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DESIGN SIMULATION & IMPLEMENTATION OF FOUR QUADRANT OPERATION OF DC DRIVE

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Abstract

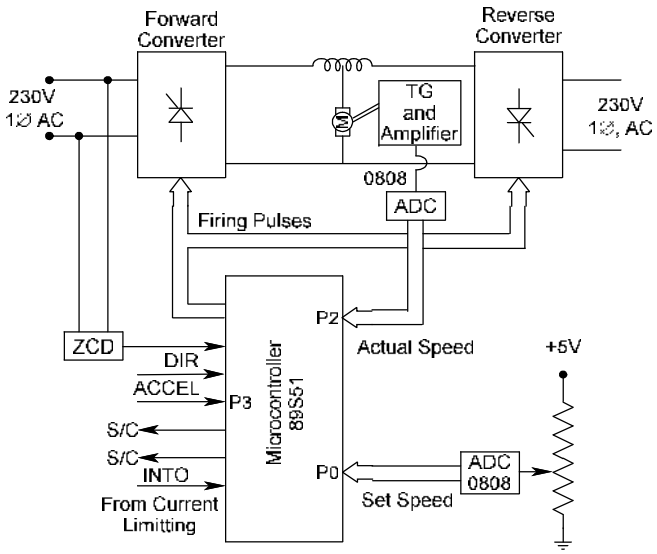
Use of microcontroller based system has given flexibility for implementation of closed loop operation, to get variable speed of DC motor irrespective of supply fluctuation and load variation by incrementing or decrementing firing angle for dual convertor. In dual converters with non circulating current, only one converter operates at a time and another converter is temporarily blocked from conducting by withdrawing firing pulses to the Thyristors. Since only one converter operates at a time no reactors are required between the converters. The paper includes details on design of zero crossing detectors to detect zero crossing instant of A.C. input to converters to determine firing angle, control circuit is designed to read some input parameters like 8-bit digitized set speed and actual speed from taco generator, use of two double pole switch to read direction and acceleration. Current limiting circuit using Hall effect IC to detect threshold voltage level corresponding to desire current limit to provide over load protection. Software development in assembly language for 89s51 microcontroller to provide real time control.

1. INTRODUCTION

In the approach to implement and control the operation of DC drives by using PID controllers however use the complex design of amplifiers and other analog control units made the system tedious to modify for further development. Inclusion of additional features was difficult. The methodology used here to implement a four quadrant operation of DC drive, two fully controlled SCR bridge are used in dual converter mode. Dual converter can be viewed as the static version of the Ward-Leonard motor generator set and microprocessors and microcontrollers considerably relieved the task of designing dedicated electronic circuitry through hardware for different instrumentation purpose. Instead of using dedicated hardware we have implemented a microcontroller based system with great flexibility through the proper embedded software. The implementation of closed loop operation, to get variable speed of DC motor irrespective of supply fluctuation and load variation by incrementing or decrementing firing angle hence became possible.

A microcontroller is used for firing angle control of dual converter. It can be programmed to read some input parameters like direction (clockwise/anticlockwise), set speed, actual speed of motor, overload current protection status and firing angle. Under software control microcontroller can generate firing pulses at desired firing angle. A great variety of circuit configurations have been developed for conversion of power from AC to DC and from DC to AC. The word rectification implies conversion of energy from AC source to DC load. Under certain conditions the power flow can be reversed then circuit can be said to be operated in the inverting mode. The words rectifier and inverter being retained when the converter operates in the particular mode. In non circulating current mode of operation, only one converter operates at a time and carries the load current and the other converter is at that time, temporarily blocked from conducting by withdrawing firing pulses to the Thyristors.

