attractive in the conversing cable TV (CATV) and telecommunication market where hybrid fiber/coax (HFC) distribution networks have emerged as one of the preferred approaches for distributing multimedia services to the consumer. The efficient conversion, control, and conditioning by static means of electrical power from its available input form into a trapezoidal form are highly possible and require very stringent control strategy. The remarkable feature of voltage feed-forward Pulse-width Modulation (PWM) control to accommodate the change in the input voltage to a converter has made it worthy of consideration in trapezoidal uninterruptible power supply system (TUPS) control. This work studies by way of voltage waveforms the high-performance of single-stage TUPS for Single-phase trapezoidal ac supply. A trapezoidal-shaped load voltage that is synchronized with the ac mains supply is generated by a single-stage configuration, which offers high efficiency. All necessary voltage waveforms which significantly allow the voltage-load transient to represent the UPS system performance are presented. Transient, Fourier, and AC analyses have been performed. The trapezoidal output waveform of the TUPS system is reasonably free from overshoot and undershoots. It also presents a considerably low total harmonic distortion (THD). The desired load voltage magnitude is achieved without necessarily using a 50Hz step-up transformer.

Keywords—Trapezoidal waveform; pulse-width modulation; harmonics; modulation index; hybrid-fiber/coax; inverter; switching frequency; transient performance.

I. INTRODUCTION

There are many telecommunication infrastructures capable of providing a platform for a wide range of broad-band, multimedia entertainment, communication, and information services [1]. In recent years, hybrid fiber/coax (HFC) distribution networks have emerged as one of the preferred approaches for distributing multimedia services to the customer [2], particularly by the cable TV industry. This hybrid dramatically network connects optical fiber to the neighborhood with coax cable to the residence. Compared with all-fiber or all-coaxial networks, this network allows for segmentation of services and high reliability, distribution efficiency, and low cost.

Using power electronics [3], trapezoidal uninterruptible power supply (TUPS) has the ability to serve as an interface, provide clean, appropriate, and reliable power for Hybrid fiber/coaxial systems. In the particular case of power outage, uninterruptible power supply (UPS) can supply power for up to 20min. to allow a back-up supply from diesel generating sets to be brought on-line or, if the generators fail to start, for a, controlled shut down of the computers, telecommunication equipments, etc, to be completed [4], [5], [6].

DOI: 10.23883/IJRTER.2017.3166.CLXVI
II. PERFORMANCE PARAMETER

Ideally, a UPS should be able to deliver: 1) a regulated trapezoidal output voltage with low total harmonic distortion (THD) during normal or backup modes, and voltage regulation, even when feeding nonlinear loads; 2) seamless transition from charging to backup mode during power failure and vice versa; 3) low THD Trapezoidal input currents with unity power factor while in normal mode irrespective of the load nonlinearities or power factor [7], [8]. The best system in this regard is the off-line UPS.

III. RESULT AND DISCUSSION

3.1. Transient Analysis

The waveforms of figure 1(a) through (j) are related to the synchronization and reference unit. The transient waveform of fig. 1(a) represents the sampled 50Hz mains voltage. This is fed into a zero-level comparator which produces a square wave at the same frequency as shown in figure 1(b). This signal serve as an input to a phase-locked loop (PLL) configured as a multiplier. This yields a square wave of 51.2 KHz shown in figure 1(c). This is then passed through an edge detector in which the waveform of figure 1(d) is obtained. This signal feeds the switch which is positioned parallel with the capacitor of the integrator which constitutes the carrier generator. Waveforms of figure 1(e), (g), (i) are obtained from the 12-stage counter (4040), positioned along the feedback path of the PLL and represent the address signals for the 74LS151 multiplexers. The waveforms of figures 1(f) and (h) are consequently generated from the multiplexers. These signals in turn control the integrator which generates the trapezoidal reference signal of figure 1(j).
Figure 1: Transient waveforms of reference and synchronization unit.

Figure 2. The above transient waveforms correspond to mains voltage of 100V.
Figure 3. The above transient waveforms correspond to mains voltage of 127V.

Figure 4. The above transient waveforms correspond to mains voltage of 155V.
Figure 5. The above transient waveforms correspond to mains voltage of 183V.

