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DIGITAL CONTROL OF A THYRISTOR-DRIVEN D-C MOTOR

BY

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ABSTRACT

Phase control represents an effective means of controlling the average power delivered to a load. The principle of phase control is used to control the speed, current and torque of a separately excited D-C motor. The interference between the operator and the control circuit is provided by a set of coded instructions through a minicomputer software. The idea of decentralized control is implemented. The computer program (written in Assembly Language)as well as the wiring diagram are included.

1. INTRODUCTION

The growth of electric drives has closely paralleled the growth of automation in industry. Electric drive systems provide a convenient means for controlling the operation of industrial machinery. The high reliability and great versatility of these systems is a direct interpretation for their wide spread applications[1].

The use of computers instead of controller units in electric drives represents a major advance in the philosophy of control. Computer control have recently been enhanced by the tremendous achievements in manufacturing integrated circuits[2]. The major contribution of computers in cotrol means a change from purely hard-ware based control to a soft-ware based systems. This actually brings out two main advantages:

1) An increase in control flexibility, and
2) A reduction and simplification in hard-ware circuits.

In other words, the modification of any drive system to suit specific needs simply means reprogramming instead of rewiring.

Another advantages of computer control is that, the closed-loop feedback device is an encoder which makes the control loop relatively simple.

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Fig. (1) illustrates the basic computer control schems using microprocessor. Because of the introduction of sampling and the use of microproceseor in this type of system, lower loop gains had to be used for the position servo loop.

The advent of microprocessors and their flexible programmability have rapidly enhanced the decentralised control of electric drives. The application of microprocessors in cotrol has opened a wide range of opportunities for improved control through strategics using the logical and computational capacity of the ever-developed microprocessors. They provids solutions to problems encountered with the early computer control systems such as data transmission, timing problems and initial investments[3]. In other words, they provide solution to tbe problems of both costs and complexity. In addition, recent generation of microprocessors operates at sufficient speeds which match the requirements of practical control systems and increase the flexibility of digital control.

This paper is intended to implement the ldeas cited above to the control of a variable speed, separately excited D-C motors. The variable speed have been obtained by the use of "phase control of a thyristor bridge[4]". Bef ore we proceed, the principle of phase control will be summarised.

2. PRINCIPLE OF PHASE CONTROL:

Phase control is the process of rapid on-off switching which connects an a.c. supply to a load for a controlled fraction of each cycle. The process is achieved using solid-state elements and the arrangement is known as "phase-controlled conventer".

Phase-controlled conventers consist, basically, of a rectifier circuit arrangement in which some or all of the rectifier devices are silicon-controlled rectifiers (SCR's).

Phase-control techniques have the following advantages:

1) The absence of wear out mechanism which is present in mechanical switches,
2) High speed performance,
3) The circuit is usually simple and less expensive, and
4) The circuit is inherently proportional control.

There are many forms of phase control with SCR's[4]. Fig.(2) shows a simplified scheme of a full wave bridge, together with the voltage curve for a given delay angle α, for a resistive load. It is obvious that the increase of α will reduce the power delivered to the load and in case of motor load, will decrease the speed. A starting resistor, in this case, is no longer necessary because the average motor voltage is zero at $\alpha = 180°$, and can be increased to its maximum value at $\alpha = 0°$.

