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Study of Analog and Digital Firing Methods for Converters

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***Abstract* — Various sectors fundamentally and widely makes use of power electronic technology for controlling mechanism. Most of the methods involved controlling power by varying firing angles of thyristor using different techniques like RC time constant triggering, UJT relaxation oscillation triggering etc. Firing schemes with digital and analog circuit are discussed along with their numerous aspects like compatibility, benefits and their confines.**

***Key Words* — Thyristor; Triggering circuit; Firing Angle.**

I. INTRODUCTION

In industrial, agronomic production and house hold applications the controlled powers through electronic technology have been widely used. The power is provided to the application via rectifier, cycloconverter, frequency converter and inverter in the power electronics technology. Among these four types, rectifier is generally used in the equipment, where in trigger circuit is very important. Because of advances in the computer technology the analog trigger circuits are replaced by digital trigger circuits [8]. The circuit like converter, cycloconverter, rectifier and inverter make use of thyristor as an elementary unit. The three terminal thyristors having additional terminal gate, along with anode and cathode; is employed to trigger the thyristor at a precise angle known as firing mechanism [10].

Power electronic semiconductors are comprehensively used and lot of research work has been carried out to derive and utilize the capability to control AC or DC driven loads of house hold and commercial applications. With the help of available digital controller such as microprocessor, microcontrollers and digital signal processor it is possible to drive the devices because of their sensitivity. These digital controllers are more accurate and precise as compared to analog controllers used in earlier stages of development of power controllers. As microcontrollers are single chip computers, which occupies less space and consumes less power [9].The phase controlled thyristors are used in controlled rectifiers or converters instead of using diodes. By the deviation in the firing angle the DC output can be change. The thyristor can turned ON by applying trigger pulse at Gate terminal of thyristor and can be turned OFF by natural or line commutation technique [13]. For analog circuit, input control signal is converted into analog signal and this signal is used as triggering signal to fire the thyristorised circuit [3].In case of microprocessor built triggering circuits, the digital output required to be converted in to analog signal for triggering of thyristorised circuit, also to accomplish this ADC and DAC may be used[4].

The motors are used extensively in industry to fulfill the need of the product based technology. With the advancements in the rotor regulated drives, including induction motors, interest has been generated for development of converters operating under variable frequency supply voltages. This yields the necessity to project the circuit for operation in extensive range of frequency for triggering of the thyristor circuit [6].In the converter based applications the two parameter need to be consider, one is synchronization of Gating pulse with the driving sinusoidal signal as input supply and other is, microprocessor has to perform various tasks due to which it cannot provide sufficient attention to the desired objective. Therefore in order to execute desired task in stipulated time a compatible hardware circuit is designed with less requirement of software programming, which is properly interfaced with microprocessor [12].

In section-I the overview of power electronic technology is discuss along with its importance in household and commercial application. A brief survey on numerous triggering techniques available in power electronics field, through various aspects like features, compatibility, advantages over other analogous technologies and their limitations are discussed in Section-II. The inference of triggering methods is covered in section-III.

II. RELATED WORK

Numerous firing devices are present for SCRs, but all earlier strategies are used fixed frequency. Several devices give different anode frequencies but difficulty arises when the same frequencies are applied to rotor of induction motor. It has to operate with identical frequency which was relative to slip of motor. So need for circuit which functions at different frequencies and can be applied to induction motor was generated. Here a solution was provided to trigger SCR with flexible frequency which fluctuating mains frequency including very low frequencies. Our triggering angle rest on anode supply i.e. If we control the anode supply by appropriate delay element, we can effortlessly control the firing angle of anode. Thus if we generate suitable set and reset pulses, which can be given with appropriate delay, it can control the gate supply and our main purpose was accomplished.

