A microprocessor-based Load voltage control using an AC chopper

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Abstract

Pulse width Modulated (PWM) control technique for an a-c choppers using harmonic elimination method is proposed. The firing switching instants of a-c chopper for the proposed technique is derived theoretically. By using a microprocessor as a controller, makes it possible to store the firing switching instants time as a look-up table for different load voltage values. Two MOSFET's are used as an a-c chopper. Experimental results verifying the simulation analysis of the a-c chopper fed static (R-L) load and dynamic load (1-ph. induction motor). The proposed strategy is low cost, simplified, and control effective.

Keywords

A-C chopper, MOSFET's, microprocessor, PWM

1. Introduction

A-C choppers or ac voltage regulators have been widely used to obtain variable a-c voltage from a fixed a-c source [1]. A-C choppers are widely used in applications such as industrial heating, lighting control, soft starting of induction motors, speed controllers fans and

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pumps. Many of these are conventional phase-controlled a-c controllers using thyristors, which have the advantages of simplicity of the control circuit and large power capability. However, these have the inherent drawbacks that power factor decreases when the firing angle increases and that, Since the content of the line current harmonics is relatively large. The size of the passive filter circuit becomes bulky. These drawbacks can be overcome by using PWM a-c chopper.

This chopper offers several advantages such as sinusoidal input current with unity power factor, fast dynamics, and significant reduction in filter size. Some of PWM a-c chopper that has been used is symmetrical angle control, asymmetrical angle control and high-frequency time ratio control [2]. The developments achieved in the field of power electronics made it possible to improve the performance of electrical system utilities. Usually solid state power switching devices are employed in source conditioning by changing either its magnitude or frequency such as converter, inverters, choppers, regulators or cycloconverters. An a-c voltage regulator is used as one of the power electronics systems to control an output ac voltage for power ranges from few watts up to fractions of mega-watts. Phase-angle microprocessor based harmonic elimination in chopper type ac voltage regulators is used [3]. In this type of regulator, output voltage is controlled by varying the ON/OFF time ratios of a series controlled switch using a microprocessor as a controller makes it possible to vary firing instants according to a predetermining firing instants such that selected dominant lower order harmonics can be eliminated. This in turn leads to improve system power factor and efficiency.

In this paper, a PWM ac inverter harmonic elimination technique is used. For a half cycle of the a-c source, a PWM switching function composed of M pulses is assumed. Fourier coefficients of PWM output voltage are then obtained, which are expressed in terms of the M switching point variables. In addition, the constrains for required output fundamental voltage and elimination of harmonics up to 2M-1 order, yield M equations. Solution of these equations enables the derivation of the required PWM switching pattern for the chopper [4]. Only two MOSFET's controlled by a microprocessor are used to achieve PWM technique for an a-c chopper. Different loads are used R-L load and dynamic load (1-ph. induction motor) in this system. Practical verification of the theoretical predictions is presented.

2. Description of PWM a-c chopper

The power circuit of a PWM a-c chopper is composed of two uncontrolled bridges and pair of MOSFET's,, connected one in series, and one in parallel (freewheeling) with the load as shown in Fig. 1. The series connected MOSFET regulates the power delivered to the load, and the parallel one provides the freewheeling path to discharge the stored energy when the series one is turn off . A power MOSFET is a voltage-controlled device and requires only a small input current. The switching speed is very high and the switching times are of the order of nanoseconds. Synchronization signal is transferred into carrier signal through synchoization circuit and input to microprocessor. An INTEL 8085 microprocessor is used in this applications because it is available, low cost and sufficient. An assembly program stored in EPROM memory interfaced with microprocessor selects the required switching instants from a look-up table that contains different switching instants corresponding to K value. Charging a timer for ON-time or OFF time and output two signals from output port of microprocessor delivers Two MOSFETs. A synchronization circuit and driver circuit of MOSFET are shown in Figs. 2, 3 respectively.

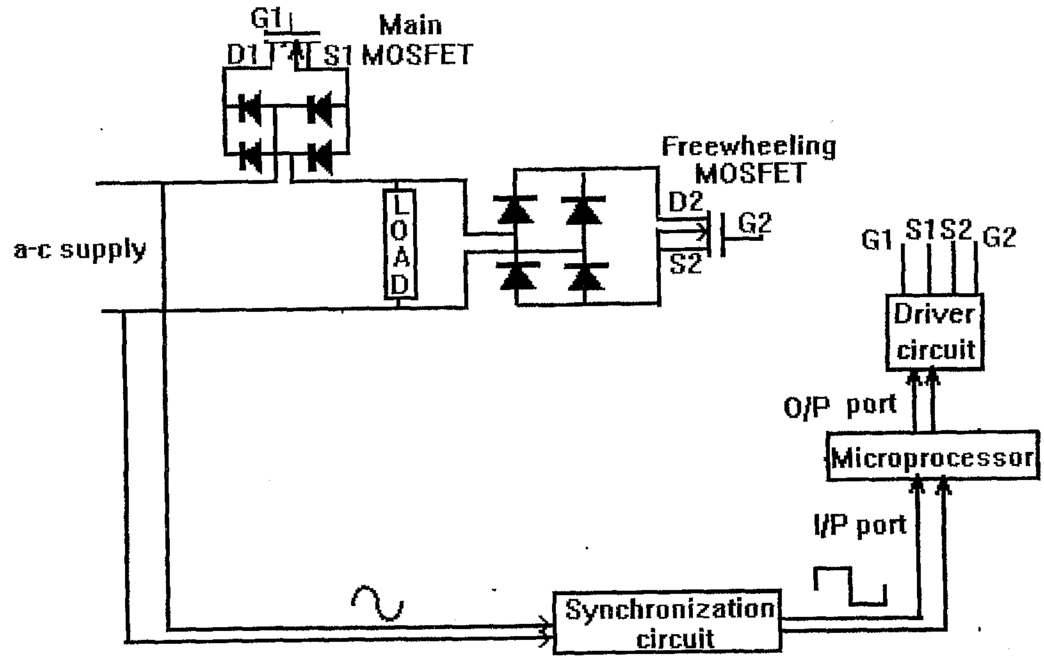

Fig. 1 A proposed system of a PWM a-c chopper

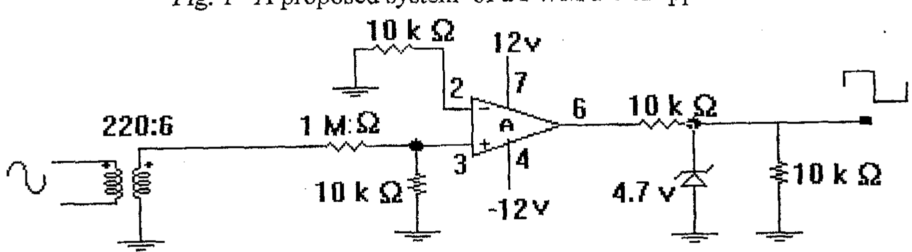

Fig. 2 Synchronization circuit

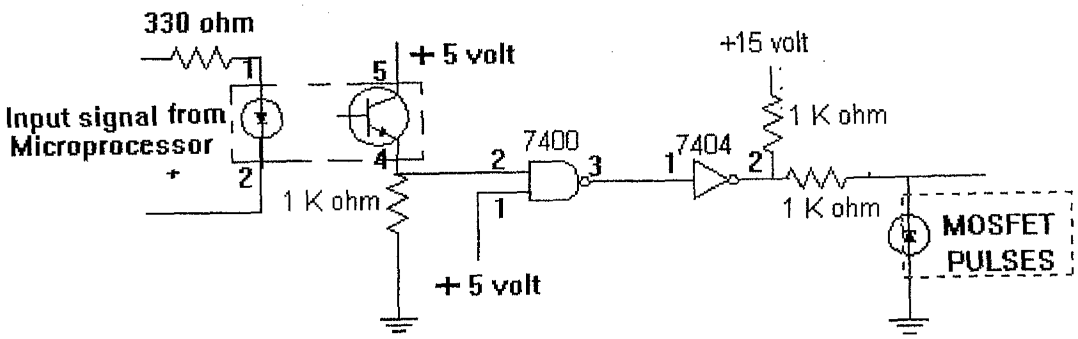

Fig. 3 Driver circuit for MOSFET

Consider the output voltage waveform shown in Fig. 4, with six off periods embracing five voltages pulses per half cycle. Here, number of On and OFF periods per half cycle is eleven that is the dominant harmonic for PWM firing strategy. Assuming arbitrary switching angles $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ per quarter of a cycle, wave is symmetric around $\pi/2$ and performing frequency harmonic analysis yields

$$A(1) = \frac{2}{\pi} \int_0^{\frac{\pi}{2}} \sin^2\Theta \, d\Theta =$$

$$\frac{1}{\pi} \left| \Theta - \frac{\sin 2\Theta}{2} \right|_0^{\pi/2} \text{ p.u.}$$

$$A(n) = \frac{2}{\pi} \left| \frac{\sin(n-1)\Theta}{n-1} - \frac{\sin(n+1)\Theta}{n+1} \right|_0^{\pi/2} \quad \text{p.u.}$$