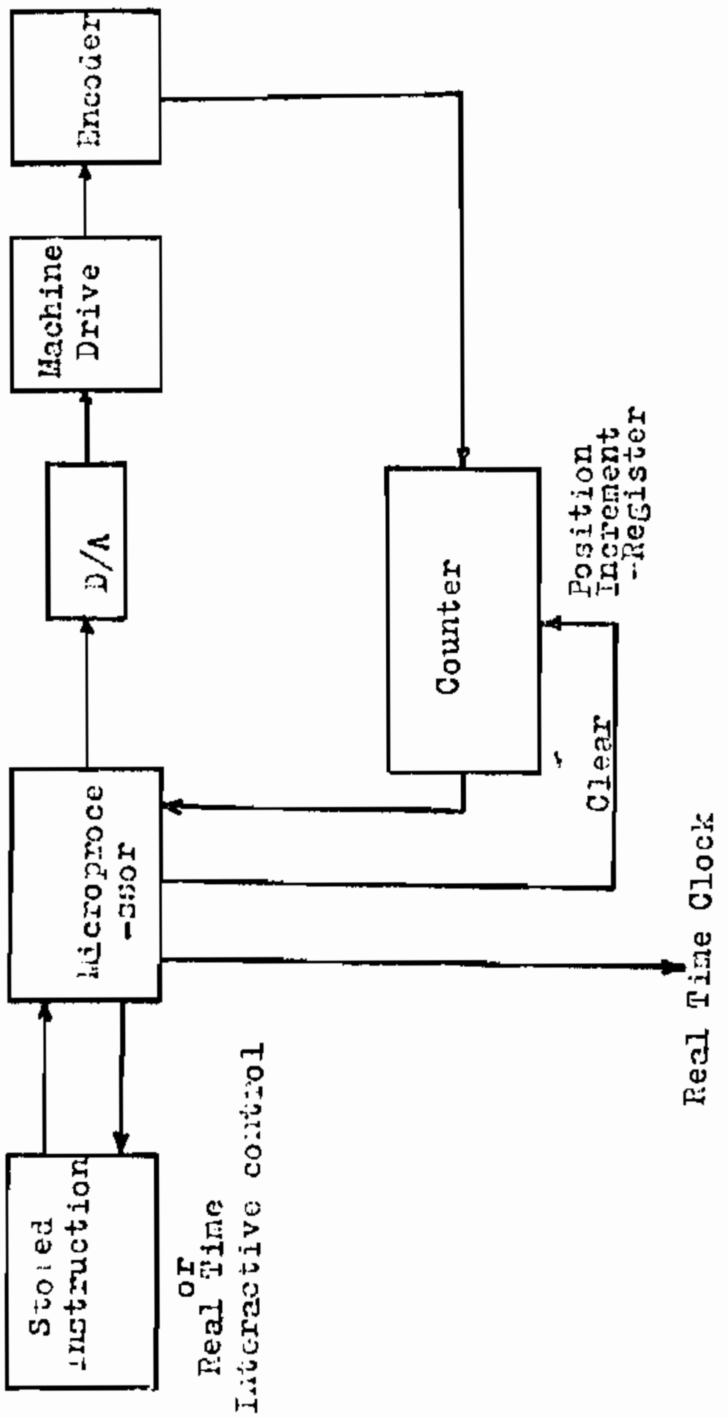

Fig. 1: Basic Computer Control Scheme Using Microprocessor

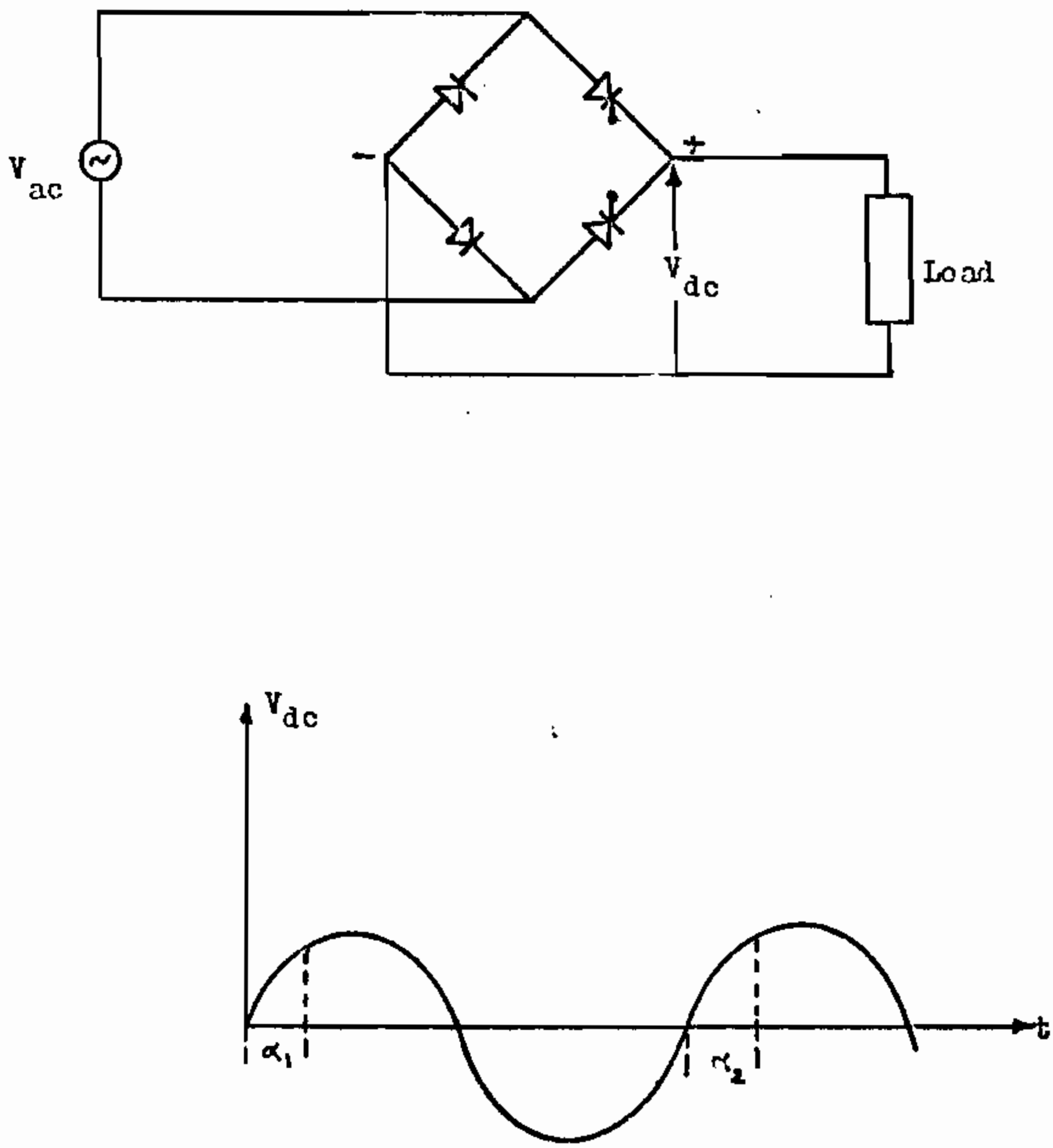

Fig. 2.

3. Description of the Wiring Diagram:

Fig. (3) represents the basic components as well as the necessary interface linking the computer to the circuit of the D-C motor. A full wave assymetrical bridge constitutes the power converter. The triggering circuit for the SCR's consists of a combination of a light emitting diode (LED) together with a light activated SCR (LASCR). This combination provides circuit isolation between the control circuit and the power circuit. When the control circuit is activated, a current flows through the LED which turns on the LASCR and the control pulse is amplified enough to turn on the main SCR. The free wheeling diode carries the inductive motor current when the SCR's are turned off.

4. Digital Control System for the Full Wave Bridge:

The program of the control system is illustrated in the flow chart of Fig. (4). An A/D converaion unit samples the line voltage and also the adjustable reference voltage. The relationship between the reference voltage and the delay angle is worked out in the program in such a way that zero reference voltage corresponds to 180 degrees delay angle and a 10-V reference voltage corresponds to zero degree delay angle. Fig.(5) shows the relationship between the reference voltage and the delay angle. Such a dependency of α from V_{ref} causes the output voltage of thebridge to increase with the value of the reference voltage.

