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A NEW THREE PHASE INVERTER WITH LOW DISTORTION FOR UNINTERRUPTABLE POWER SUPPLY APPLICATIONS

KGK UYGULAMALARI ÝÇÝN DÜÞÜK DÝSTORSÝYONLU YENÝ BÝR ÜÇ FAZ EVÝRÝCÝ

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ABSTRACT

The ways of providing low distortion in inverter or UPS applications without using large and high cost filters are whether applying PWM technique [1] or producing several appropriate steps on the output waveform called as multilevel operation. Combining both methods multilevel PWM technique is achieved [2] [3]. But, in this method, in order to reduce harmonics, it is necessary to increase the number of pulses at the output waveform. It is obvious that it causes an increase of power losses in the switching components particularly during ON/OFF transitions. Additionally in PWM applications, the harmonic distortion depends on the pulse widths due to output regulation need.
In this study, a new three phase multilevel inverter using chopper technique will be presented.

Keywords: *UPS, Multilevel operation, PWM, DC Chopper, Harmonic Reduction*

ÖZET

Evirici içeren bir sistemde örneðin bir Kesintisiz Güç Kaynaðýnda çýkýþlarýnda büyük ve pahalý filtreler kullanmadan harmoniði azaltmanýn çeþitli yöntemleri vardýr.Bunlardan en yaygýn olanlarý Darbe Geniþlik Yönteminin uygulanmasý ile uygun basamaklardan oluþmuþ çok seviyeli çalýþma biçimidir.Bu iki yöntem birleþtirildiðinde artýk çok seviyeli bir Darbe Geniþlik Modulasyonlu iþaretten söz edilebilir.Fakat çýkýþtaki harmoniði yeterince azaltmak için basamaklardaki darbe sayýsýný arttýrmak bir baþka ifade ile frekansý arttýrmak gereklidir.Bu ise doðal olarak iletim ve kesim geçiþlerindeki anahtarlama kayýplarýnýn yükselmesi demektir.Öte yandan böyle bir eviricide gerilim ayarý yapabilmek için darbe geniþliklerinin deðiþtirilmesi bir zorunluluktur.Bu çalýþmada DC kýyýcý kullanan mikrodenetleyici destekli, çok seviyeli üç fazlý bir Kesintisiz Güç Kaynaðý tasarlanýp gerçekleþtirilerek sözü edilen sakýncalarýn giderilmesine çalýþýlmýþtýr.

Anahtar kelimeler : *KGK, Çok Seviyeli Çalýþma, DGM, DC Kýyýcý, Harmonik azaltma*

1. INTRODUCTION

In terms of output waveforms of inverters, multilevel technique is a applicable method in addition to PWM technique to reduce the harmonic content. According to this method, some rectangular pulses are arranged so as to approach the output signal to sinewave. In this technique, it is needed more than one inverter circuit [4]. In the realized system, the mentioned method has been used but the output voltage has been adjusted by means of DC chopper supported by a microcontroller [5]The improved inverter has six levels in the output signal pattern.

2. SYSTEM DESCRIPTION

The system consists of six main units as shown in Figure .1.

1. Power supply
2. SMPS (Switch mode power supply)
3.DC chopper and output voltage sampling unit.
4. Logic driver and control unit
5. ADC and microcontroller
6. Power circuit and transformers