$B(1), B(3), B(5)$ .... $B(n) = 0$ (quarter-wave symmetry)

It is clear that there exist five unknown which in turn requires five equations for its evaluation. This implies that there are five constraints ought to be fulfilled in selecting values of these angles. These constraints can be set in the following way:

$$A(1) = K = \frac{2}{\pi} \left| \Theta - \frac{\sin 2\Theta}{2} \right|_0^{\pi/2}$$

Where: K = ratio between peak value of fundamental load voltage component to peak value of input supply voltage. It could be then concluded that number of constraints equals number of switchings per quarter of a supply voltage cycle. This means that increasing number of switchings will in turn lead to eliminate more harmonics. [3].

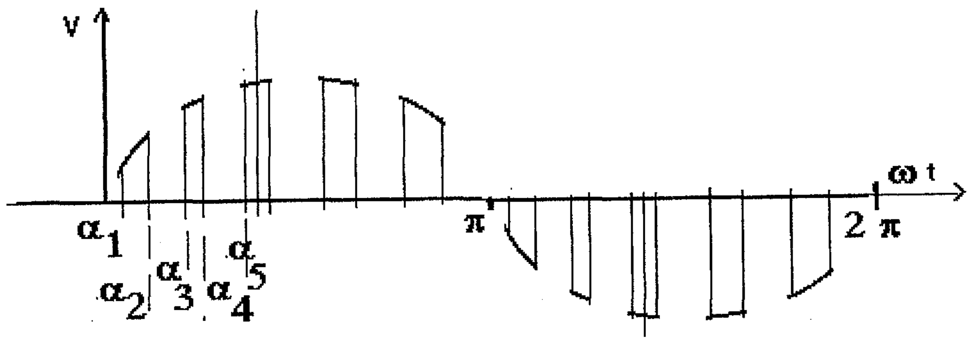

Fig. 4 Voltage waveform harmonic elimination

3- Simulation and Experimental results

A program was constructed for evaluating MOSFET switching angles with eleventh components eliminated. A flowchart is shown in Fig. 5 represents a program. Load current is calculated from the following equation:

$$V_L = R\, I_l + L \frac{d\, I_l}{dt}$$

$V_L = V_S$ at main MOSFET is turned ON but VL= 0 at main MOSFET is turned OFF

So, the last equation is solved using 4 th order Rung-Kutta technique taking a step of calculation is 0.1 m. Sec., hence supply current is determined from load current . Theoretically, and in ideal case, supply current = load current in case of turning ON main MOSFET, but reaches to zero otherwise.

The calculated and experimental results are presented for five switching instants per quarter cycle of supply voltage waveform and R-L load with R= 56 ohm and L= 50 m.H., supply voltage = 110 volt and supply frequency = 50 Hz. In ideal case, during turn on of main MOSFET (in series) , load voltage equals to supply voltage (neglect drop voltage through uncontrolled bridge and MOSFET) but in other hand, at main MOSFET is turn off, load voltage equals to zero because of freewheeling MOSFET parallel path across load. The main, parallel MOSFETs and synchronization signal at different values of factor K where K = ratio between peak value of fundamental load voltage to peak value of input supply voltage is shown in Fig. 6, the result shows that a good accuracy of a zero crossing determined by a microprocessor program and hence an appropriate pulse to MOSFETS. Also, simulation studies of supply current, load current and terminal load voltage are represented at Figs. 7a,b - 10 a, b for different values of K. A good agreement between experimental and simulation results, load current is nearly sinusoidal as increased in factor K. Instead of R-L load, a single phase induction motor (1/6 HP, 220 volt, 0.5 Amp.) is connected as a load. Supply current, motor current and terminal voltage for different values of K are shown in Figs. 11-14 . The a-c input current has discontinuities during every cycle even the load current becomes roughly sinusoidal. The speed of the motor against the variation of factor K is shown in Fig. 15 . To make the filtering burden less, it is required to increase the number of pulses per quarter cycle. Also this can improve the wavform of the load voltage close to the pure sine wave but it is necessary to use a suitable microcontroller or a fast microprocessor to generate a required pulse to MOSFETs. Fourier analysis of load voltage for different values of K factor is shown in Fig. 16a,b,c,d

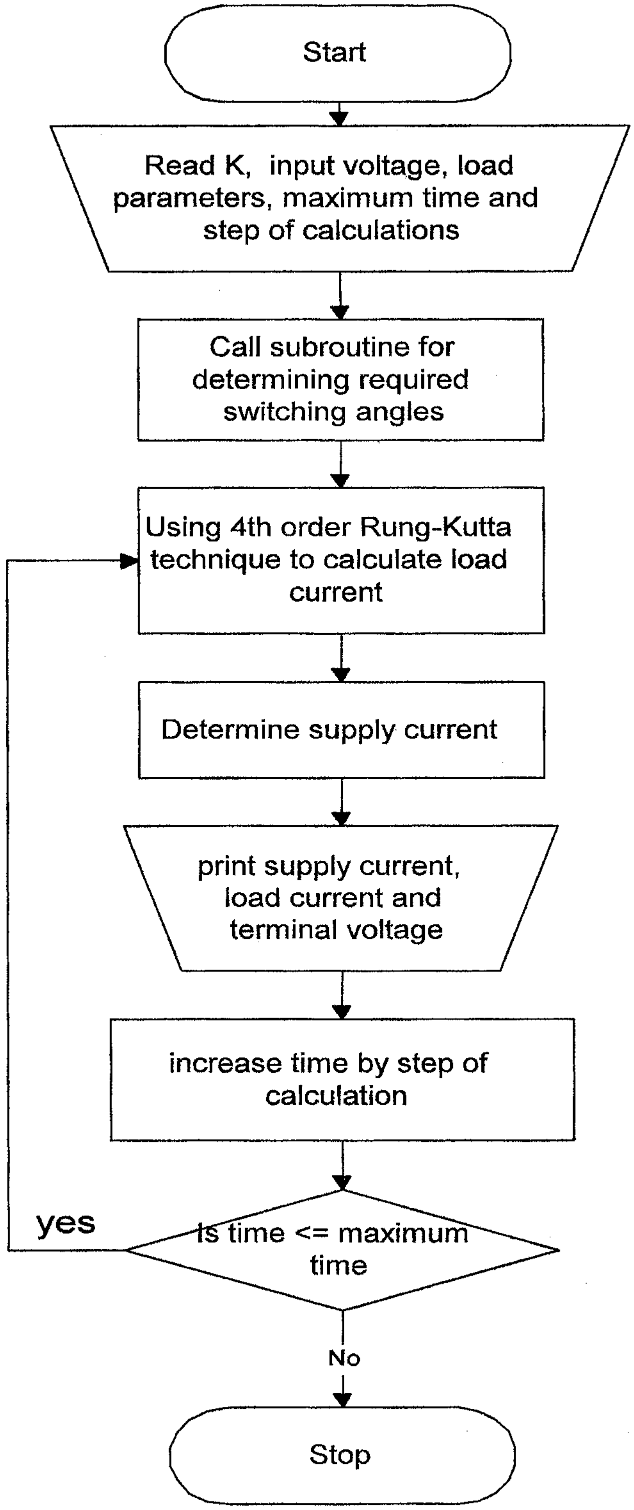

Fig. 5 A flowchart represents a simulation program.

4. Conclusion

In this paper, a real time control of load voltage is proposed based on an harmonic elimination of PWM ac chopper using microprocessor as a controller for selecting a required switching instants of chopper from a stored look-up table in EPROM memory interfaced with a microprocessor. Experimental result has been constructed using a microprocessor to verify the feasibility of the control system. A good agreement is obtained between the calculated and experimental results.