The elementary circuit contains some circuits like zero crossing detector (ZCD) to transform the sine wave into square wave, time delay and bistable multivibrator. The

sinusoidal input (anode voltage) was applied to inverter terminal of op-amp which acts as zero crossing detectors gives square wave as output. To generate spike, the output of ZCD was given to op-amp circuit which was acting as differentiator, contributes positive and negative spikes. Thus generation of square wave from that spike was entirely independent on frequency of anode voltage. Delay unit was used for delaying the gate pulse in generalized triggering circuit. In general, time delay can be accomplish using monostable multivibrator which gives specific time delay, depends on RC network used in it. After time delay unit, these pulses are applied to Gate of thyristorised circuit, but it requires large current for triggering the circuit. So rather than applying directly to Gate, we apply it to bistable multivibrator which drives additional current to gate of SCRs. Limitations of this technology are nonlinear relation of difference of time delay with respect to control voltage. The time delay was fixed for a given control voltage and hence firing angle for a given control voltage varies when the frequency of the anode supply varies [1].

In case of three phase thyristorised circuit, six thyristors has six Gates firing pulses. Equidistant pulse firing scheme provides reasonable and cost-effective solution to industrial applications. General ways to produce equidistant firing pulses consist of attaining indistinguishable firing angle. Scheme aims at suppression of non-characteristic harmonics of the DC converter. The scheme accelerates maintenance of persistent firing and extinction angles under respective modes of operation. Industrial applications uses scheme for firing separate thyristor at a time termed as individual phase control .There was generation of single pulse train using ring counter with controllable phase was proposed in this scheme. The scheme comprise of VCO having frequency six times mains frequency, which sustains the output frequency using PLLs. Output frequency was attained by dividing the VCO frequency by modulo 6N counter, however the use of proposed scheme has limitations in the cycloconverter firing [2] .

S. Murugesan and C. Kameswara in 1977 proposed analog and digital triggering, which works on wide range of frequency supply. The trigger pulse was generates in which firing angle was influenced only by control signal and was independent of supply frequency. With the support of digital control signal, the firing angle can be controlled. The main feature of this scheme was that, for the generated triggering pulse, firing angle was same at a specified control voltage for extensive variety of frequency. In digital trigger circuit, digital control signal was used to govern firing angle directly in short of the use of DAC. Analog supply was delivered to Zero crossing detector with frequency F_s, this signal was given to frequency to voltage converter and it yields the voltage V_f. This signal was intended for the programmable ramp generator to produce a constant amplitude signal, in synchronization with zero crossing of the supply Voltage. Run down ramp comparator was used to equate the ramp signal and control signal which yields the trigger pulse for triggering of thyristorised circuit [3].

Hoang Le-Huy in 1987 proposed that, with help of 8 bit digital word, the delay angle was controlled. Circuit operation was subjected to disturbances, in the course of input voltage transitions, as the line voltage was used as reference input. Digital pulse delay circuit was used to trigger thyristorised converter circuit. Voltage Controlled Oscillator (VCO) and line frequency by phase locked loop are coordinated to generate a phase coherent control wave form. As a result, the trigger circuit becomes free from distortion, in the wave form and transients in the signal. Phase lock loop was intended to have fast response and have minimum disturbances at turn ON by supply frequency transients. It was found that the circuit operation was precise and it was exempted from waveform distortion. The trigger circuit was useful in microprocessor-based thyristor control circuit with cost-effective design [4].

S. C. Gupta, K. Venkatesan and K. Eapen proposed firing angle controller using phase locked loop for thyristor control. In generalized phase detector circuits, various types of firing angle deviations are observed. The controller works in wide range of mains frequencies and was immune to the transients in the input voltage. Firing angle was not affected by variation in the amplitude of the input voltage.

The requirements for firing angle controller are -

1. The controller must make use of less numbers of components. This results in simple and cost-effective design.
2. The controller should be flexible for converter or cycloconverter.
3. The variations in the amplitude of the input signal should be compensated by the controller.
4. Response time should be as less as possible.
5. Circuit operation should accompany with the variations in the circuit parameters, to achieve optimal performance.
6. The firing angle control should be convenient and precise.
7. Synchronization between input signal and output trigger should be established [6].

