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Software based approach for Triggering 3-phase, 6-pulse, AC to DC Controlled Converter

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Abstract—**This paper presents the development of a software for triggering the circuit of 3-phase, 6-pulse, ac to dc controlled converter using PIC microcontroller. The microcontroller will generate six equidistant, synchronized triggering pulses for the converter which finds application in power systems(high voltage DC transmission) and industrial drive systems. The controller is required to sense the input voltage and generate the required six trigger pulses irrespective of the variation of the mains frequency and to control the delay angle of these signals equally to control the DC output voltage.**

Index Terms—**controlled converters, PIC16F877A Microcontroller, power electronics, trigger pulses.**

I. Introduction

Power electronics applications span the whole field of electrical power system, with the power range of these applications extending from a few VA/ watts to several MVA/MW. The main task of power electronics is to control and convert electrical power from one form to another. In case of SCR based converters, gate signal is generated from a separate gate trigger circuit. These signals are used to control the conduction period of SCR which ultimately controls the output or the performance of the power electronic converters[3]. As far as triggering circuits are concerned, simple triggering circuits can be realized by R or RC network but they depend on gate trigger charecterstics of the thyristors used, and they cannot be used easily in self-programmed, automatic or feedback controlled systems. Because the use of power-electronic controllers is increasing steadily in industry as well as in power systems, different types of controllers are required for specific applications. In a controller , a group of thyristors or power-semiconductor devices are required to be switched at different switching instants for different durations and in a particular sequence. Different three-phase converters, for example dual converters, cycloconverters, and regenerative reversible drive, may require 12 to 36 such devices. Thus switching a large no. of these power devices with different control strategies by a simple trigger circuit becomes almost impossible[3]. Moreover, incorporation of feedback and different control approaches for same load or drive systems requires an intelligent controller. Therefore the use of advanced triggering circuits become necessary. Some modules of power semiconductor devices include a gate drive as well as transient protection circuitry. Such commercially available modules are called intelligent modules or smart power. They include input-output isolation and gate drive circuits, microcomputer control, a protection and diagnostic circuit(for over current, short-circuit, open load, overloading and excess voltage) and a a controlled power supply. In case of three phase converters, six trigger pulses are required for each SCR. Therefore generation of six trigger pulses and their delay control , equally and simultaneously, becomes difficult using convensional analog and digital circuits. Moreover these circuits become complex and proper control over wide range becomes difficult[5].

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II. PHASE CONTROLLED AC-TO-DC CONTROLLED CONVERTERS

There are several conventional methods by which the output dc voltage can be controlled, e.g. a diode bridge with a tap-changing transformer or with an auto-transformer[3]. Although these methods are simple, but suffer from the demerits due to size, weight and cost of transformers. Previously, this type of control scheme (a diode bridge with tap-changing transformer) was used to control the dc voltage hence speed of dc motors used in electric traction of Indian Railways. In case of ac-to-dc phase-controlled switching, the phase controller works as an ordinary contactor switch. For a certain period of time, the switch is closed (on), thus the input supply voltage (*v*) reaches to the load and the output voltage becomes equal to *v*. Similarly, for a certain period of time, switch is open (off), thus the input voltage does not reach to the load. Thus, instead of the complete input voltage (whole cycle) reaching to the load, the switch (phase-controlled converter) slices the input voltage and only its part (or parts) reaches to the load[3]..

A. Three-Phase, Controlled Converters.

The applications of uncontrolled converters are limited due to lack of output voltage controllability. For high power applications, three-phase controlled converters are extensively used. The performance resembles with their single-phase counterparts. Three-phase, semi-converters operate in the first quadrant of v_o–i_o plane. While full-converters are able to be operated in the fourth quadrant too but only for R-L-E(–) loads. There are three and six voltage pulses (peak) in three-phase, half-wave and full-wave converters, respectively. The use of three-pulse, controlled converters is limited. Because it introduces dc component in the input supply current which may results in core saturation of the distribution transformer. In comparison to single-phase system, here due to increased pulses hence frequency of the output voltage pulses, the requirement of filter circuit components reduces[3].