Symbols

D1, S1, G1: drain, source and gate of mosfet number 1.

D2, S2, G2: drain, source and gate of mosfet number 2.

K: ratio between peak value of fundamental load voltage to beak value of input supply voltage.

R-L : staric load consists of resistance and inductance.

M: number of pulses per one cycle for driving mosfet.

V_L : Load voltage

V_S: Supply voltage

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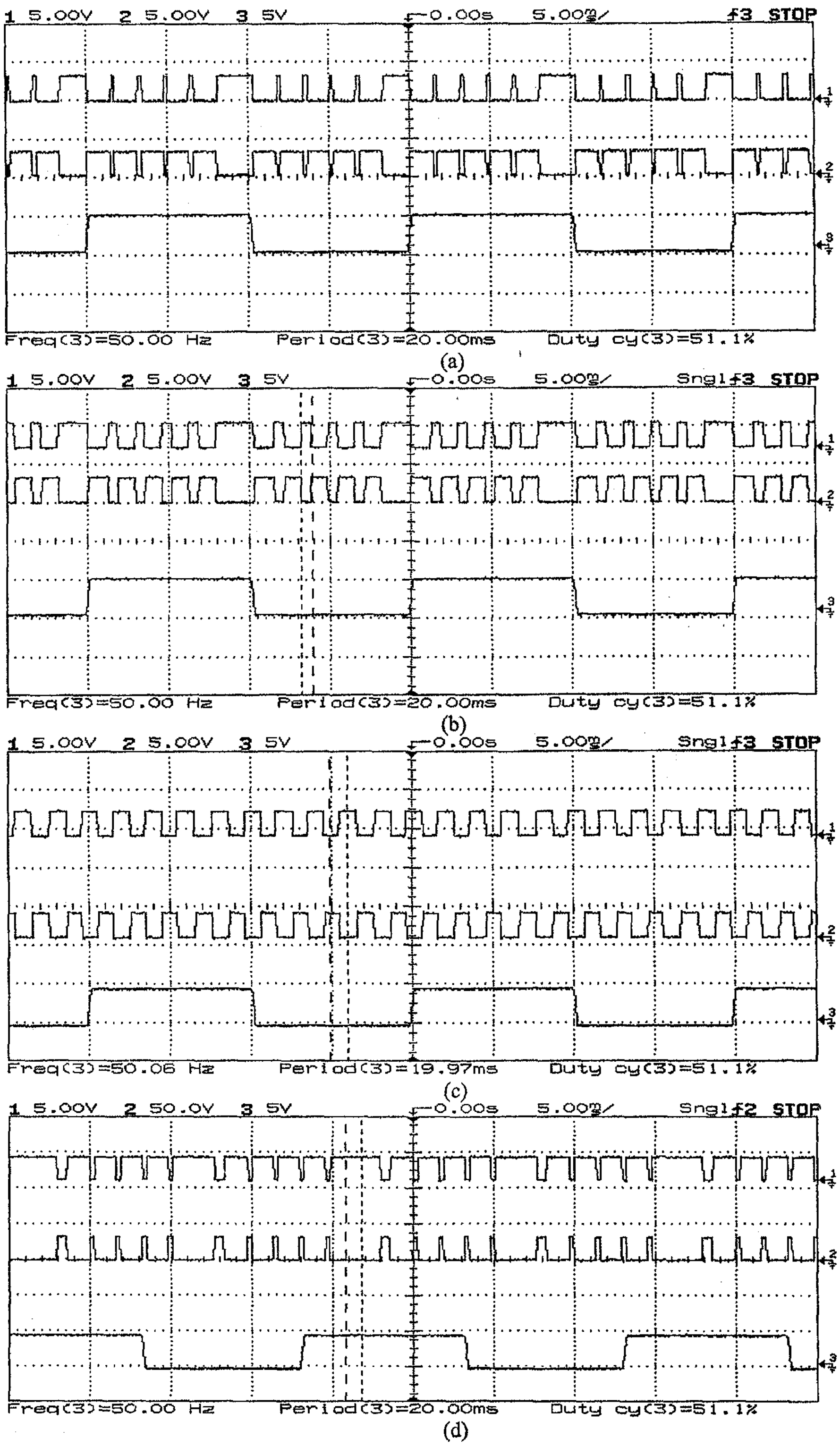
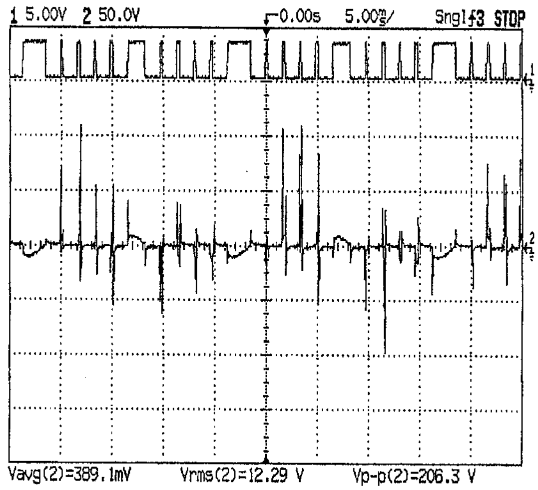
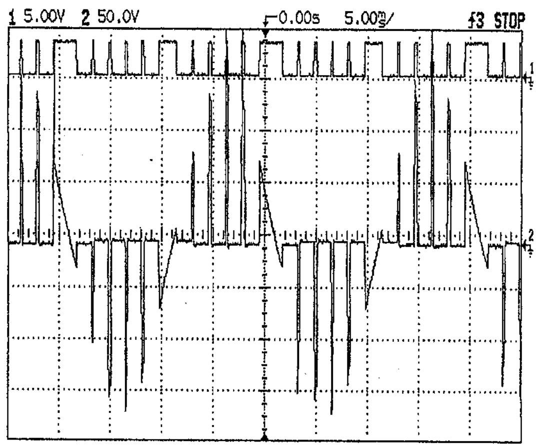


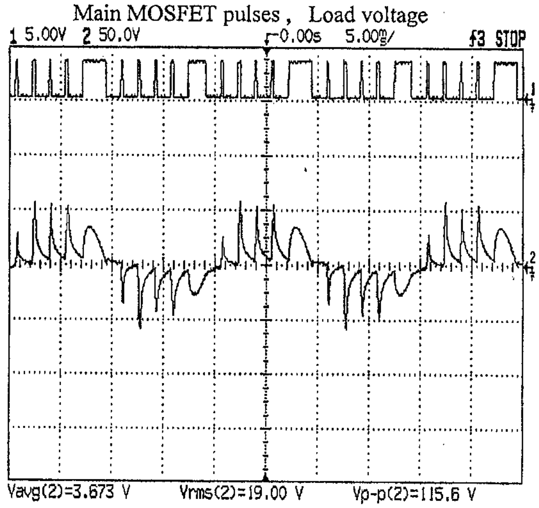
Fig. 6 Main MOSFET pulses, parallel MOSFET pulses and synchronization signal at
(a) K= 0.2 (b) K= 0.4 (c) K= 0.6 (d) K= 0.8



Main MOSFET pulses, and supply current
(1 amp. = 1 div. / 16)



Main MOSFET pulses , Load voltage



Main MOSFET pulses, and load current
(1 amp. = 1 div. / 56)
Fig. 7a Experimental results of R-L load for K=0.2