The program, a list of which is given at the end of this paper, determines the positive and negative zero crossings of the line voltage by testing the sign of the two cosecutive line samples (Fig. 6). After each zero crossover, the delay angle α is calculated from the sample of the given reference voltage. A digital clock counts down in time until the desired value of α is reached. Then the clock counts down again for a time of 3.3 ms, which is equivalent to a 60-degree pulse of a 50-Hz waveform. During the 3.3 ms period, a positive pulse is generated in the computer output device. If the delay angle α is more than 120 degrees, the pulse width is decreased so that the pulses always terminate at the next zero croseing.

The generated pulse turns on a transistor in the computer which drives a current through LASCR. There of the main SCR is activated.

5. CONCLUSIONS

Decentralized control represents a major advance in control philosophy. This paper has implemented this idea for controlling a D-C separately excited motor. The speed, current and torque are controlled through a set of coded instructions provided by a minicomputer system. The control scheme is presented in compact,

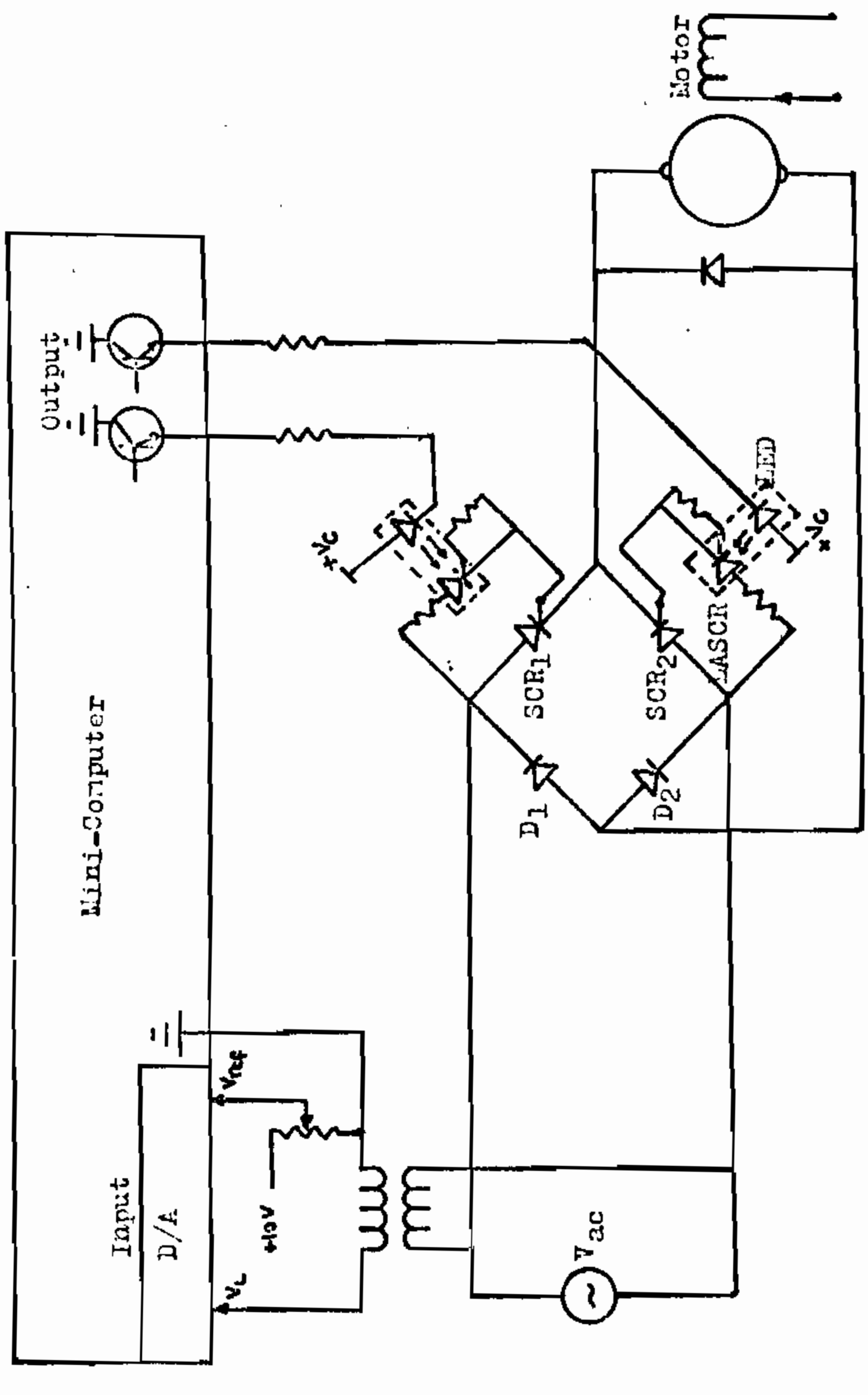

Fig. 3: Digitally Controled Motor

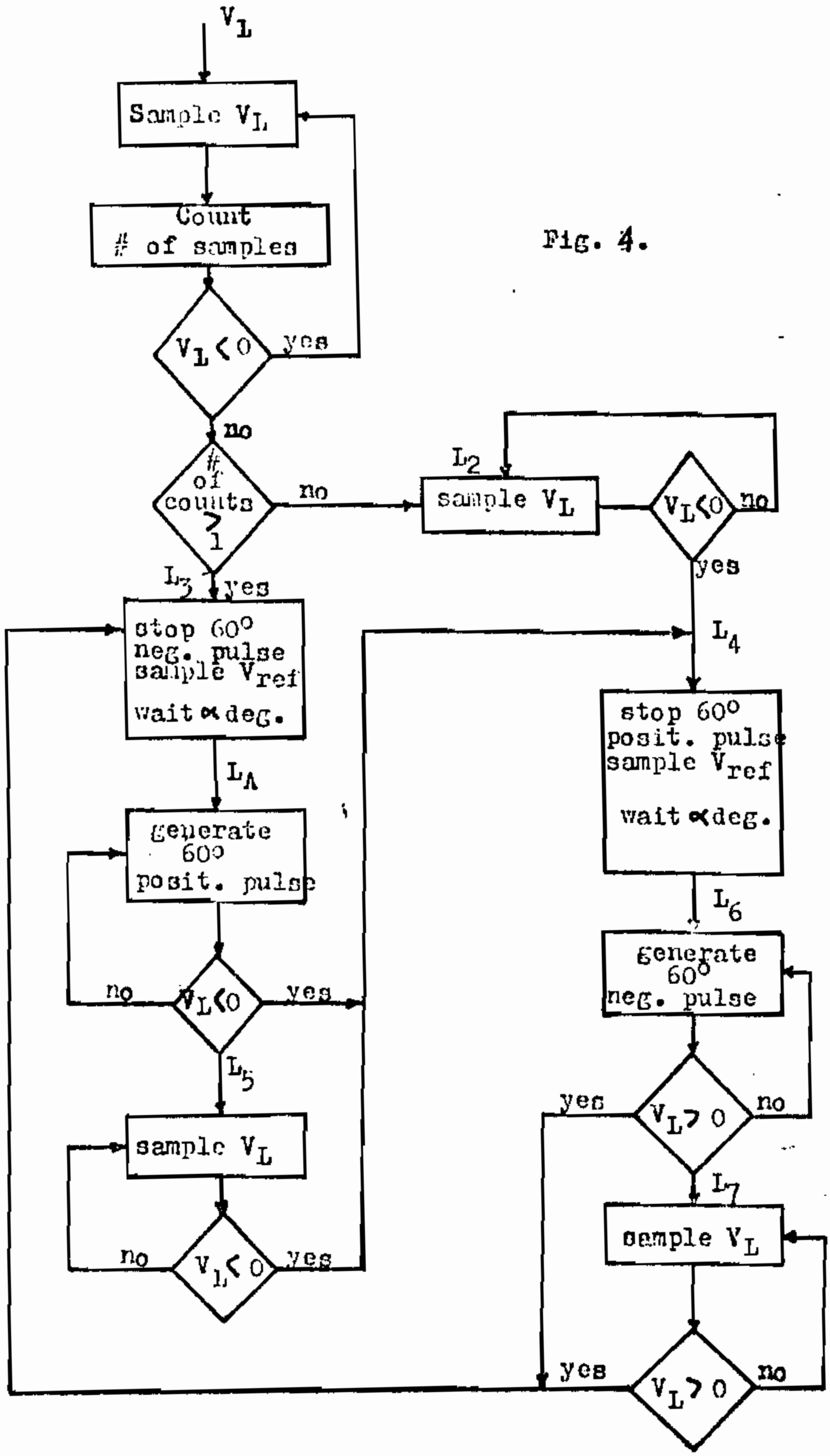
VL
Sample VL
Count
# of samples
VL < 0
yes
no
# of counts ≥ 1
no
sample VL
VL < 0
no
yes
L2
L3
yes
stop 60°
neg. pulse
sample Vref
wait α deg.
L4
stop 60°
posit. pulse
sample Vref
wait α deg.
L6
generate 60°
posit. pulse
no
VL < 0
yes
L5
sample VL
no
VL < 0
yes
generate 60°
neg. pulse
yes
VL > 0
no
L7
sample VL
yes
VL > 0
no