B. Six-pulse, Full-wave Converters

In a six-pulse, full-wave, uncontrolled converter bridge six thyristors are used as shown in the fig . It is similar to a single-phase system. Here each thyristor is switched at an interval of 60° sequentially, from T_1, T_2,….T_6 (They are purposely numbered properly for a bridge configuration). When T_1 and T_2 is conducting v_{AN} and v_{BN} voltage with respect to star point of transformer appears at the load i.e. $v_{AN}=v_{XN}$ and $v_{BN}=v_{YN}$. The load voltage $v_o=v_{XY}=v_{AN}-v_{BN}=v_{AB}$, which is the line voltage V_L (where $V_L=\sqrt{3}V$, $V_{Lm}=\sqrt{2}(V_L)$ and V is the rms value of the phase voltage). When $\omega t=\alpha+60°$, T_2 is triggered. At this condition, v_C is more negative than v_B, therefore due to conduction of T_2, v_Y (negative bus) becomes equal to v_C (Fig.1). Thus a more negative voltage appears at the anode of T_6 to make it reverse biased. Then T_6 commutates and the load current transfers from T_6 to T_2. Again, when T_3 is triggered it supplies a positive (higher) voltage $(v_B>v_A)$ at the cathode of T_1 to turn it off and the load current transfers from T_1 to T_3. There are six voltage pulses and the instantaneous output voltage (v_o) becomes negative for an inductive RL load. However, V_o is always positive except for R-L-E(–) loads where the converter is able to operate in the fourth quadrant of v_o-i_o plane[3].

C. Synchronization

The main function of the trigger circuit is to generate trigger signal for each SCR at same delay angle (α) which is synchronized with the mains or three phase supply voltage. Otherwise SCR would be triggered at irrelevant instant or will fail to trigger at all due to improper biasing. Here a controller circuit is required to sense the zero crossing instant of the input voltage and from thereof generates six equidistant trigger pulses in each cycle (one time period or 20 ms) for switching of SCR of three phase converter (Fig. 2) . Moreover to control or vary the output voltage the trigger pulses are shifted or delayed with respect to the zero crossing instant of the mains voltage[5].

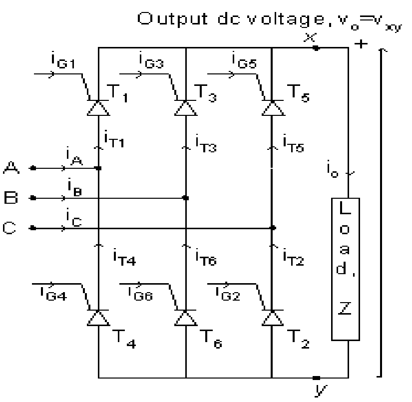

Fig.1 Power circuit of three-phase, full-wave six-pulse, controlled ac to dc converter.