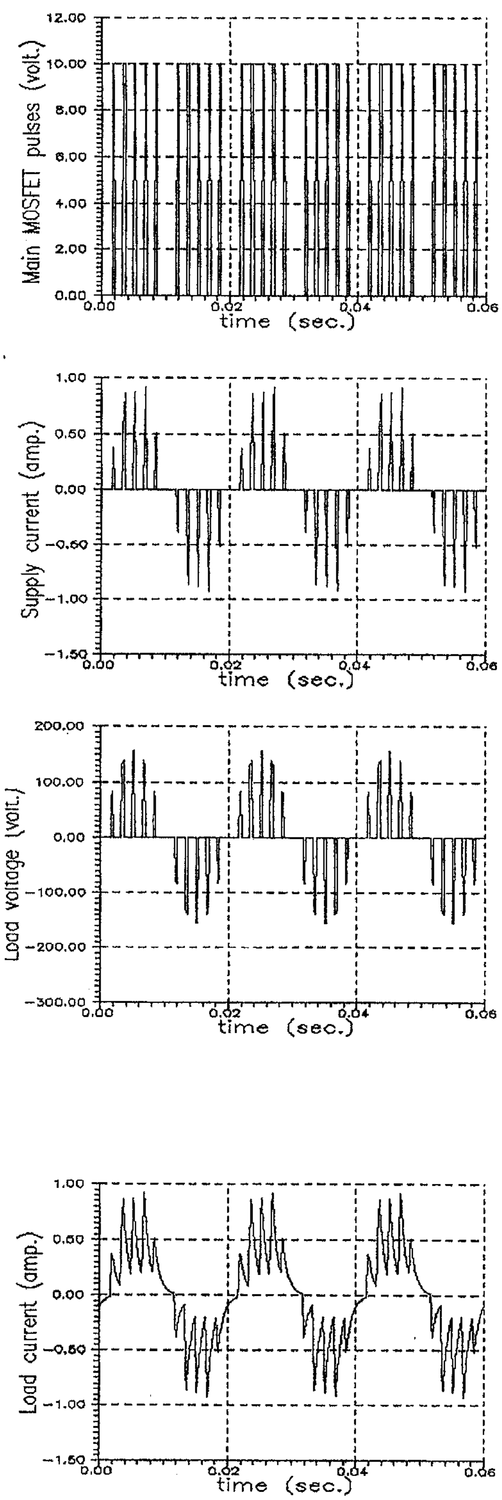
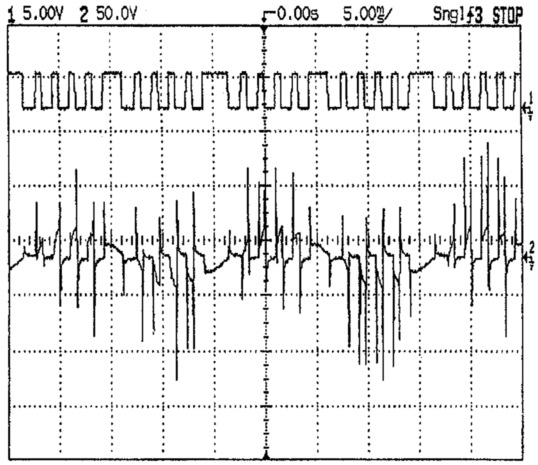
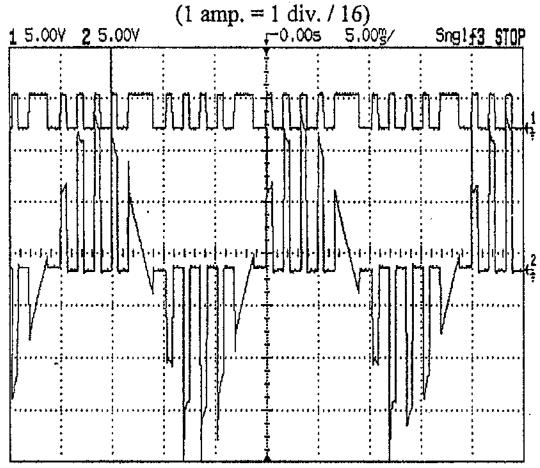


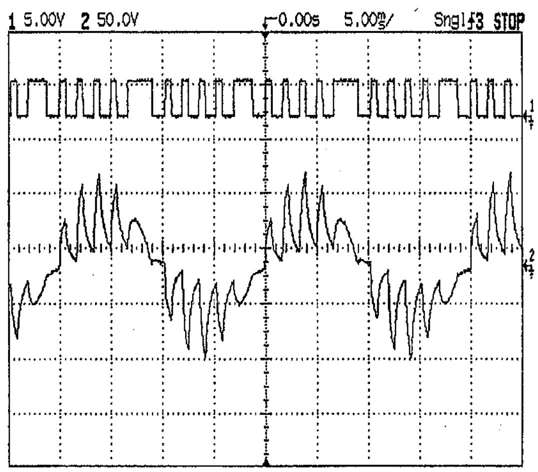
Fig. 7b Simulation results of R-L load for K= 0.2



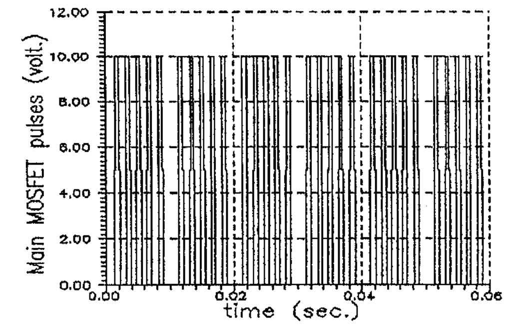
Main MOSFET pulses, and supply current
(1 amp. = 1 div. / 16)

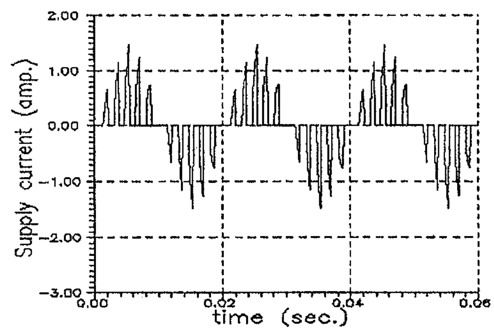


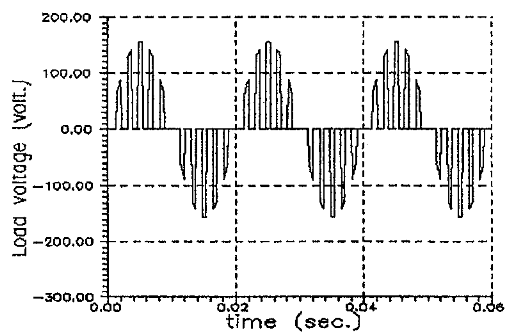
Main MOSFET pulses , Load voltage



Main MOSFET pulses, and load current
(1 amp. = 1 div. / 56)
Fig. 8a Experimental results of R-L load for K=0.4







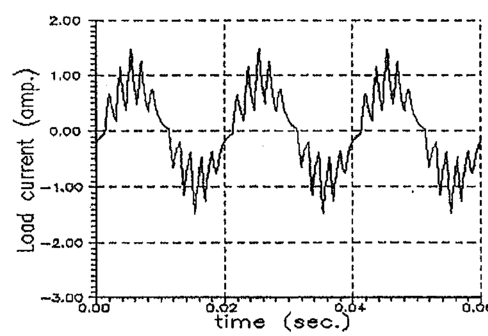
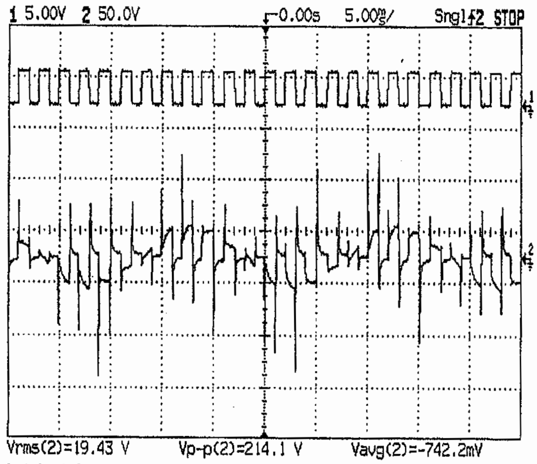
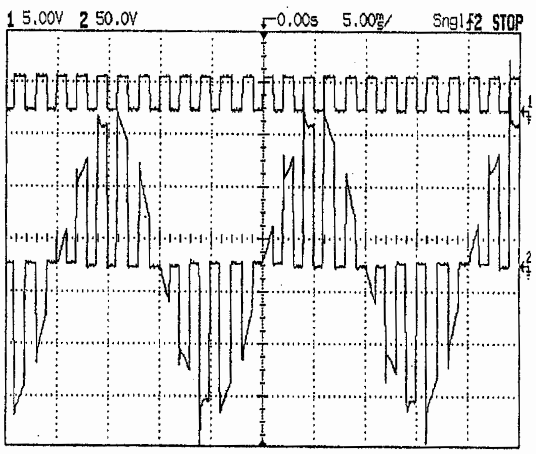