Fig. 4.

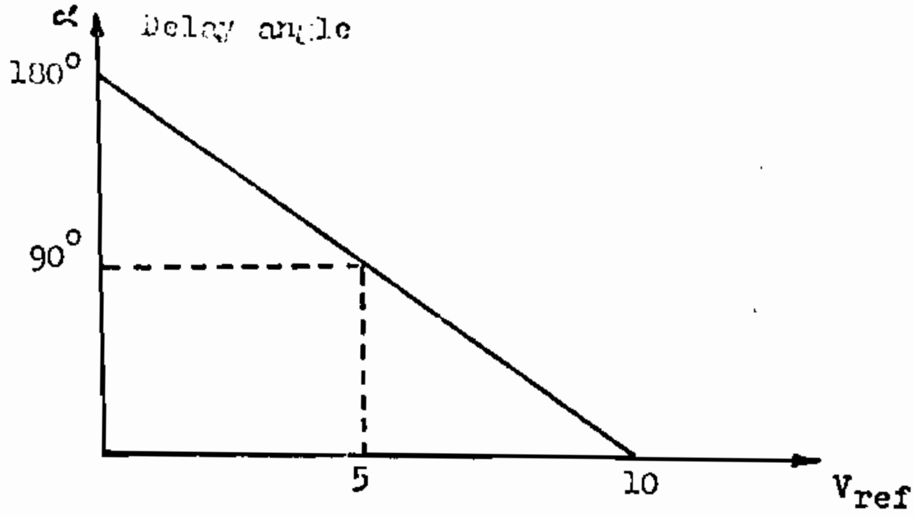

Fig.5: Relation between V_{ref} and delay angle

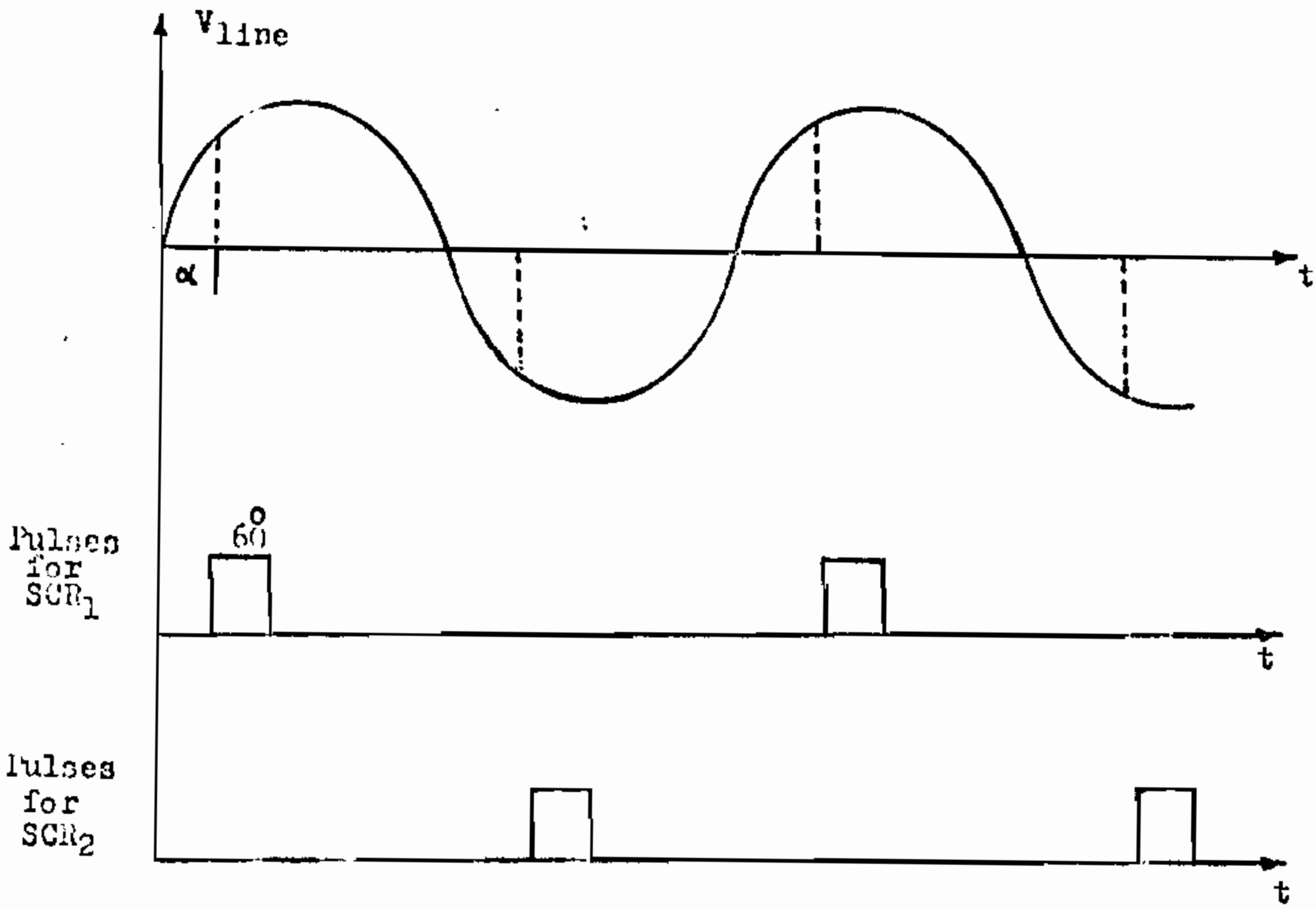

Fig.6: Line voltage samples

efficient and flexible way. The introduction of soft-ware control introduces a smooth transition from one operating point to another excessive wear on the moving parts.

6. REFERENCES:

1. R. Sohiemen et. al., "Solid State Control of Electric Devices", Proc. IEEE, Dec. 1974, pp 1643-1660.

2. Technology 78 "An Application Review", IEEE Spectrum, Jan. 1978.

3. "Applying Microprocessors", Book, McGraw-Hill, 1976, Edited by L. Altman and S. Scrupski.

