DIGITAL CONTROL

OF

A THYRISTOR-DRIVEN D-C MOTOR

BY

Elsayed H. El-Konyaly, A. Abdul-Magid Hassan and
Reda M.K. El-Dewieny[*]

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 ooded 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.

Fig. (1) illustrates the basic computer control scheme using microprocessor. Because of the introduction of sampling and the use of microprocessor 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 strategies using the logical and computational capacity of the ever-developed microprocessors. They provide 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 the 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 ideas 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]". Before 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 $\alpha = 0°$.
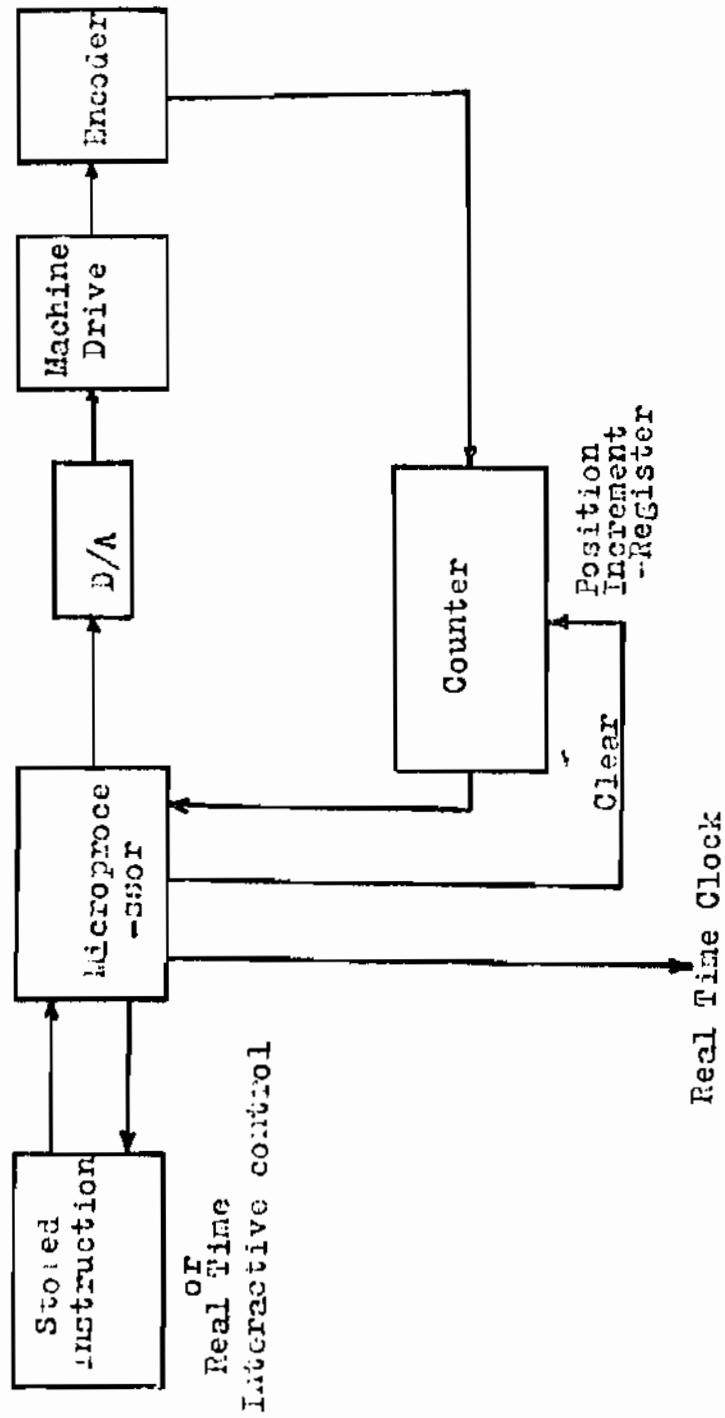
Fig. 1: Basic Computer Control Scheme Using Microprocessor
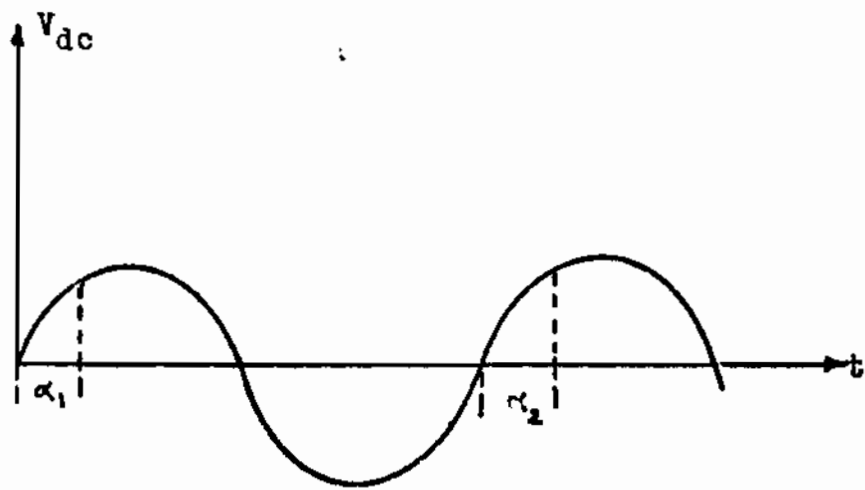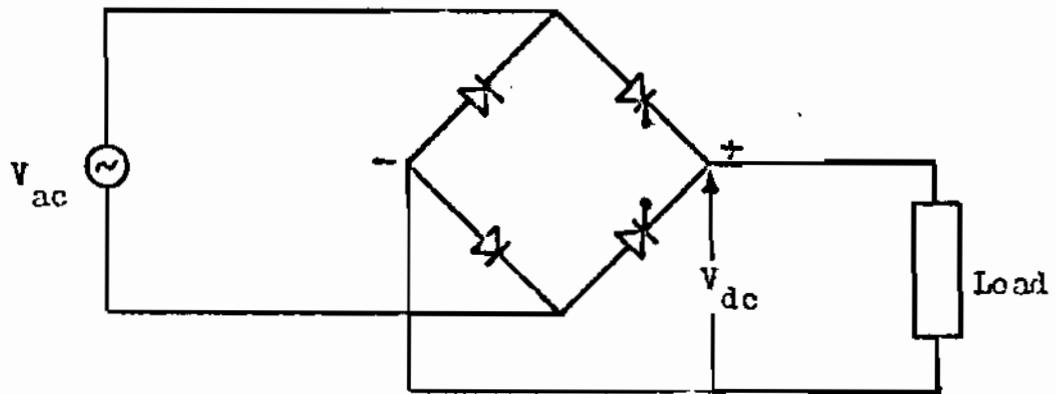
Fig. 2.

