

Design and Implementation of Dual Converter by Using Microcontroller with DC Motor as Load

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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 regulated power supply and 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.

Keywords: Microcontroller, DC Motor, Silicon Controlled Rectifiers, MOSFET

I. INTRODUCTION

The rapid growth in science and technology offers several advantages of using integrated circuits, microprocessors, microcontrollers, embedded chips, etc., in designing electrical and electronics projects and circuits by reducing their size, cost, and complexity. Using these embedded chips and microcontrollers is increasing due to its simplicity and benefits. The microcontrollers can be programmed to perform various tasks based on requirement of the circuit operation. Thus, simply by changing program instructions various tasks can be performed by a single circuit without changing any hardware circuitry of the project. Thus, the application of microcontroller in science and technology is increasing rapidly. Power electronic applications have become very common in modern commercial and industrial environments particularly in applications of AC-DC conversions. Electrical system is mostly AC in nature. But the traditional DC drives are still in operation, due to ease

of speed control requiring forward and reverse operation.

To achieve this effective control on speed and direction of chosen DC drive and AC-DC conversion, a simple controllable dual converter is used in this work. Dual converters consist of two converters or bridges. Left bridge acts as a forward converter and other (right) acts as reverse converter. Single-phase full converters allow only two-quadrant operations. If two fully-controlled converters are connected back-to-back, then a four-quadrant operation is possible and such types of converters are called dual converters as shown in Figure-1. They are used in high power variable speed drives. Conventional dual converter is built by employing two full bridge converters as shown in Figure-1. One of them is used to allow the current of motor to flow only in one direction whilst the other is used for reverse direction. Hence two bridge converters are required to perform four-quadrant operations. A Dual-Converter is a converter

which can handle a load with all four combinations of voltage polarity and current direction. The positive current converter is operated for positive current to load. The negative current converter is operated for negative load current.

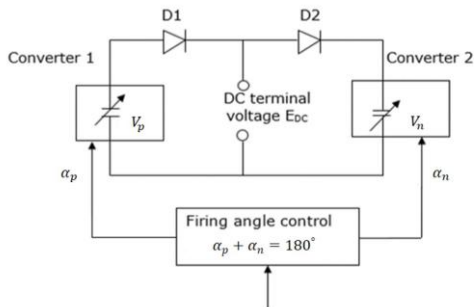


Figure 1. Block diagram of dual converter

There are two modes of dual converter.

- (1) Non-circulating current mode.
- (2) Circulating current mode.

A. Non-circulating Current Mode

In this mode, complex controlling unit is needed to trigger the thyristor. When a positive converter is triggered the negative converter is blocked temporarily. So, that time interval (10 to 20 ms) is needed between the two converter's triggering pulses. Based on the triggering the load current may be continuous or discontinuous in nature. The circuit diagram of non-circulating current mode dual converter is shown in the Figure 2

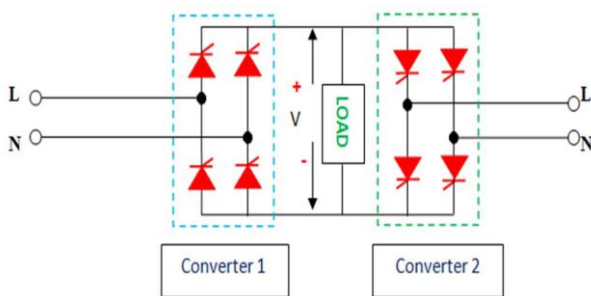


Figure 2. Circuit diagram for Non-circulating current mode.

B. Circulating Current Mode

Both the converters are always in conduction. Due to this a large amount of circulating current flow present in the circuit. To limit the over flow of the circulating

current reactors are used as shown in the Fig. 3. To operate the converters 1 and 2 concurrently firing angles should be maintained in such a way that, $\alpha_p + \alpha_n = 180^\circ$. The main advantage of this mode is its faster response. The cost and size of the reactor reasonably quite large in higher power level. Circulating current increases the power losses. So, the power factor (pf) and efficiency (η) are low. The inductance value chosen such a way that the circulating current is 30% of full load current.