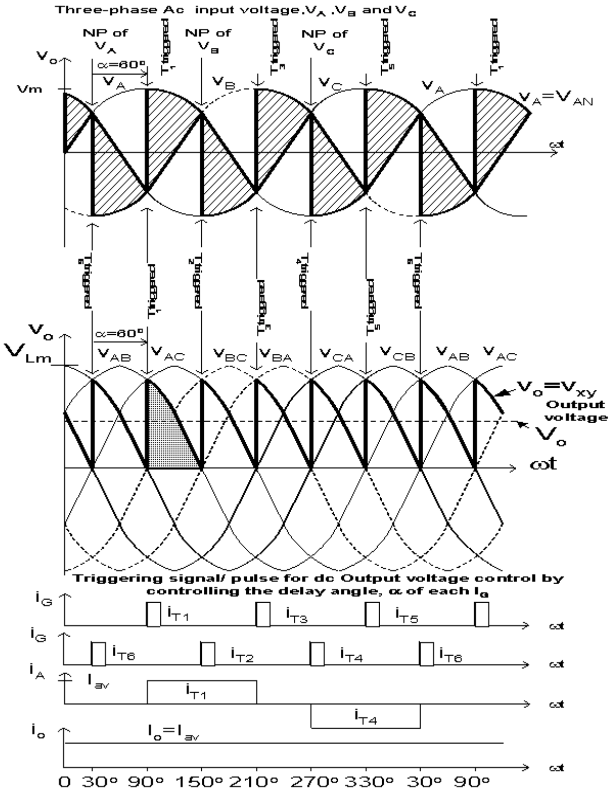

Fig.2 Triggering signal/pulse for dc output voltage.

III. TRIGGERRING PULSE GENERATION

PIC16F877A Microcontroller[1] has been programmed for triggering the power circuit of three-phase, full wave, six-pulse, ac to dc controlled converter. The execution of the program in terms of step by step process is explained by the use of flowchart, which is shown in the figure . First of all a delay pulse has been generated synchronized with the mains voltage by detecting the zero crossing instant of the voltage. Then this program is extended for generating six pulses. The RP0 and RP1 bits of STATUS register should be configured to select the correct bank as the PIC16F877A has banked memory in the SFR(Special Function Register) area[1]. Configure the bits of port B to make it as input. The GIE bit(bit-7) and the INTE bit(bit-4) of INTCON register is made high to enable the global and external interrupt and the INTF bit(bit-1, the external interrupt flag bit) should be low(0). When the external input pulse is given the, the INTF bit of INTCON register is cleared and at delay angle of 30^0 which is approximately 0 .001667sec. the first pulse is generated. We set port B bit-1 high and provide a delay for pulse- width, then we clear port B, bit-1. Thereafter delay of 60^0 which is approximately .003334sec is given for consecutive five pulses. Thus equidistant six pulses are generated.

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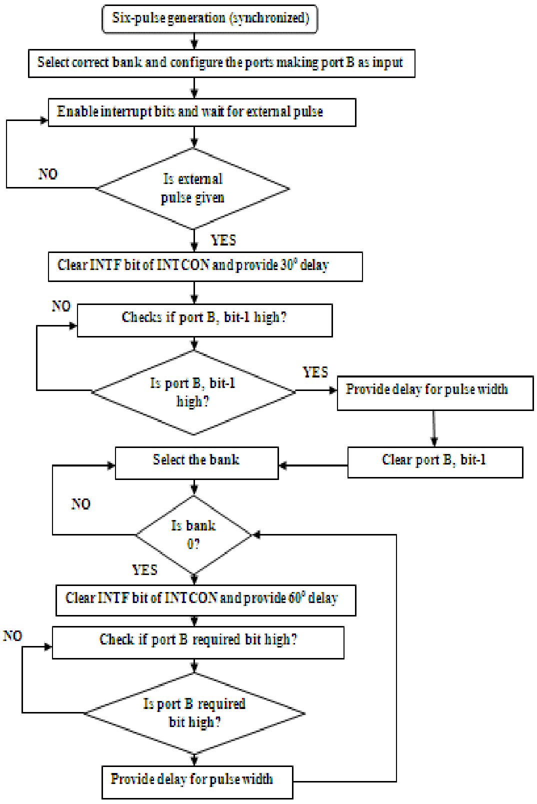