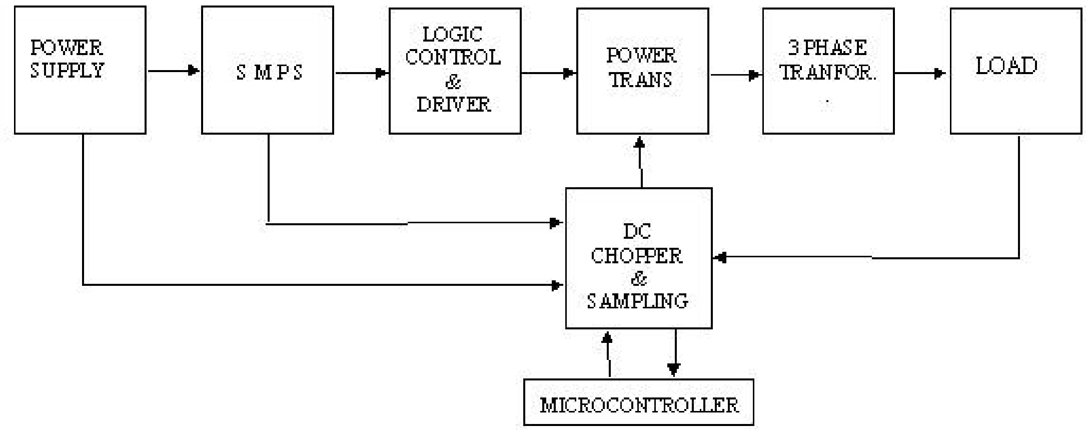

Fig 1**. Structure of the inverter**

The inverter is designed for 24V DC as input voltage and 220/380V - 50 Hz as output voltage. But in practical circuit, output voltage and frequency may be easily changed to any other appropriate values. For this propose, rewriting only one line of the microcontroller program that corresponds to the desired output voltage level of the inverter would be enough.

Another feature of the improved system is that the output voltage level is quite independent of the input voltage within ±%30 limits.For the sake of output regulation, the rectified and divided output voltage is sampled and applied to ADC and 80C32 microcontroller respectively. This signal is compared with the reference level by means of a program with PI algorithm written for 80C32. The pulses derived from the microcontroller are applied to the control input of DC chopper in order to keep the inverter output voltage within desired limits.

3. GENERATING OUTPUT SIGNALS

The power circuit is constructed to provide three phase six level waveform at the output as shown in Figure (2) MOSFETs are selected as output switching elements due to low voltage drop (V_{DSON}) and ease of driving circuits. The MOSFET driving signals are given in Figure (3) The driving pulses are stored into two 8-bit EPROMs operating in parallel driven by a clock signal. At the output of power circuit there is a three phase star/delta connected transformer with the winding ratio ‘x’

Although, the output level is given versus different x winding ratios in Figure (4), the winding ratio between star/delta windings is calculated and applied as $x=\sqrt{3}/1$ by optimizing total harmonic distortion of the output.