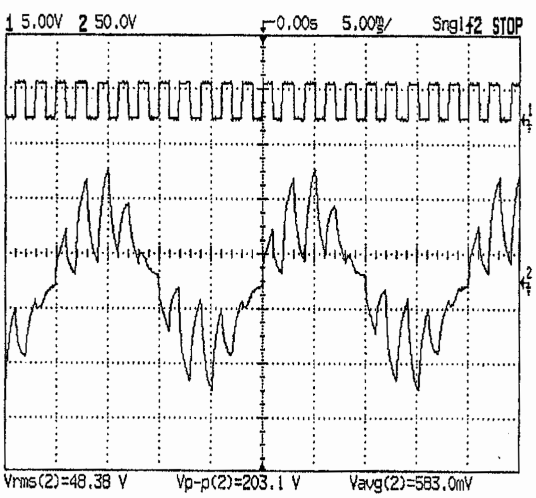
Fig. 8b Simulation results of R-L load for K= 0.4



Main MOSFET pulses, and supply current
(1 amp. = 1 div. / 16)



Main MOSFET pulses , Load voltage



Main MOSFET pulses, and load current
(1 amp. = 1 div. / 56)
Fig. 9a Experimental results of R-L load for K=0.6

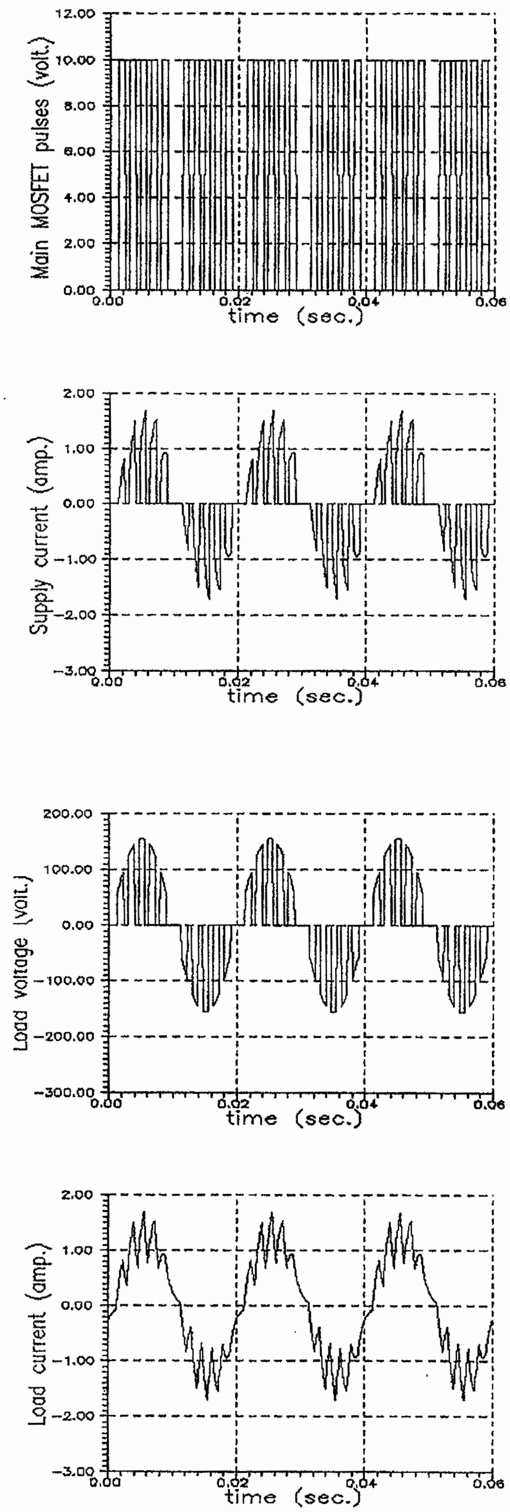
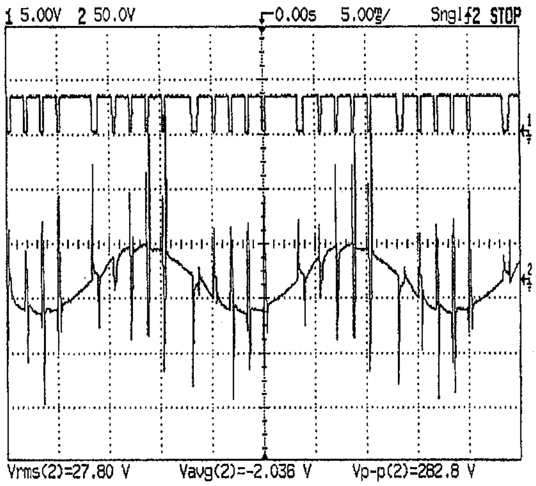
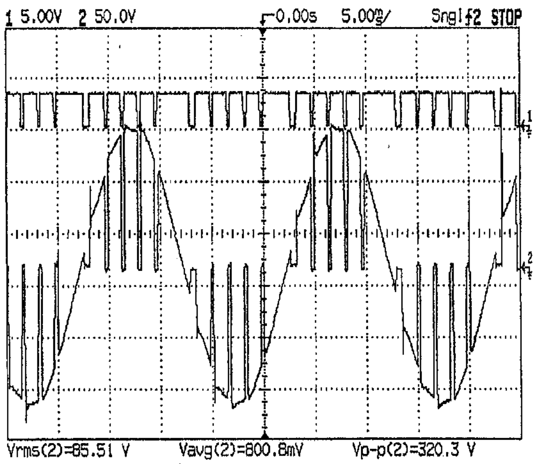


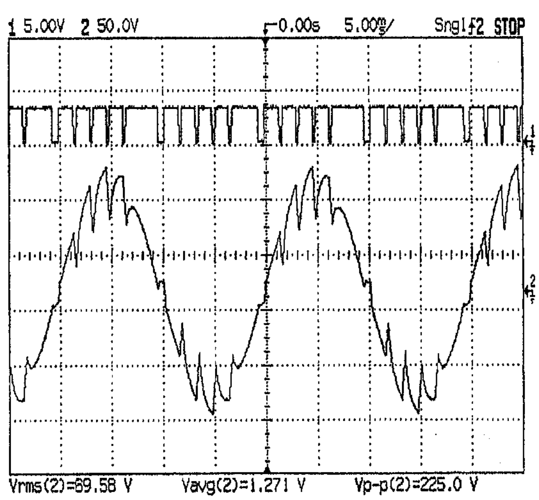
Fig. 9 b Simulation results of R-L load for K= 0.6



Main MOSFET pulses, and supply current
(1 amp. = 1 div. / 16)



Main MOSFET pulses , Load voltage



Main MOSFET pulses, and load current
(1 amp. = 1 div. / 56)