Fig.3 Flowchart for six-pulse generation

IV. ADC PROGRAM FOR DELAY CONTROL

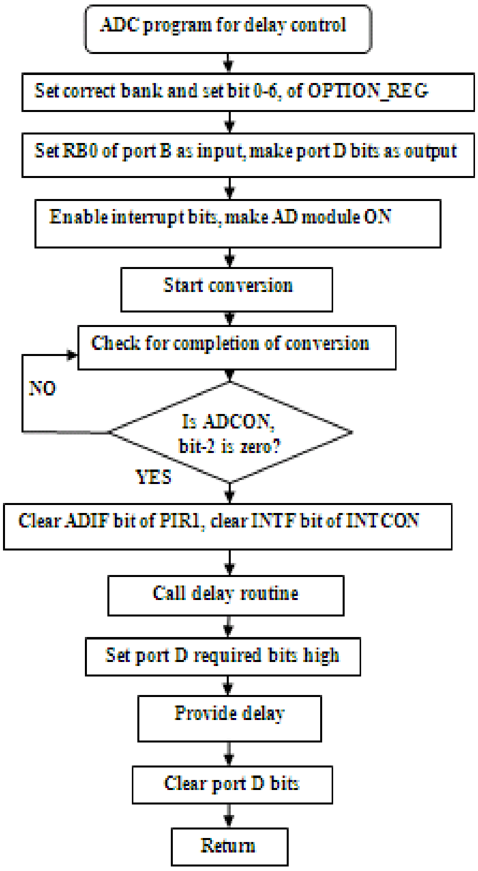

Fig.4 Flowchart of ADC program for delay control

To control or vary the output voltage the trigger pulses are shifted or delayed with respect to the zero crossing instant of the mains voltage. The flowchart for the ADC program for the delay control is shown in the figure 4 and 5 . After selecting the appropriate bank , bits 0-6, of the OPTION_REG register is configured. After enabling the interrupt bits the analog-to-digital module is ON when we set bit-0 of ADCON register. The GO/DONE bit of the ADCON register is set high to start the conversion. The conversion is completed when ADCON register's bit-2 is zero. The ADIF bit of PIR1 and INTF bit of INTCON registers are cleared and delay control routine is called.

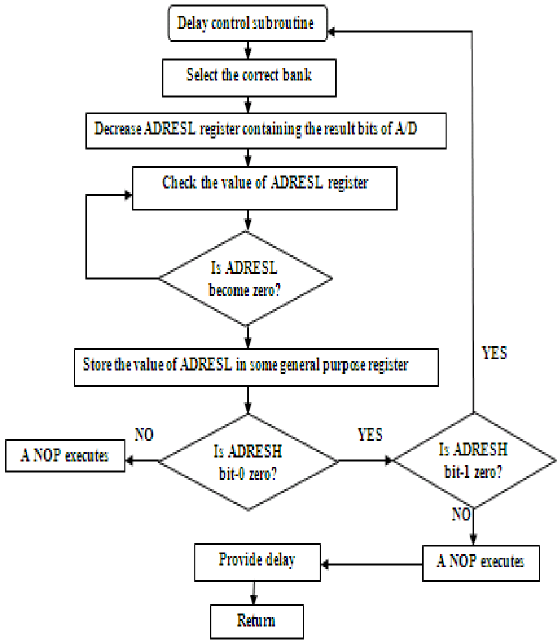

Fig.5 Flowchart for delay control subroutine

The ADRESH:ADRESL registers contain the 10-bit result of the A/D conversion. When the A/D conversion is complete, the result is loaded into this A/D result register pair, the GO/DONE bit (ADCON0<2>) is cleared and the A/D interrupt flag bit ADIF is set. The block diagram of the A/D module [1]is shown in Figure 6.