In 1982 P. C. Tang, S. S. Lu, Y. C. Wu et.al. Applications of motors are growing very promptly and to control DC motor speed, thyristor was used so it was very significant to control thyristor for fast response. Here a digital scheme was used which was divide by 6 counter and can give angles like 0^0, 60^0, 120^0, 240^0, 300^0, 360^0 . A microprocessor based firing scheme was used with the help of some software algorithm to find correct firing angle for output signal. The advantage of the scheme was minimum hardware with less complication and easy control over firing angle. Using this scheme we can control the triggering of SCRs and according to the triggering, current generated by converter was given to the microprocessor. This signal was given to power signal operation for separation of power into three components as

$Ø_a$, $Ø_b$, $Ø_c$, which are given to microcomputer. Microprocessor has two inputs one from converter output and other from power signal operations ($Ø_a$, $Ø_b$, $Ø_c$). In micro-controller a different firing angles are placed accordingly to $Ø_a$, $Ø_b$, $Ø_c$ and according to that look up table was placed in memory. Look up table gives complete description about how much firing angle will be there at particular $Ø_a$, $Ø_b$ and $Ø_c$. In memory of microcontroller look up table and algorithm will decide the firing angle of Gate [7].

In 1982 S. S. Upadhya et.al. suggested microprocessor interfacing hardware for SCR triggering. Microprocessor was used to control the firing angle of SCR in complete converter range. This interface synchronizes the real time input with microprocessor output. In this scheme the supply was provided via step down transformer to the ZCD. ZCD output was square wave which was it was fed to the 8 bit counter, this gives the uninterrupted counting process from 00H to FFH in one high ZCD period, and the rate was controlled by a circuit obtained from astable multivibrator**.** 8 bit desired value of the trigger angle was calculated by microprocessor which was compared with 8 bit output of counter, when both value become equal the pulse was out. At the 1st instant, pulse generated resembles to delayed angle and at the 2nd instant was not appropriate. The monostable was trigger by 1st pulse which has some time period to that of supply voltage and thus 2nd pulse was restricted. The required triggering angle was through the delay in the output pulse of comparator. During positive half cycle the output of monostable was practice to trigger the SCR, the complement of monostable output was used to trigger the SCR in negative half cycle in similar way [12].

In the digital triggering method, an 8 bit microcontroller was used, that provide triggering pulse to 3-phase full wave converter. It uses 1-phase voltage as synchronization signal. In the output of microcontrollers, 6 trigger pulses which were indistinguishable and can be moved within cycle of a sine wave from 0 to 180 degree were observed. The circuit comprise of microcontroller, keyboard, LED display, synchronization phase shift module and trigger pulse output module. The design was extremely stable and reliable in operation. Using timer of microcontroller, programmable pulse train will be generated in desired sequence as six outputs of microcontroller port. These pulse trains can be manipulated with software program for microcontroller. These manipulated pulsed will be used through proper isolation for triggering SCR gates there by controlling converter's output. Synchronization will be achieved by using sample from raw AC signal, converting it in square wave pulse and using it for interrupt of microcontroller. Firing angle control will be through key board interfaces to microcontroller [8].

In one of the studies it was found that, the trigger circuit was designed with the help of double sided isolation which was economic and was easy to implement. The use of keypad and uneconomic ways to implement ZCD circuit was eliminated to make the design efficient for the implementation in industry as well as house hold applications. The use of pulse transformer in pulse output circuit was eliminated which results in cost-effective design and avoid magnetic coupling which was harmful to the controller circuit. The design was universal in nature which was use for house hold and commercial application which work on either 50 or 60 Hz supply or DC signal, also the design work effectively with 50 and 60 Hz power supply. The scheme proposed was full isolated and provides full and stable control from 0 to Π radian to control the firing angle of SCR. The special care need to take regarding the spike and electromagnetic interference from other circuitry which may damage the controller. Gate driving circuit must be isolated from the controller circuit to avoid reverse current flow; this problem was solved by the use of Optothyristor.