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 whseling 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 conversion 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 correseponds 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 ths two cosecutive line samples (Fl g. 6). After each zero crossover, the dslay angle α is calculated from the sample of ths given referance 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 ths delay angle α is more than 120 degrees, the pulse width is dscreased so that ths 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,
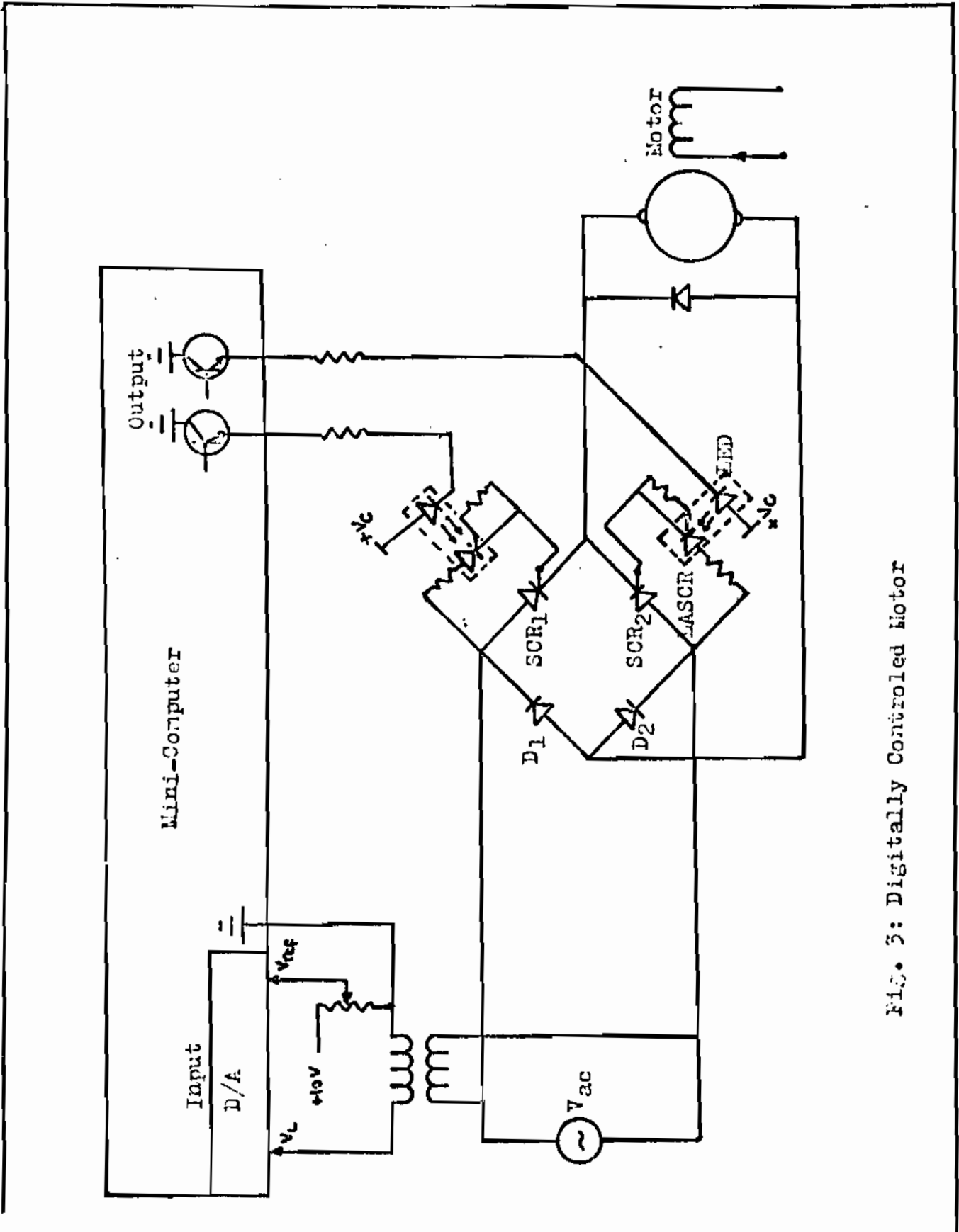
Fig. 5: Digitally Controled Motor
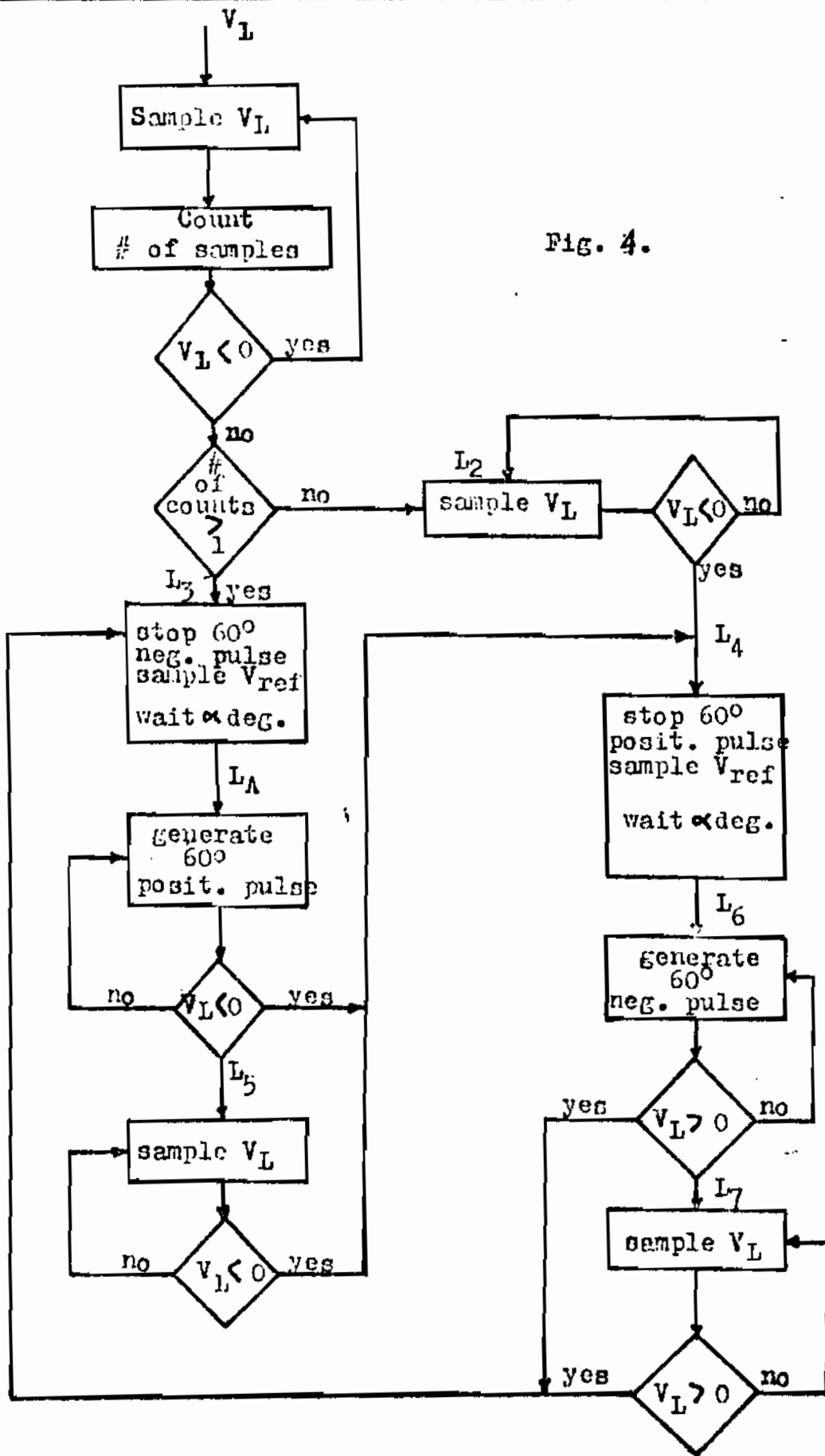
Fig. 4.
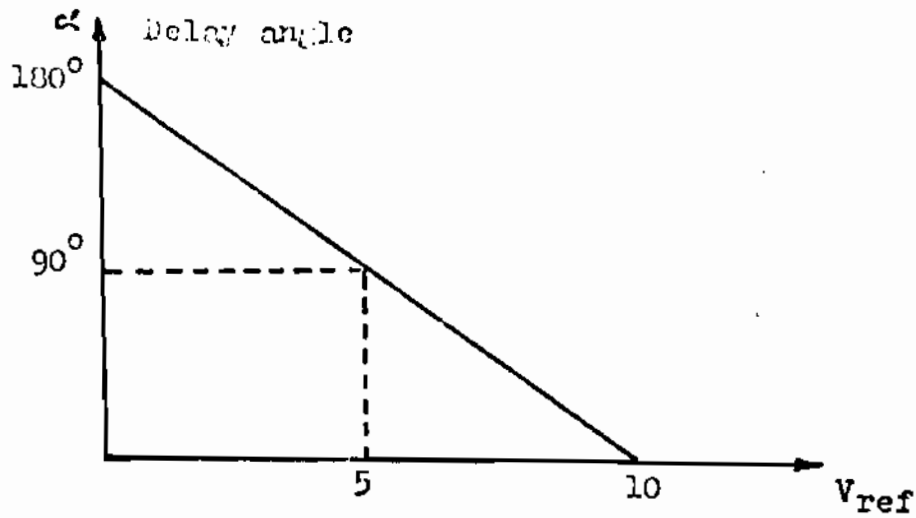
Fig.5: Relation between V_{ref} and delay angle
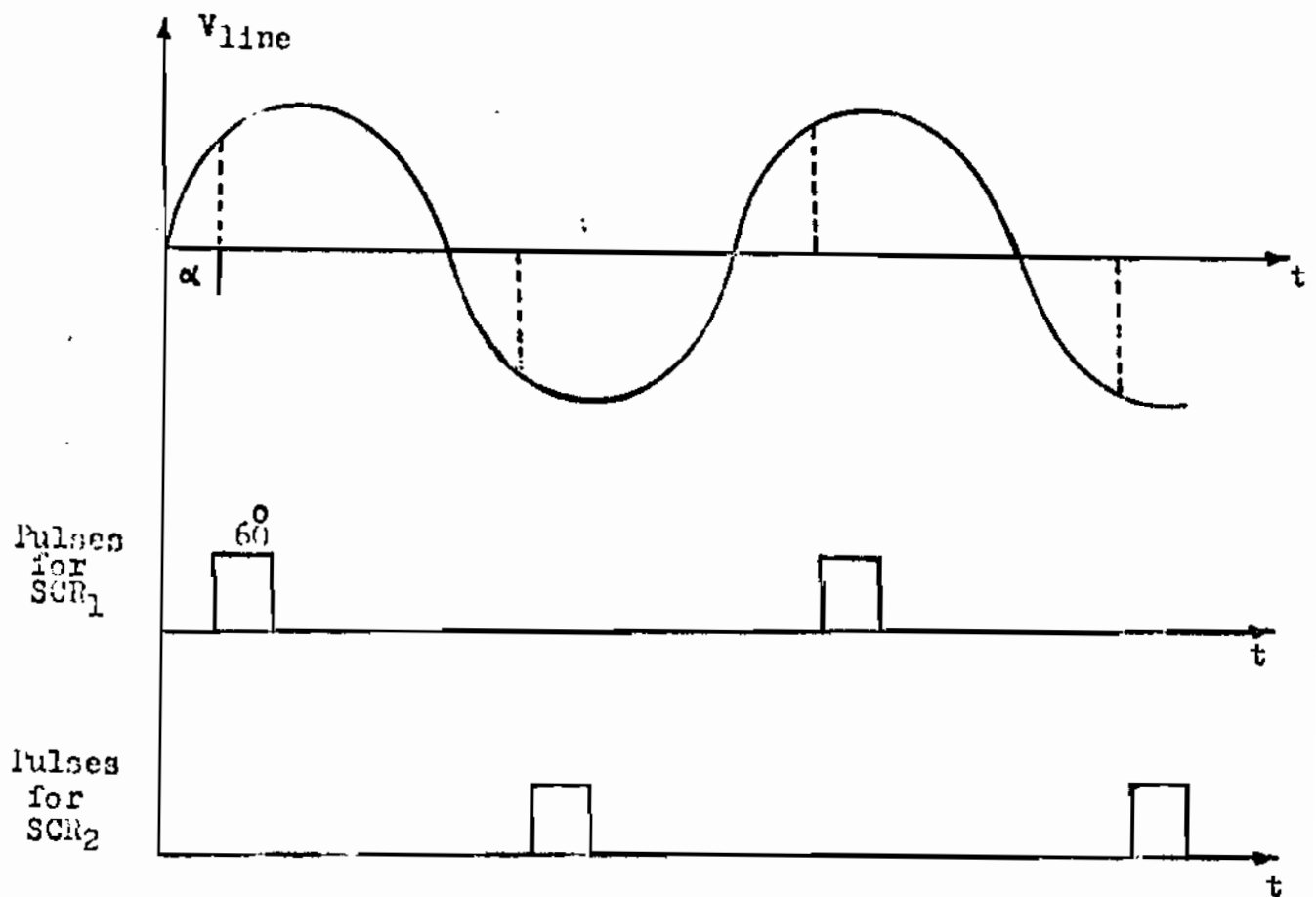
Fig.6: Line voltage samples