Block Diagram:



2. BLOCK DIAGRAM EXPLANATION:

The microcontroller based system developed has been interfaced with ADC 0808. As seen in the block diagram, to read Set Speed a potentiometer has been connected to the ADC. The output of ADC is given through port PO to the microcontroller. The potentiometer gives a voltage drop between 0 - 5 V which is digitized using ADC from FFH -00H. Another ADC 0808 is interfaced to read the Actual Speed from the Taco generator. Gain of the Taco generator amplifier is adjusted to provide 5V output at the rated speed. Thus both the SET Speed and Actual Speed has been adjusted to fall in the range of 0-5 V, so that this can be used for tracking the output speed.

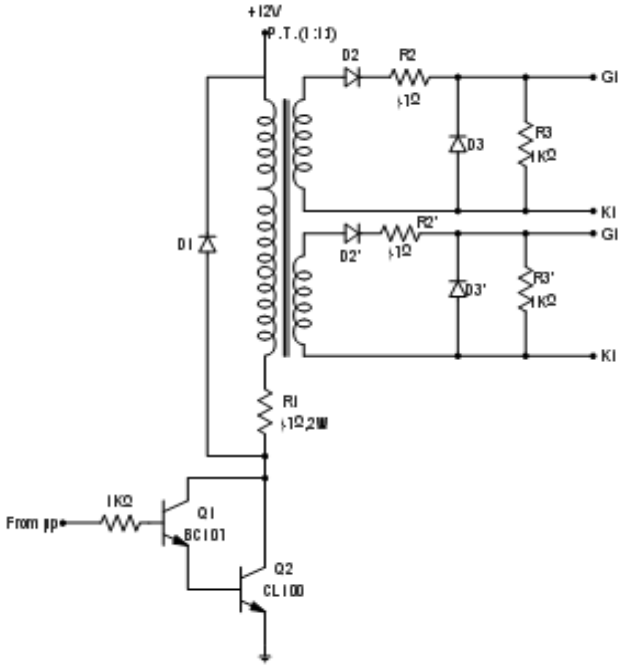
The output speed is controlled by varying the firing angle for the active convertor (of the two convertors) in the range of 0-180 degrees. The mains supply of 230V, 50 Hz single phase is also given to the Zero Crossing Detector (ZCD) through the Step down transformer. This helps to determine the Zero Crossing Instant of time for both the positive and negative half cycles of the ac input. The ZCD is designed using the open loop Configuration of op-amp IC 741 as a non inverting comparator with reference voltage of 0V.

The double pole switch used in the system will generate two logic levels 0 and 1 for the selection of direction, clockwise and anticlockwise respectively. This is read by microcontroller through Port pin 3.1.

Two level acceleration is provided through double pole switch which provides two logic levels viz. logic 0 and logic 1 for low level and high level acceleration respectively when the set speed is changed.

Current limiting and overload Protection Feature: To add the extra feature of current limiting which helps protect the motor from overload condition, we have op-amp IC 741 based open loop comparator circuit with 5V reference and o/p of Hall effect IC for current sensing in the armature circuit for rated current of. When the current exceeds rated current limit, the o/p voltage Hall effect current sensor will be greater than 5V and this causes change in the state of the comparator. This output of the comparator is used to interrupt the microcontroller.

Firing Circuit:



Triggering Circuit

The inputs towards the port pins P3.0 (ZCD), P3.1 (direction), P3.2 (Interrupt), P3.7 (Acceleration) are used as input parameters and with the help of suitable programming software , firing pulses are generated from P3.3 to P3.6. These pulses are applied to the driver circuit of the (1:1:1) pulse transformer. The driver circuit is designed using BC 107 and CL100 BJT in Darlington pair to increase the driving current of the pulse transformer.

3. OPERATION

Half controlled converter provides single quadrant operation only. Since operation of fully controlled converters can be either positive or negative, they can operate in two quadrants (first and fourth). The first quadrant operation is called rectifier mode with power flow from A.C. source to D.C. load while fourth quadrant operation indicates the inversion mode with the power flow from D.C. circuit to A.C. network. Since only one converter operates at a time no reactors are required between the converters. However for safety purpose we have kept a reactor between both convertors.