In one of the literature it was found that, design has 3 major parts ZCD, microcontroller and gate drive. Finding zero crossing point was very important to have a control on entire input cycle. ATMEL's ATmega32 was a controller having RISC architecture was used. The microcontroller accepts the firing angle from the user accordingly it generates the triggering pulse for firing of the SCR at a particular firing angle. To turn ON the SCR the gate current needs to be more than threshold level of nominal rating, and it should be applied for more time than the turn ON period of the SCR. This was necessary to transform SCR from blocking to conduction state [9].

III. CONCLUSION

The paper provides a review of analog and digital firing circuit for converters used for household and commercial applications. Initially the significance of power electronics technologies is discussed, subsequently with the advantages and limitations of various thyristor control methods over each other are described.

From the literature available related to the thyristor triggering methods, it is observed that, the digital triggering method have advantages like equidistant triggering pulse, simple circuit with fewer components and having precise and easy operation along with strong anti-interference capability. In case of analog circuit more number of components are used and design becomes complex, it consequence in debugging difficulty, also there is uneven spacing of adjacent triggering pulses and shifting phase inaccuracy.

REFERENCES

[1] R. Arockiasamy and S. Doraipandy, "A novel trigger scheme for Thyristor operating under variable frequency anode supply," IEEE Trans. Ind. Electron. Contr .Instrum., vol. IECI−22, No. 1, pp. 83−85, Feb.1975.

[2] R. Simard and V. Rajagopalan, "Economical equidistant pulse Firing scheme for Thyristorized D.C. drives," IEEE Trans. Ind. Electron. Contr. Instrum., vol. IECI-22, No.3, pp. 425−429, 1975.

[3] S. Murugesan and C.Kameswara, "Simple adaptive analog and Digital trigger circuits for thyristors working under wide range of

Supply frequency," IEEE Trans. Ind. Electron. Contr. Instrum., vol. IECI-24, No. 1, pp.46−49, 1977.

[4] L.H.Hoang ,"A digitally controlled thyristor trigger circuit," Proc. IEEE, vol. 66, No.1, pp. 89−91, Jan. 1978.

[5] B. Ilango, R. Krishman, R. Subramanian, and S. Sadasivam, "Firing circuit for three-phase thyristor-bridge rectifier," IEEE Trans. Ind. Electron. Contr. Instrum., vol. IECI−25, no. 1, pp. 45−49, 1978.

[6] S.C.Gupta, K.Venkatesan, And K.Eapen, "A Generalized Firing Angle Controller Using Phase-Locked Loop for Thyristor Control," IEEE Transactions On Industrial Electronics And Control Instrumentation, vol. IECI-28, No. 1, February 1981.

[7] P.C. Tang, S.S.Lu, and Y.C.Wu, "Microprocessor-Based Design of a Firing Circuit for Three-Phase Full-Wave Thyristor Dual Converter," IEEE Transactions on Industrial Electronics, vol. IE−29, No. 1, February 1982.

[8] XU Wuxiong, "Design of Thyristor Digital Trigger Circuit Based on Microcontroller Unit," The 1st International Conference on Information Science and Engineering (ICISE2009)

[9] M. U. Rafique, "A Universal and Optimized Embedded System to Control Firing Angle of Thyristors with Double-Sided," 2011 Third International Conference on Communications and Mobile Computing.

[10] T. C. Pimenta, L. L. G. Vermaas, P. C. Crepaldi, R. L. Moreno "The Design of a Digital IC for Thyristor Triggering," 10th Intentional Conference on VLSI Design−January 1997.

[11] Muhammad H. Rashid, Power Electronics (Circuits, Devices, and Applications), 3rd ed., Pearson Prentice Hall, 2006, pp. 339.

[12] S.S.Upadhya, K. Kant and G. Singh, "A New Microprocessor Interfacing Hardware for SCR Triggering," proceeding of the IEEE, vol. 70, No. 10, October 1982.

[13] T. Thepmanee, S. Pongswated, P. Ukakimapurn, and K. Tirasesth "The Technique to Generate Firing Signal for Converter for Linear DC Output," SICE Annual conference, The University Electro-communication, Japan 2008.

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