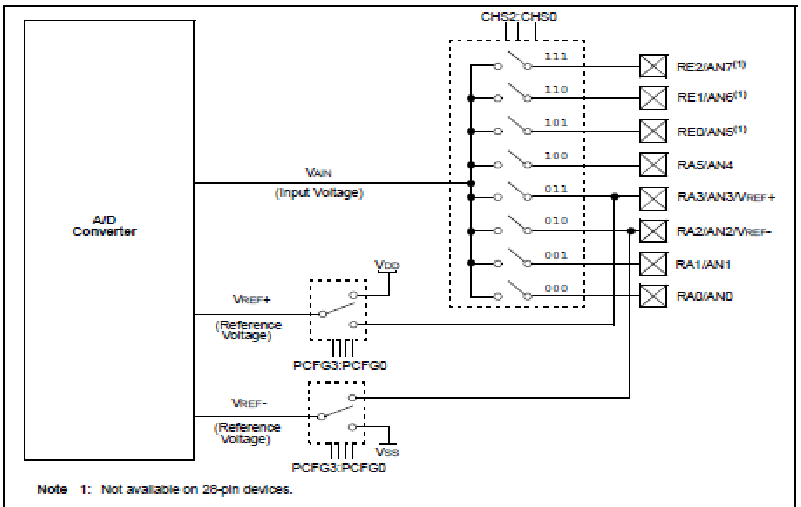

Fig. 6 A/D Block Diagram

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V. RESULTS

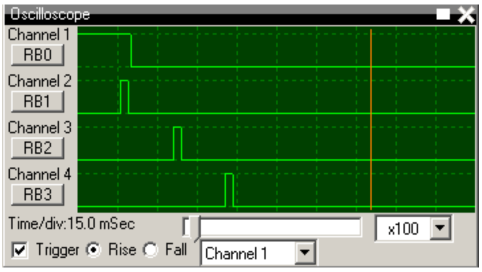

Fig.7(a) Triggering pulses on Real PIC Simulator

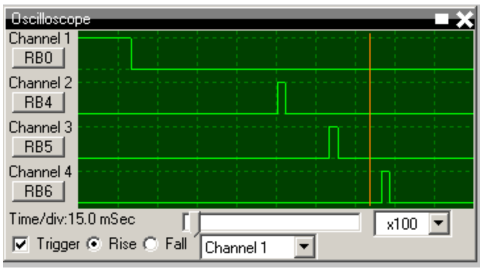

Fig.7(b) Triggering pulses on Real PIC Simulator

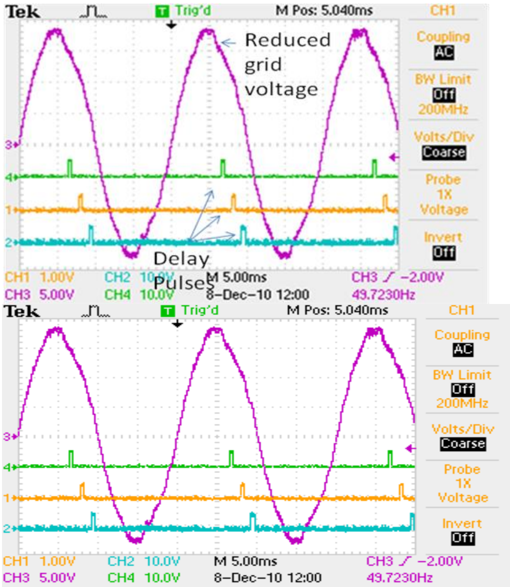

Fig.8 Triggering pulses on the oscilloscope

The six triggering pulses on the Real PIC simulator software [6] and on the oscilloscope is shown in figure 7and 8. The controller will sense the zero crossing instant of the input voltage and from thereafter generate six equidistant trigger pulses in each cycle(one tome period or 20 ms). To control or vary the output voltage the trigger pulses are shifted or delayed with respect to the zero crossing instant of the mains voltage.The controlled delay pulses on proteus[6] are shown in figure 10.