Fig. 10a Experimental results of R-L load for K=0.8

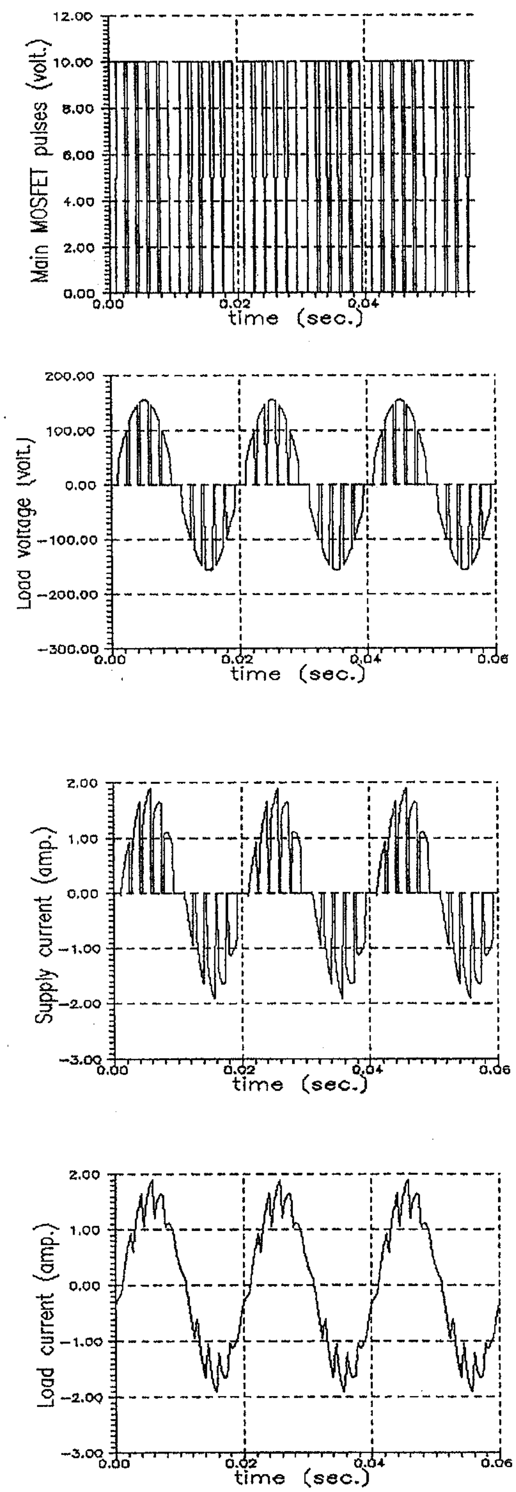
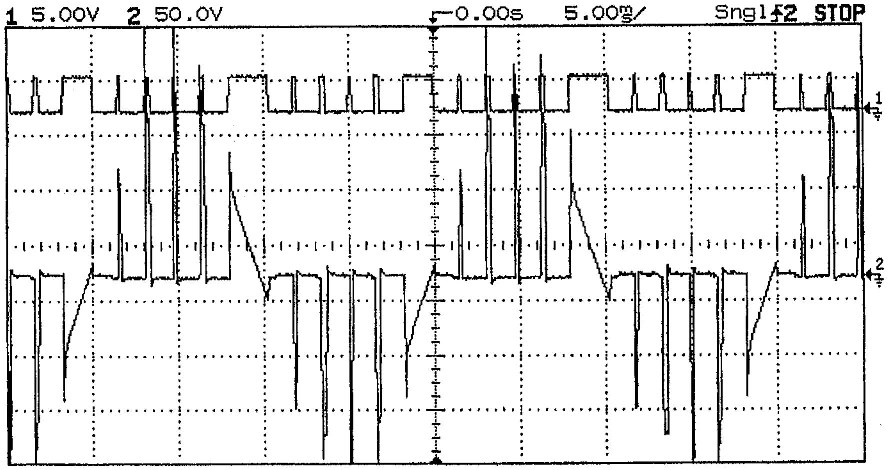
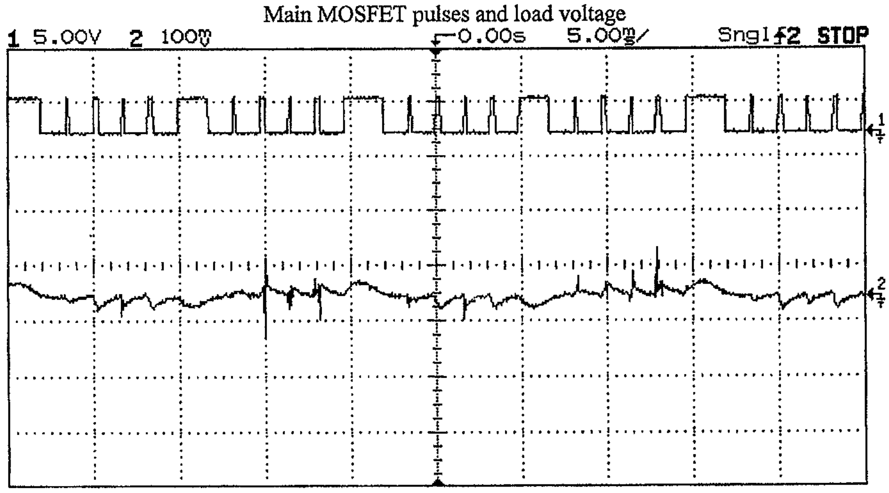


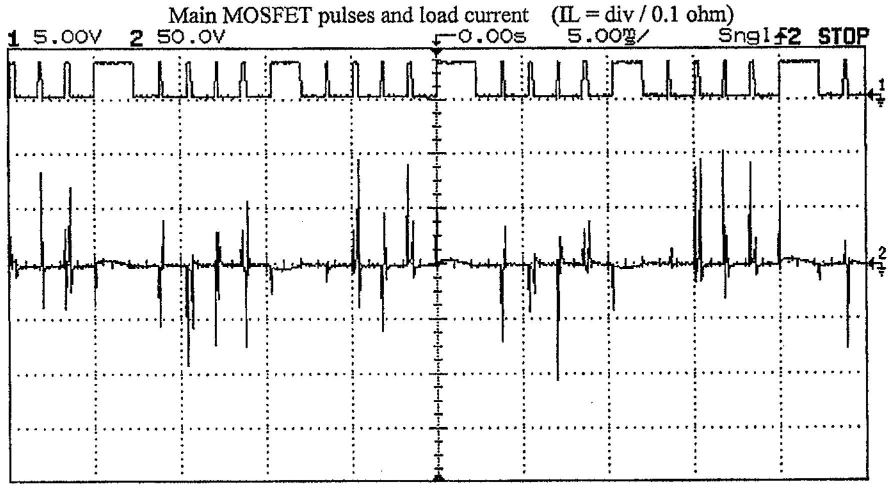
Fig. 10b Simulation results of R-L load for K= 0.8



Main MOSFET pulses and load voltage

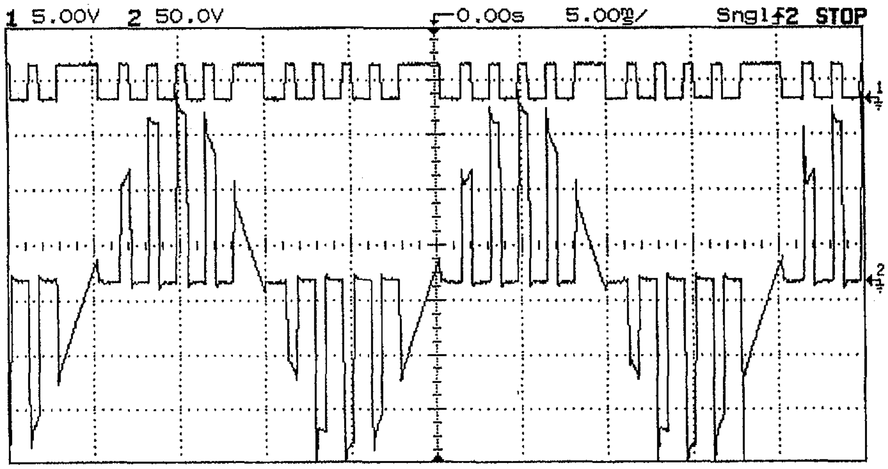


Main MOSFET pulses and load current (IL = div / 0.1 ohm)

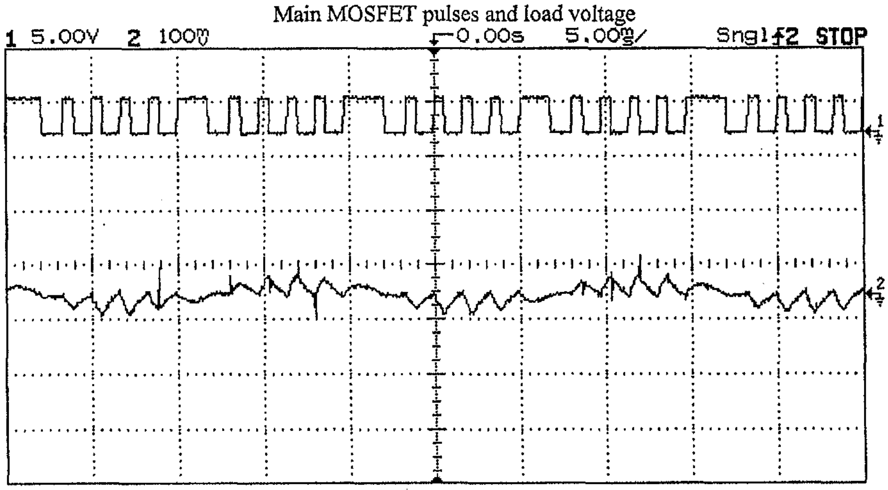


Main MOSFET pulses and supply current (Is = div. / 20 ohm)