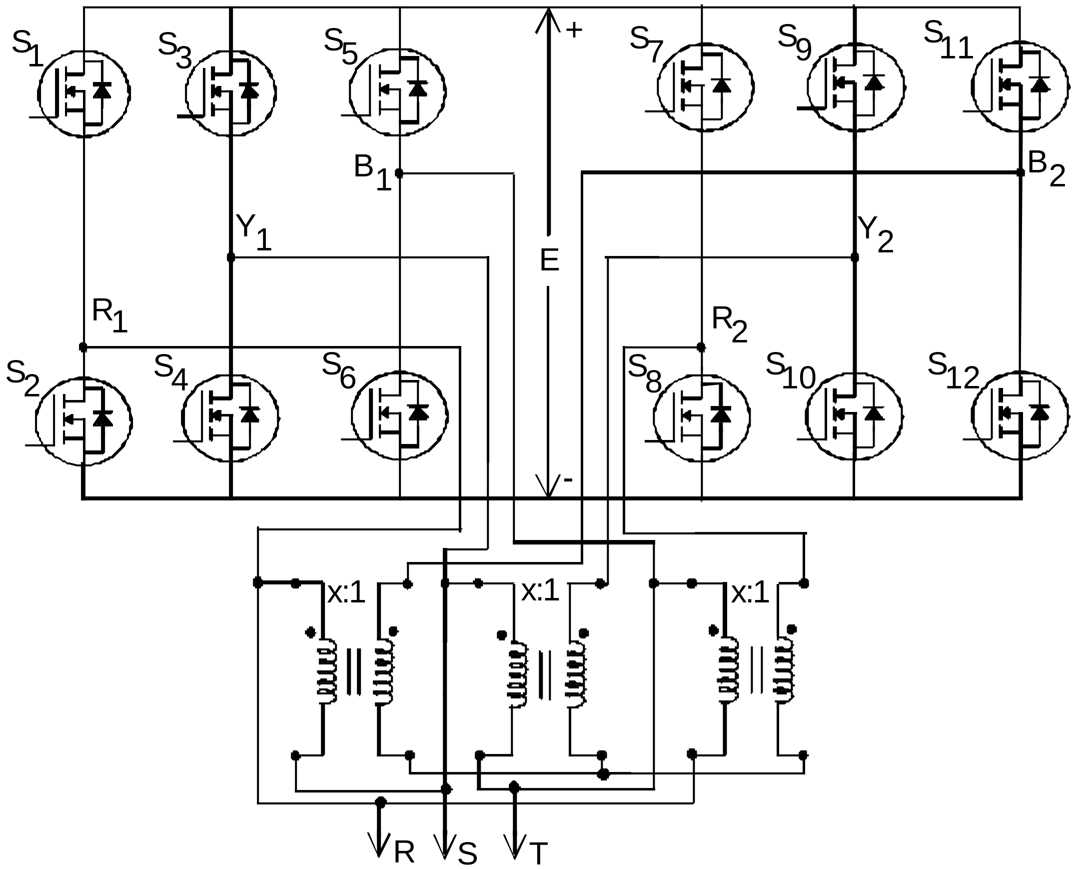

Fig. 2 Power circuit of the proposed inverter.

4. ANALYSIS AND PERFORMANCE OF THE SYSTEM

If the harmonic spectrum is examined for the system, every component of the spectrum for (x) transformer winding ratio may be written as follows

$$a_n = \frac{4}{n\pi}\left[(2-x)\cos\left(\frac{n\pi}{24}\right) + (x-1.5)\cos\left(\frac{3n\pi}{24}\right) + (x-1.5)\cos\left(\frac{5n\pi}{24}\right) + \left(1-\frac{x}{2}\right)\cos\left(\frac{7n\pi}{24}\right) + \left(1-\frac{x}{2}\right)\cos\left(\frac{9n\pi}{24}\right)\right] \quad .(1)$$

The RMS value of output voltage for the proposed system is given as follows

$$V_{rms} = \sqrt{\frac{2}{p}\left[\frac{p}{12}(2-x)^2 + \frac{p}{48} + (x-1)^2\frac{p}{12} + \frac{x^2}{4}\frac{p}{12} + \frac{p}{8}\right]} \quad (2)$$

In most of the inverters improved until now, in order to stabilize the output voltage, the width of the pulses in every period has to be changed as needed. A conventional inverter called “six level PWM inverter” is shown in Fig. 3 .As may be seen from the Figure 5 ,there is only one pulse in every level. However multi-pulses can be arranged on a level, but it will increase switching losses.For the proposed inverter, Fourier coefficients for minimum total harmonic distortion can be calculated by the formula given below

$$\mathbf{a}_n = \frac{4}{n\pi}\left[\left(2-\sqrt{3}\right)\left(\cos\left(\frac{n\pi}{24}\right)-\cos n\left(\frac{\pi}{24}+\delta\right)\right)\right.$$
$$+0.5\left(\cos\left(\frac{n\pi}{8}\right)-\cos n\left(\frac{\pi}{8}+\delta\right)\right)+$$
$$\left(\sqrt{3}-1\right)\left(\cos\left(\frac{5n\pi}{24}\right)-\cos\left(n\left(\frac{5\pi}{24}+\delta\right)\right)\right)+$$
$$\left.\cos\left(\frac{9n\pi}{24}\right)-\frac{\sqrt{3}}{2}\left(\cos\left(\frac{7n\pi}{24}\right)-\cos\left(\frac{7\pi}{24}+\delta\right)\right)\right]$$

(3)

The RMS value of output waveform is given

$$V_{rms} = \sqrt{\frac{2d}{p}\left(13.5-6\sqrt{3}\right)} \qquad (4)$$

(where δ is pulse-width duration)

With reference to equation (3) and (4), in case of $\delta=\pi/12$ the RMS value of the output waveform reaches to its maximum value and THD goes low such as 7.7%. Therefore, this technique seems to have more advantages than PWM technique to provide both output regulation and minimum THD especially for UPS applications.