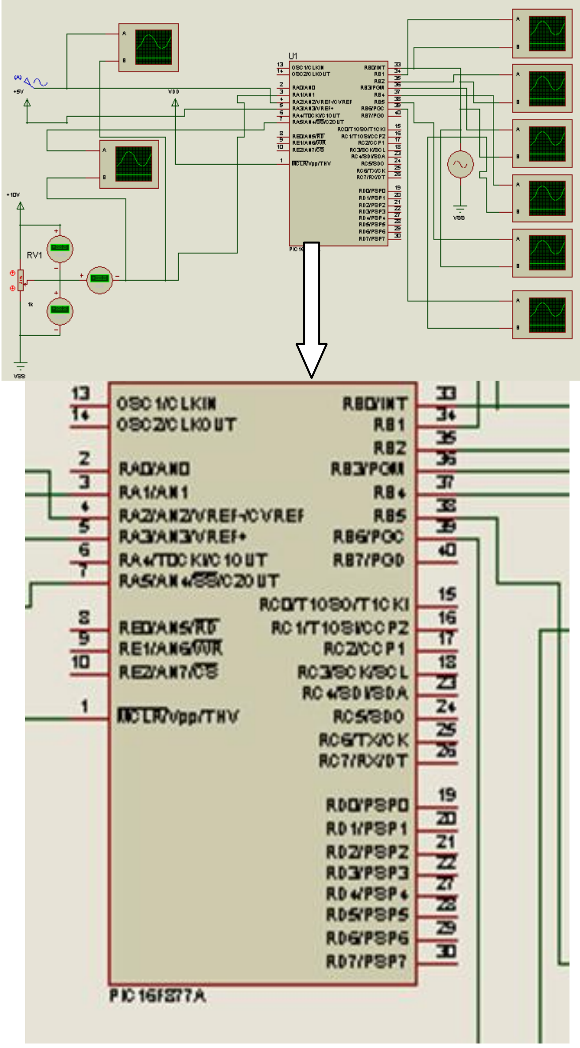

Fig.9 ADC Circuit(PIC16F877A) on proteus

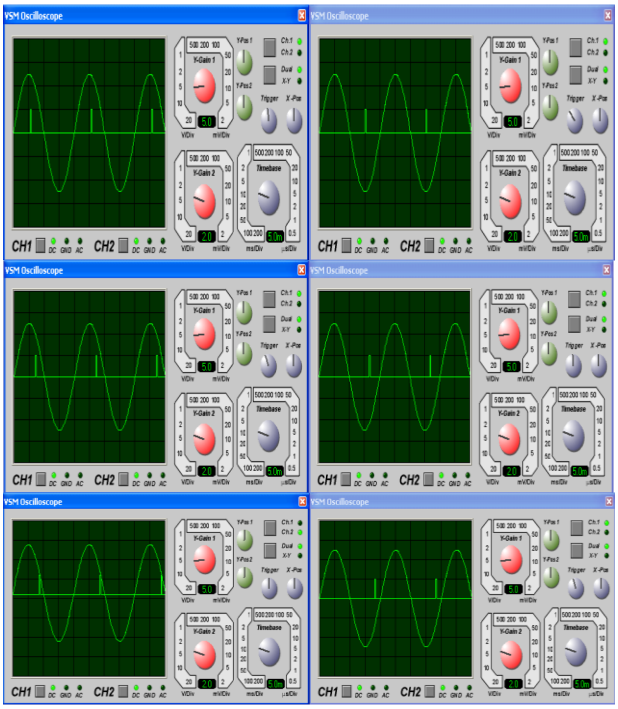

Fig.10 Controlled delay pulses

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VI. CONCLUSION

In this paper development of software to trigger six thyristors or SCRs used in the power circuit of three-phase, six-pulse, controlled converters, has been discussed. Three phase fully controlled converters are very popular in many industrial applications particularly in situations where power regeneration from the dc side is essential. It can handle reasonably high power and has acceptable input and output harmonic distortion. The configuration also lends itself to easy series and parallel connection for increasing voltage and current rating or improvement in harmonic behavior. However, this versatility of a three phase fully controlled converters are obtained at the cost of increased circuit complexity due to the use of six thyristors and their associated control circuit. This complexity can be considerably reduced by using this software for easily triggering the six thyristors or SCRs. Moreover the trigger pulses generated by this software are controllable, i.e. their delay angle can be controlled thus finds application in controlled converters.

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