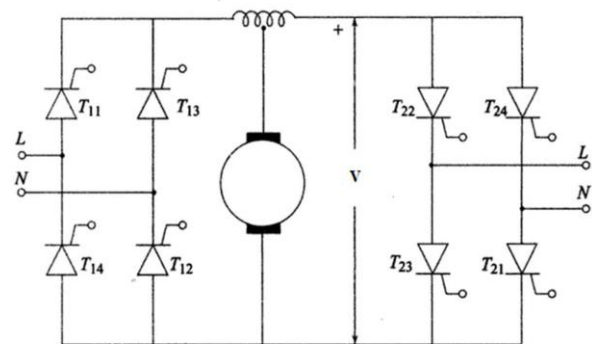


Figure 3. Dual converter in circulating Mode

MICROCONTROLLER BASED TRIGGERING CIRCUIT

Thyristors or Silicon Controlled Rectifiers (SCRs) are widely used as a switching device in the medium and large power levels starting from few kilowatts to several mega watts at voltage levels of few hundred to several kilo volt levels. Bipolar Junction Transistors (BJTs) and Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) although have very fast switching characteristics compared to SCRs, their uses are limited to medium power levels at few hundred volts. Insulated Gate Bipolar Transistors (IGBTs) are switching devices which have positive points over the MOSFETs and thyristors. However, their higher cost and inability to work at very high voltages makes SCR a better choice even today, so far as line commutated converters are concerned. Because of advances in the switching technology the analog trigger circuits are replaced by digital trigger circuits. The circuit like converter, cycloconverter, rectifier and inverter make use of thyristor as an elementary unit. There are 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. It is observed that in analog triggering circuit, trigger circuit is too complex with many components; which may lead to debugging difficulties, uneven spacing of the adjacent trigger pulses and shifting phase inaccuracies. Hence digital trigger mechanisms designed which overcomes the limitations of analog trigger circuit. Simple, reliable gate drives for interfacing logic to power devices enhanced the control of large amounts of power. Recently, advances in microcontroller technology have led to self-contained systems capable of performing much more than mere computation. Peripheral tasks so necessary to high speed, real time control can now be incorporated with a microprocessor onto a single controller chip. These include high speed data collection, analog-to-digital data conversion, timing (including sampling rates), multiplexing, and high speed output of digital data. Microcontrollers perform such high speed control functions plus microprocessor computation at reasonable cost and as an easily interfaced to a larger control system. This paper describes the design and development of microcontroller based firing angle control, using Arduino microcontroller. The microcontroller is used as the firing controller. This IC chip takes input from a variable resistor, convert it to digital data, calculate delay time and trigger thyristors accordingly. The firing angle is adjustable from zero to 180°.

II. HARDWARE

A. zero-crossing detector and the power supply

The main sections of the circuit are a rectifier, regulated power supply and zero-crossing detector. Figure.3 shows the supply waveform, zero-crossing circuit and synchronised output waveform. The 230V AC mains is stepped down by transformer to deliver the secondary output of 9V, 500 mA. The transformer output is rectified by a full-wave centre tapped rectifier comprising diodes and then regulated by IC

7805. Capacitors are used for bypassing the ripples present in the regulated 5V power supply. LED acts as the power-on indicator and resistor limits the current through LED.

B. Switch

Switches are used to increase and decrease the triggering angle. In this microcontroller based triggering circuit two switches are used, one for increasing and decreasing the triggering angle and other for direction control i.e, forward and reverse.

C. Isolation circuit

Transformers not only provide higher or lower voltage differences between their primary and secondary windings, but they also provide “electrical isolation” between the higher voltages on the primary side and the lower voltage on the secondary side. In other words, transformers isolate the primary input voltage from the secondary output voltage using electromagnetic coupling by means of a magnetic flux circulating within the iron laminated core. But we can also provide electrical isolation between an input source and an output load using just light by using a very common and valuable electronic component called an opto-coupler. Pulse transformer can also be used for isolation. An optocoupler, also known as an opto-isolator or photo-coupler, is an electronic component that interconnects two separate electrical circuits by means of a light sensitive optical interface. To protect the triggering circuit from high voltage converter circuit isolation is necessary. So opto-coupler is used here to isolate the triggering circuit from the converter circuit.

III. CONCLUSION

This paper discussed the detailed study of DC machine speed control using dual converter in both the direction (forward and reverse) and in both the mode of operation (generating and motoring). Dual converters are used for four-quadrant operation of DC drive. In circulating mode of operation there is no

need of dead time. So the speed reversal is very quick and smooth. The results of circulating current mode of operation in open loop control is shown in MATLAB simulation Relationship between motor speed and firing pulses generated by Arduino microcontroller was also found to be Linear.

IV. REFERENCES

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