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. <u>REFERENCES</u>:

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                          L2:   MOV    #1001,ADCS
ADDB = 176772                                TSTB   ADCS
DR110= 167772                                BPL    .-4
CCSR = 172540                                MOV    ADDB,R1
CCSB = 172542                                TST    R1
PERK = 164000                                BGT    L2
  MQ = 177304                                BR     L4
  R0 = %0                          L3:   CLR    PERK
  R1 = %1                                CLR    DR110
  R2 = %2                                MOV    #0,CCSR
  R3 = %3                                MOV    #1401,ADCS;
  R4 = %4                                       A/D Sampling of REF
  R5 = %5                                       V ON' CH#3
          CLR    R0                         TSTB   ADCS
          CLR    R1                         BPL    .-4
          CLR    R2                         MOV    #1777,R3
          CLR    R3                         SUB    ADDB,R3
          CLR    R4                DIVID:   MOV    #MQ,R5
          CLR    R5                         MOV    R3,(5)
Start:    CLR    COUNT                      MOV    #0,-(5)
          CLR    PERK                       MOV    #14,-(5)
          CLR    DR110                      TST    (5)+
L1 :      MOV    #1001,ADCS;                TST    (5)+
                 A/D Sampling of            MOV    (5),CCSB
                 LINE V ON'CH#2             MOV    #3,CCSR
          INC    COUNT                             Clock STARTS TO
          TSTB   ADCS                              SET FIRING ANGLE
          BPL  · .-4                        TSTB   CCSP
          MOV    ADDB,R1                     BPL    .-4
          TST    R1                          CLR    R4; GENERATION OF
          BLT    L1                                 60 DEGREE +ve PULSES
          CMP    COUNT,#1           LA:   MOV    #2,CCSB
          BGT    L3                         MOV    #3,CCSR
```

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