4. "SCR Manual" General Electric, U.S.A., 1972.

Computer Program for

D-C motor control

```
ADCS = 176770
ADDB = 176772
DR110= 167772
CCSR = 172540
CCSB = 172542
PERK = 164000
  MQ = 177304
  RØ = %0
  R1 = %1
  R2 = %2
  R3 = %3
  R4 = %4
  R5 = %5
          CLR     RØ
          CLR     R1
          CLR     R2
          CLR     R3
          CLR     R4
          CLR     R5
Start:    CLR     COUNT
          CLR     PERK
          CLR     DR110
L1 :      MOV     #1001,ADCS;
                  A/D Sampling of
                  LINE V ON'CH#2
          INC     COUNT
          TSTB    ADCS
          BPL     .-4
          MOV     ADDB,R1
          TST     R1
          BLT     L1
          CMP     COUNT,#1
          BGT     L3
L2:       MOV     #1001,ADCS
          TSTB    ADCS
          BPL     .-4
          MOV     ADDB,R1
          TST     R1
          BGT     L2
          BR      L4
L3:       CLR     PERK
          CLR     DR110
          MOV     #0,CCSR
          MOV     #1401,ADCS;
                  A/D Sampling of REF
                  V ON' CH#3
          TSTB    ADCS
          BPL     .-4
          MOV     #1777,R3
          SUB     ADDB,R3
DIVID:    MOV     #MQ,R5
          MOV     R3,(5)
          MOV     #0,-(5)
          MOV     #14,-(5)
          TST     (5)+
          TST     (5)+
          MOV     (5),CCSB
          MOV     #3,CCSR
                  Clock STARTS TO
                  SET FIRING ANGLE
          TSTB    CCSP
          BPL     .-4
          CLR     R4; GENERATION OF
                  60 DEGREE +ve PULSES
L4:       MOV     #2,CCSB
          MOV     #3,CCSR
```

```
          MOV     #1001,ADCS
          TSTB    ADCS
          BPL     .-4
          MOV     ADDB,R1
          TST     R1
          BMI/    L4
          TSTB    CCSR
          BPL     .-4
          MOV     #1,PERK
          MOV     PERK,DR110
          INC     R4
          CMP     R4,#14
          BLT     LA
L5:       CLR     PERK
          CLR     DR110
          MOV     #1001,ADCS
          TSTB    ADCS
          BPL     .-4
          MOV     ADDB,R1
          TST     R1
          BGT     L5
L4:       CLR     PERK
          CLR     DR110
          MOV     #0,CCSR
          MOV     #1401,ADCS;
                  A/D Sampling of
                  REF V ON' CH#3
          TSTB    ADCS
          BPL     .-4
          MCV     #1777,R3
          SUB     ADDB,R3
TEILN:    MOV     #MQ,R5
          MOV     R3,(5)
          MOV     #0,-(5)
          MOV     #14,-(5)
          TST     (5)+
          TST     (5)+
          MOV     (5),CCSB
          MOV     #3,CCSR
          TSTB    CCSP
          BPL     .-4
          CLR     R4; GENERATION
                  of 60 Degrees
                  -ve pulses
L6:       MOV     #2,CCSB
          MOV     #3,CCSR
          MOV     #1001,ADCS
          TSTB    ADCS
          BPL     .-4
          MOV     ADDB,R1
          TST     R1
          BPL     L10
          BMI     L11
L10       JMP     L3
L11       TSTB    CCSR
          BPL     .-4
          MOV     #2,PERK
          MOV     PERK,DR110
          INC     R4
          CMP     R4,#14
          BLT     L6
L7:       CLR     PERK
          CLR     DR110
          MOV     #1001,ADCS
          TSTB    ADCS
          BPL     .-4
          MOV     ADDB,R1
          TST     R1
          BMI     L7
          JMP     L3
OUT:      EMT     60
COUNT:    .WORD 0
BUFF:     . = .+4000
          . END START
```