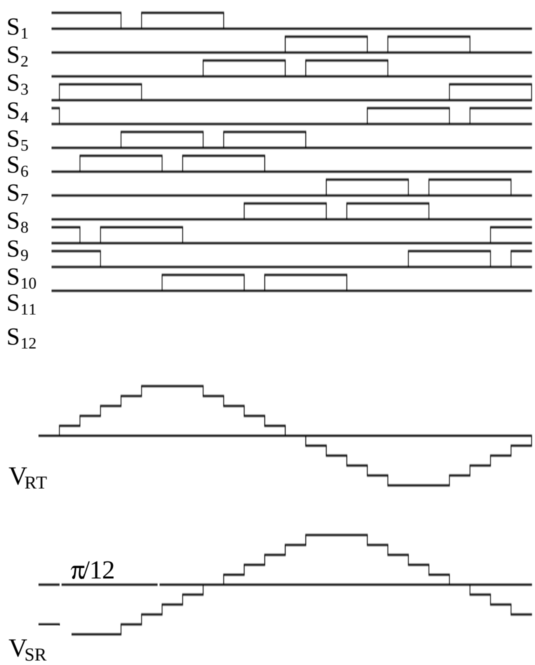

Fig. 3. MOSFET drive pulses and targeted output waveforms

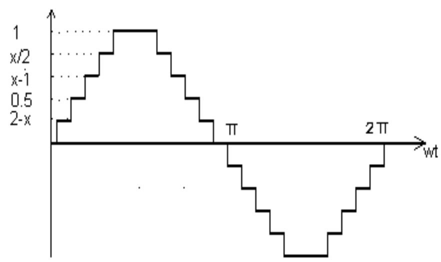

Fig. 4. Output waveform versus transformer winding ratio(x)

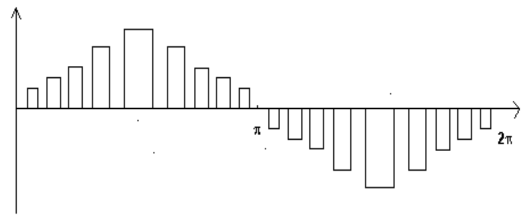

Fig. 5 Output voltage waveform of a convencional inverter

The following advantages have been provided by the proposed method.

- δ is always constant so THD can not increase for different loads and line conditions
- Need a smaller filter
- Lower switching losses
- Lower EMI & acoustic nois e
- No need to deal with modulation indexes.
- Both techniques are compared regarding this harmonic spectrums in Figure 6a and 6b. It is obvious that the decrease of pulse duration δ increases harmonic distortion which can be easily seen as in the example for $\delta=3^0$ compared with the proposed method.