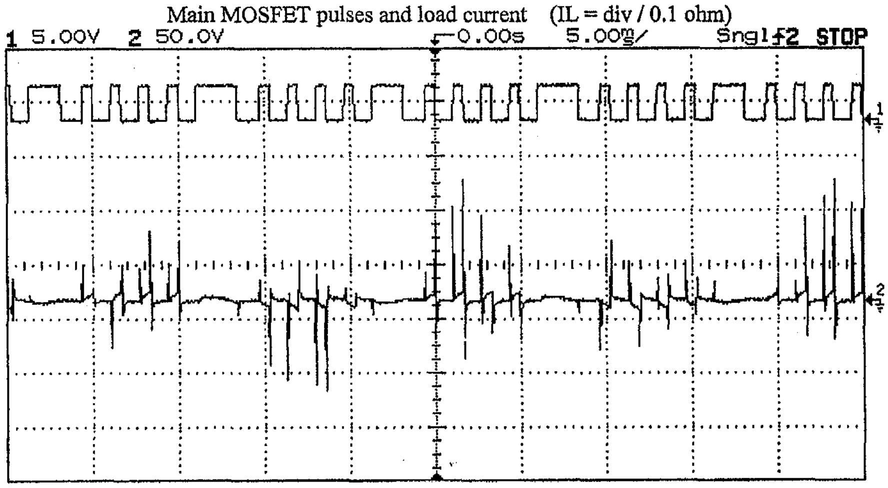
Fig. 11 Motor performance for K=0.2 and motor speed =287 r.p.m.



Main MOSFET pulses and load voltage

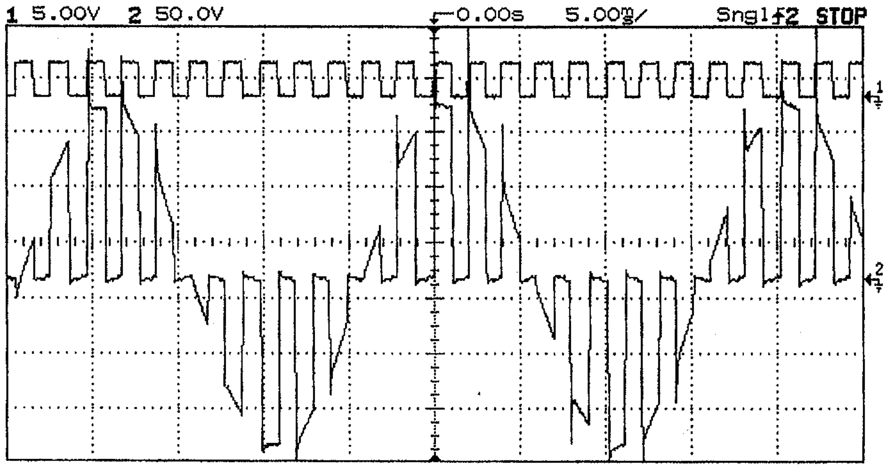


Main MOSFET pulses and load current (IL = div / 0.1 ohm)

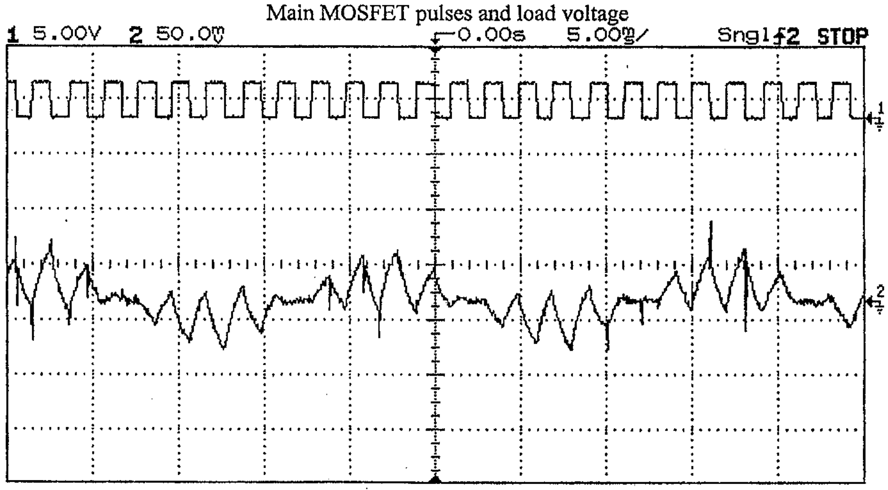


Main MOSFET pulses and supply current (Is = div. / 20 ohm)

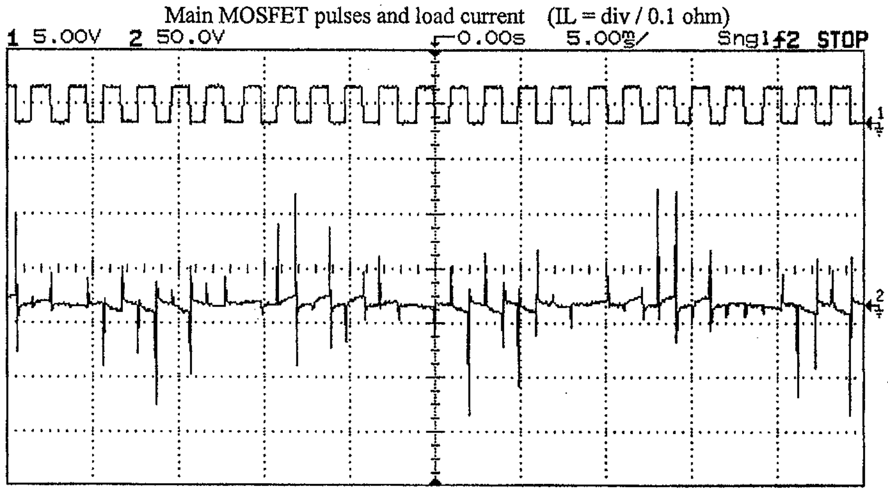
Fig. 12 Motor performance for K=0.4 and motor speed =2560 r.p.m.



Main MOSFET pulses and load voltage

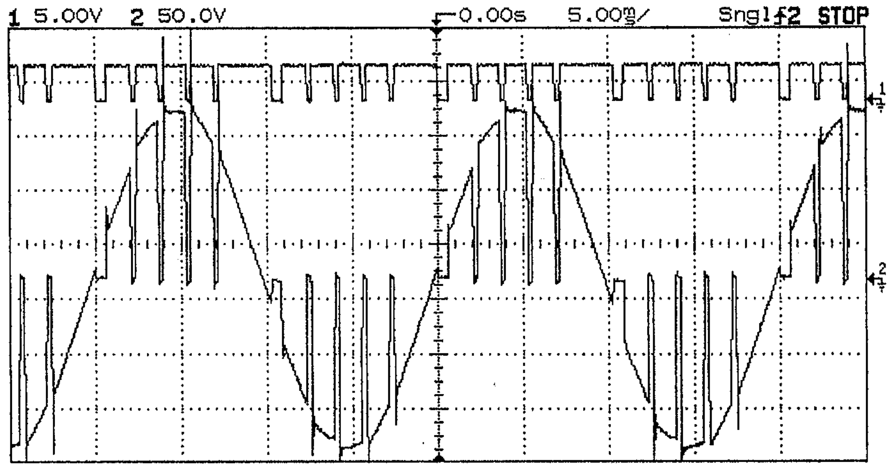


Main MOSFET pulses and load current (IL = div / 0.1 ohm)

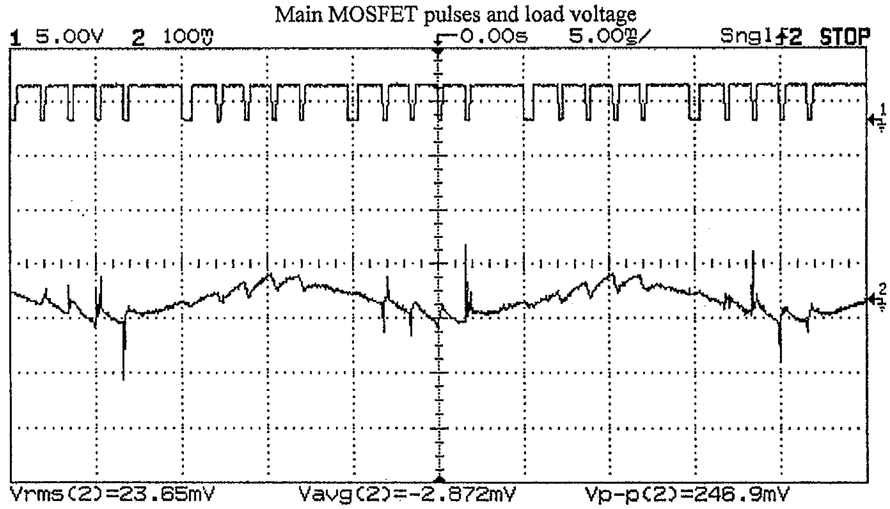


Main MOSFET pulses and supply current (Is = div. / 20 ohm)