Figure 6. The above transient waveforms correspond to mains voltage of 212V.
In each of Figure 2 through 8, the first part shows a 51.2 KHz saw-tooth carrier signal corresponding to the specified mains voltage. Each has different amplitude. The second part shows the comparison of the saw-tooth carrier and the trapezoidal reference (2.6V peak) signal using LM339 as a modulator. The normal and inverted output of the modulator called pulse-with modulated signal are shown in the third and fourth parts.

Figure 9 through 15 show the transient waveforms of the unfiltered output of the inverter stage.

**Figure 7.** The above transient waveforms correspond to mains voltage of 240V.

**Figure 8.** The above transient waveforms correspond to mains voltage of 280V.
Figure 9. Output waveforms of inverter stage for mains voltage of 100V.

Figure 10. Output waveforms of inverter stage for mains voltage of 127V.

Figure 11. Output waveforms of inverter stage for mains voltage of 155V.

Figure 12. Output waveforms of inverter stage for mains voltage of 183V.
Each of Figure 9 through 15 shows the pair of power pulses at the two legs of the inverter. Each pair corresponds to the specified mains voltage. The mains nominal voltage is 220V. However, an increase in mains voltage causes a decrease in pulse width while a decrease cause an increase in pulse width. This change in pulse width is easily noticed if the waveforms of fig. 26 and 29 are compared. At nominal mains voltage pulse width is 2.872us. At mains voltage of 100V pulse width is 8.638us, while at mains voltage of 280V pulse width is 2.159us. Irrespective of pulse width, these pulses are fed into a second-order filter \((L_o = 27mH \text{ and } C_o = 23uF)\) to produce the trapezoidal voltage waveform of Figure 16.
Figure 16. Trapezoidal output voltage of the UPS system.

Figure 17. Trapezoidal load current of the UPS system.

Figure 16 and 17 show the trapezoidal load voltage and current respectively for a load step increase from 200 Watts (40.5ohm, 2.22A) to 400 Watts (18.0ohm, 5.0A). It can be seen that the load voltage presents an oscillation that features an unseen undershoot, i.e the solution of the characteristic polynomial of the second-order filter is complex and therefore the oscillations quickly die away.

Figure 18 shows the transient waveforms of supply voltage sensor. This unit senses mains failure and restoration. Any of these situations is followed by the provision of the appropriate signal to the battery On/off switch.

The first part of Figure 18 shows the sampled mains voltage which has been rectified using precision rectifier. This is then compared with the processed 50Hz signal (shown in the second part of figure 18) from the PLL circuit. The output of the comparator is further processed to provide a delay of 60ms to ensure that the battery is switched off only after the load-voltage reference is synchronized with the ac mains. The third part of Figure 18 shows a test digital signal of 50Hz. The high state of the digital signal corresponds to the presence of mains voltage, while the low state means absence of mains voltage. The delay in the signal which controls the battery on/off switch is depicted in part four of figure 18.

3.2. Fourier Analysis
The Fourier analysis pictures the effectiveness of the filter in suppressing the high-frequency-voltage components generated by the PWM operation of the inverter.
The Fourier series or analysis provides a practical way of evaluating the frequency harmonics of inverter output voltage. In Figure 19 (a) and (b), even harmonics are present because bipolar switching algorithm is not strictly respected. However, the effectiveness of the filter circuit has ensured the reasonable suppression of both odd and even harmonics has seen in figure 20. The total harmonic distortion (THD) of the system is a little high and it’s attributable to the compromise between magnitude and frequency of the load voltage waveform, and filter components.

3.3. Fourier Analysis
AC analysis allows for stability study of the closed loop system of the trapezoidal UPS system.
The performance evaluation of TUPS system has been presented. The circuit realization is sufficiently representative of the system performance. The adoption of feed-forward control has allowed main ac voltage fluctuation to be factored into the amplitude of the saw-tooth carrier signal. The theoretical analysis result is impressive and lead to the conclusion that carrier-based pulse-width modulation based on the method of fluctuating inverter input voltage can very accurately be used to improve the efficiency and performance of a TUPS system. Also, the desired peak to peak voltage of 90V, 50Hz has be achieved without the use of a low frequency step-up transformer which has always characterized the conventional triangulation method based uninterruptible power supply system. The concept of carrier-based pulse-width modulation based on the method of fluctuating inverter input voltage which has been given prominence in this work can provide the potential for the design and implementation of transformer-less domestic voltage stabilizer.

REFERENCES