Let us consider, Converter-1 is supplying the load current and load current is to be reversed, firing pulses to converter-1 are either blocked or the firing angle is first increased to a maximum value and subsequently firing pulses are withdrawn from converter-1. Load current will decay to zero and speed of motor also will become zero. Now a delay of 10-20ms is introduced. After this the firing pulses to converter-2 are applied. The load current will now build up through the load in the reverse direction. As long as the current is negative it is supplied by the converter-2 and the converter-1 is non operative since the firing pulses are blocked to it.

The change over from one converter to another must take place after the load current has gone to zero. The switching over from one converter to another must take place only from an external command given through direction switch (P3.1).

If load current exceeds rated limit (overload condition) firing pulses are blocked to both converters and to attract the attention of operator, buzzer can be introduced. System can resume with initial condition only when operator turns off the buzzer.

3.1 Selection Criteria of Microcontroller:

ATMEL 89s51 microcontroller is used for control system implementation, the main features of 89s51 microcontroller used here are 4KB on chip ROM for program and data storage, four 8 bit bidirectional I/O ports for the interfacing of ADC, ZCD, Direction control switch, Acceleration control switch, firing pulse

generation through one of the output port pins, two 16 bit timers for precise time delay calculation and hardware interrupt pin for detecting overload current condition. Keil programmer which is an IDE (integrated Development Environment) that helps to write, compile and debug embedded programs is used for software development.

Software is developed in assembly language for 89s51 microcontroller to provide real time controlling. Initially program reads three parameters from control panel as direction, set speed and acceleration.

4. ALGORITHM

Read three input parameters direction, set speed, acceleration and load max firing angle. Activate only one converter according direction switch and set a count for acceleration. Read ZCD to count firing angle start firing from max firing angle first. Read and compare actual speed with set speed and accordingly increment or decrement count for firing angle. SCRs are fired at an angle calculated by multiplying set speed count with delay for one count equals 39 microsecond, which smallest possible change in firing angle in this case which is less than one degree. For low level acceleration firing angle is advanced by 1 count after every 5 cycles of AC input and for high level acceleration firing angle is advanced per AC cycle. And complete control over firing position in both the half cycles of AC input achieved. After firing at one of the firing angle each time new samples of three parameters are taken for set speed, direction and acceleration. When direction is detected firing pulses to both converters are blocked, by reading actual speed wait until still condition observed, here when load current decays to zero then only another converter is activated by firing from max angle and then decrementing it until it fulfills set speed condition

5. OBSERVATION AND INFERENCE

Using ZCD a proper square wave is generated which is used further and the rising and the falling edges of the square wave are used for the measurement of the firing angles 0 – 180 degrees and 180 -360 degrees.
By changing the position of the potentiometer for the set speed, various firing angles are calculated using 89s51 program and thus firing pulses are generated using the pulse transformer.
The SCR's of the active convertor thus triggered using these firing pulses and DC voltage is obtained corresponding to the firing angle. Thus this DC voltage is driving the motor as per the set speed.
Under No Load condition load current is within rated current limit and hence the system works uninterruptedly.

The direction input at port P3.1 leads to blocking the firing pulses to the active convertor and as explained in the previous section speed is monitored continuously till the speed becomes zero. And then other convertor comes into action with the set speed.

Thus use of microcontroller based control system has brought precision and accuracy to operate DC motors by calculating precise firing angles and thereby generating accurate DC voltages.

6. CONCLUSION

All the circuits required as per the objectives of project decided are assembled and operations are verified separately and under software control. Control program is developed for the generation and variation of firing pulses for 0 to 180 degree and it verified that firing pulses can be as per change in the position of set speed potentiometer which is again a verification of integrated system response for the specific module of program. Output DC voltage is highly stable for resistive load with minor change of + or – 1 Volt from the steady state o/p. With inductive load a DC motor for no load condition speed remains constant for a particular set speed and perfectly varying according to change in set speed

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