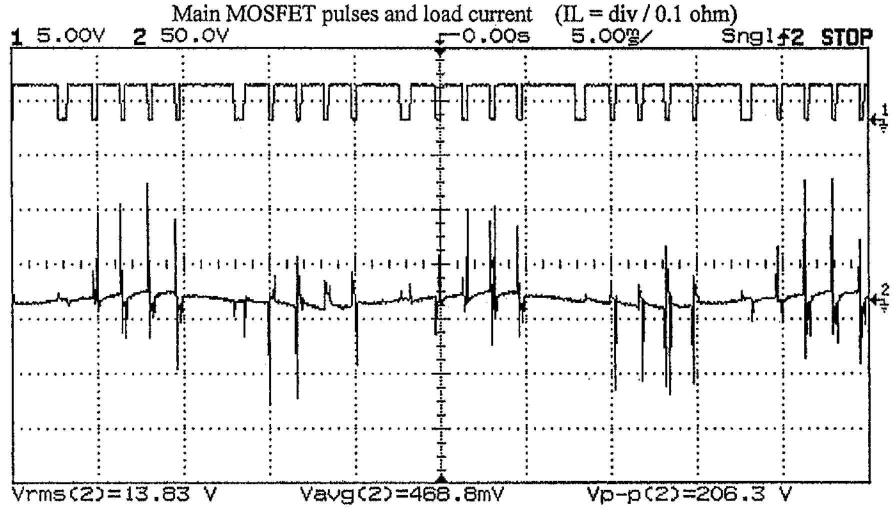
Fig. 13 Motor performance for K=0.6 and motor speed =2812 r.p.m.



Main MOSFET pulses and load voltage



Main MOSFET pulses and load current (IL = div / 0.1 ohm)



Main MOSFET pulses and supply current (Is = div. / 20 ohm)

Fig. 14 Motor performance for K=0.8 and motor speed =2910 r.p.m.

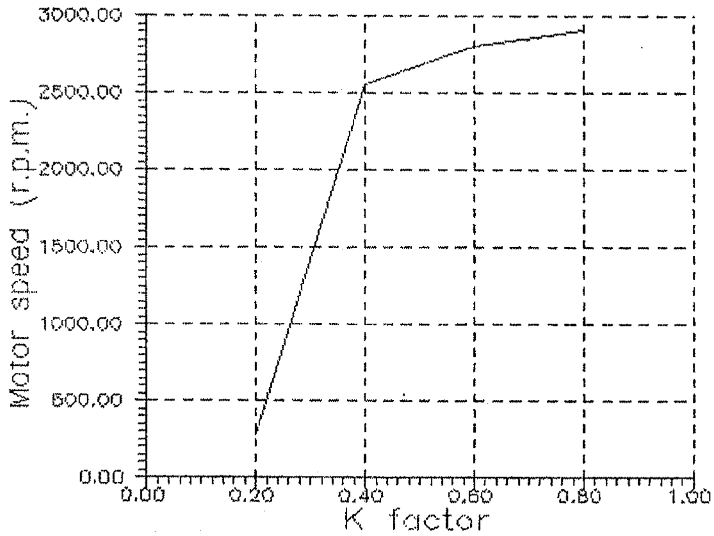


Fig. 15 Motor speed against K factor

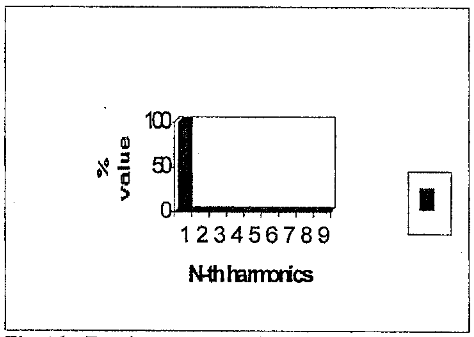


Fig. 16a Fourier spectrum of load voltage for K=0.2

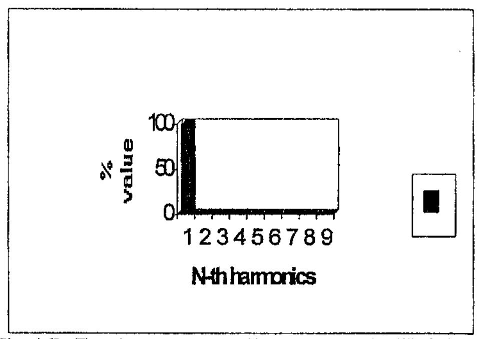


Fig. 16b Fourier spectrum of load voltage for K=0.4

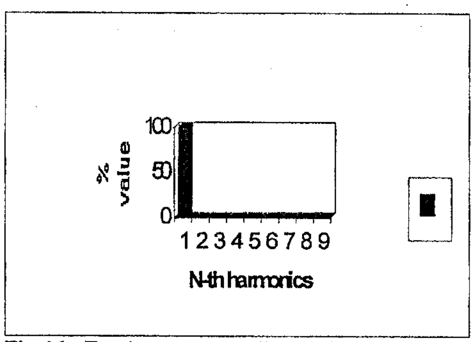


Fig. 16c Fourier spectrum of load voltage for K=0.6

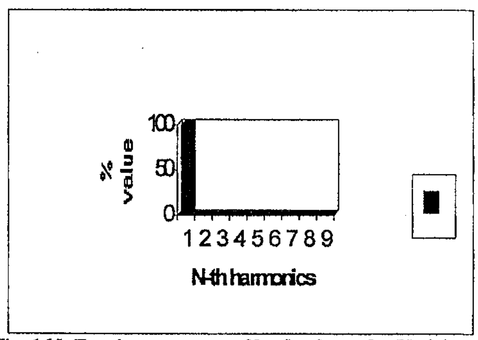


Fig. 16d Fourier spectrum of load voltage for K=0.8

التحكم في جهد الحمل بإستخدام مجزئ الجهد متغير مستخدما الميكروبروسيسور

د٠أشرف زين الدين ، م٠ زياد محمد
أ٠د٠عباس على الحفناوى ، أ٠د٠عادل شبل عبد الغفار

الملخص

يتناول هذا البحث التحكم فى جهد الحمل طبقا للقيمة المراد ضبط الجهد عندها وذلك بإستخدام مجزئ الجهد مع حذف التوافقيات وفى هذه الطريقة يستخدم إثنين من الترانزستور من النوع MOSFET ويتصل إحداهما على التوازى (الفرعى) مع الحمل بينما يتصل الآخر على التوالى مع مصدر الجهد المتغير(الترانزيستور الرئيسى) مع ملاحظة وجود قنطرة إلكترونية مكونة من أربعة diodes مع كل ترانزستور ويتم ضبط جهد الحمل عن طريقة تغذية كل من الترانزيستورين الرئيسى والفرعى بنبضات كهربية كمخرجات من بوابة الميكروبروسيسور الذى يلعب دور كبير فى تحديد الفترات الزمنية لإشعال كل من الترانزيستورين طبقا للبرنامج الذى تم كتابته بلغة التجميع والذى يقوم بتحزين قيم مختلفة لفترات الإشعال داخل ذاكرة قابلة للكتابة والبرمجة متصلة بالميكروبروسيسور على هيئة جداول لحالات مختلفة من جهد الحمل ثم يقوم بإختيار الجدول المناسب للإشعال طبقا لجهد الحمل المطلوب٠ وتم عمل دراسة تحليلية وعملية للطريقة المقترحة وذلك على حمل إستاتيكى مكون من مقاومة وملف وأيضا على حمل ديناميكى عبارة عن محرك أحادى الوجه٠ وبمقارنة النتائج التحليلية والعملية وجد تطابق بينهما٠ هذا بالإضافة إلى ان إنخفاض التكلفة للنظام المقترح للتحكم فى جهد الحمل والآداء الجيد للنظام مع البساطة والفاعلية ٠