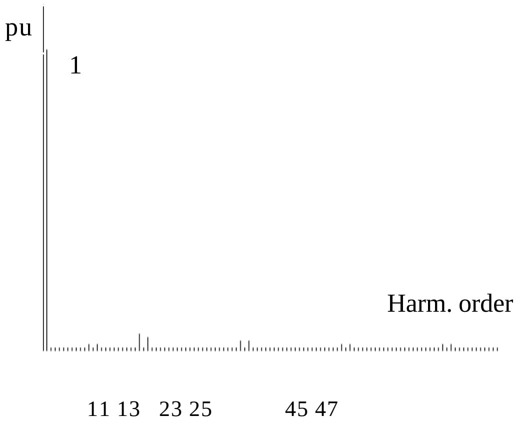

Fig. 6.a. Harmonic Spectrum of proposed inverter sistem

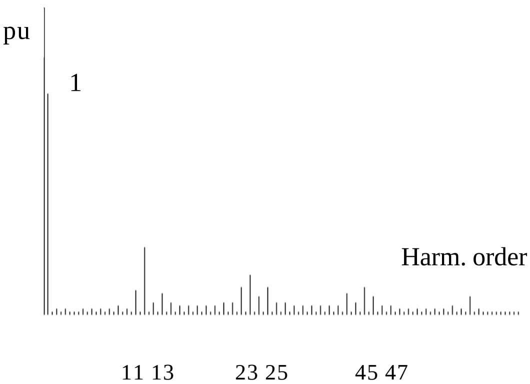

Fig.6.b. Harmonic spectrum of PWM inverter for for $\delta=3^0$

5. DESIGN

As illustrated in Figure 2, an unique three phase transformer may be connected to the switching elements properly to have desired waveforms. In the realized inverter, three single phase transformers are used instead of three phase transformer due to practical reasons. Every transformer has three isolated windings two of them have $\sqrt{3}/1$ ratio. The three seconder windings are star connected so as to have 220/380 V three phase output. Three equivalent transformers have the following parameters:

Transformer rating	N=3x100 VA
First primer windings	$n_1=38$
Second primer windings	$n_2=22$
Secondary windings	$n_S=940$
Iron cross section	$S=13.5x10^{-4}m^2$

As output power is limited at 300W, IRF250 Mosfet is considered to be convenient that has 33A continuos drain current, 200V maximum drain-source voltage. A widespread microcontroller (80C32) is selected from Intel cooperation which has speed high enough for the application. The output waveform of UPS loaded with 100 ohm and a capacitor less than 1 microfarad at the output of the inverter is shown as a osilogram in Figure 5. It may be seen that output voltage waveform of UPS between two different phases would be satisfied for many applications.

6. CONCLUSION

In this study it has been shown that instead of arranging each voltage output step from pulses it is more convenient to implement a microcontroller controlled DC chopper to control DC level in order to have the desired regulated output AC level as an alternative concept in the literature. By the new proposed and realized system THD that increases with the decrease of pulse-width as in the case of pulse-width modulation technique is prevented and kept always at minimum level

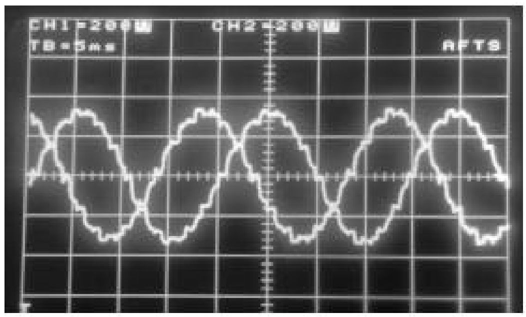

Fig. 7.. Osilogram of Output waveforms (for V_{RT} AND V_{SR} for realized system

Switching loses in power mosfets are also reduced by this way. Considering that the THD is low such as 7.7% without filtering it can be said that the proposed system is very suitable especially for UPS applications.

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Biography of S. Hakan Ündil

S. Hakan Ündil was born in Istanbul, Turkey, 1959. He received both B. Sc. and M. Sc. degrees in Electronics and Telecommunication Engineering from Faculty of Electrical and Electronics Engineering in Istanbul Technical University. He received his Ph.D. degree in Electrical Engineering from the Institute of Science and Technology in Yýldýz Technical University in 1994. He is currently assosiate professor and head of Industrial Electronics Programme in Vocational School of Technology in Istanbul University. His research interests include modeling and simulation, power electronics, control of electrical machines. He is married and has two children.

Biography of Erhan Tunalý

He was born in Istanbul, on may 4th ,1958. After primary school, he continued his education in Deutsche Schule Istanbul , in 1977. He entered Istanbul Technical University in 1977 and received both B.Sc. and M.Sc. degrees from its Faculty of Electrical and Electronics Engineering . From 1984 to 1999, he worked as a research assistant in Control and Computer Department at the same Faculty. In 1998, he received his Ph.D. degree in Electrical Engineering from the Institute of Science and Technology in Yýldýz Technical University, Istanbul with the thesis "A new proposed low distortion inverter for three-phase uninterruptable power supply". Since 1999, he is working in Turkish Standards Institution as calibration engineer. He is married and has a daughter.