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DC Motor Speed Control System with Electronic Regenerative Breaking

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Abstract*: The paper aims to provide an alternative way to build a DC motor drive system with speed control and regenerative breaking. It provides a feature of locking on to a particular speed, which will be maintained by the system irrespective of the change in certain conditions like load, friction etc, much like cruise control for an electric vehicle. A control loop is implemented to carry out the desired functions. The aim is to implement a system that provides an easy, fast and cheap method to vary speeds accurately and efficiently. The system implements dynamic electronic regenerative breaking as an inherent feature. The system can readily be integrated with electric automotives, forklifts or several other DC motor industrial applications.*

Keywords: DC motor speed control, regenerative breaking,

I. INTRODUCTION

The most popular method of speed control of DC motors is using PWM waves. Here pulses with different duty cycles are applied to the motor coil, resulting in a different RMS voltage, and hence different speed.

This method is very effective, but is complex and expensive to implement. Also, speed is usually changed only using a microprocessor, making it difficult to operate for a general user.

Perhaps a better solution is to control the firing angle of a single-phase AC supply using a simple TRIAC based circuit and convert it to DC using a rectifier bridge. Simply changing the resistance in the TRIAC circuit, Rc, shown in the Figure 2 below, can control the RMS value of the final DC voltage. This method allows us to control and vary speeds of high voltage rating (practically up to 1000s of Volts) DC motors easily and efficiently.

II. THE PROPOSAL

We will use a single-phase AC supply to run and control a DC motor.

The change in firing angle, and hence the RMS value, of a voltage signal can be easily changed using a DIAC-TRIAC circuit. When this signal with varying firing angle is fed to a SCR bridge rectifier, the output will be a corresponding RMS voltage signal. This can be used to alter the coil voltage supplied to the DC motor and hence easily control its speed. Now if the motor is disconnected from the supply, it will gradually come to a halt. Although, if we provide a way for the kinetic energy of the motor to dissipate, for example by charging a bank of capacitors, this process will be much faster. If we can control the rate at which this dissipation of energy occurs, we have a method of breaking action for a DC motor. [1]

These are the fundamental principles used in this paper.

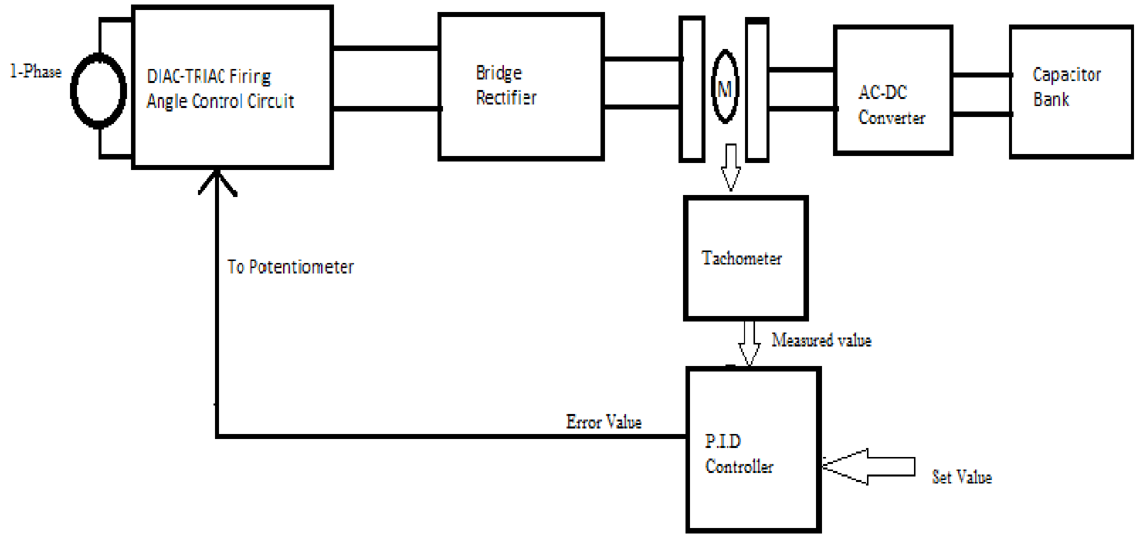

Figure 1: Basic Block Diagram

The system can be broadly divided into 3 parts or circuits.
These are:
Part I: Input Circuit
Part II: Regeneration/Breaking circuit
Part III: Control Circuit.

Now we will look into each of these parts closely, and see how they can be integrated with each other to get a DC Motor control system

A. *Part I: Input Circuit*

1) *Working of Input Section*

The single-phase input voltage is applied to a firing angle control circuit[2], whose output is fed to a AC-DC Converter, i.e., bridge rectifier, as shown in Fig. 2.

Note that this circuit also serves as an adequate motor starter circuit.

The output waveforms are shown in Fig. 3. This shows voltage signal with varying RMS values is applied to the converter, which gives a corresponding varying DC voltage.

This DC voltage is used to drive our DC Motor.

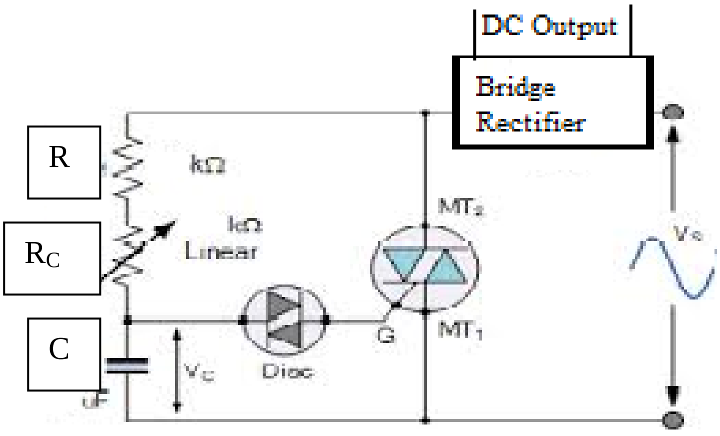

Fig. 2: Input Circuit

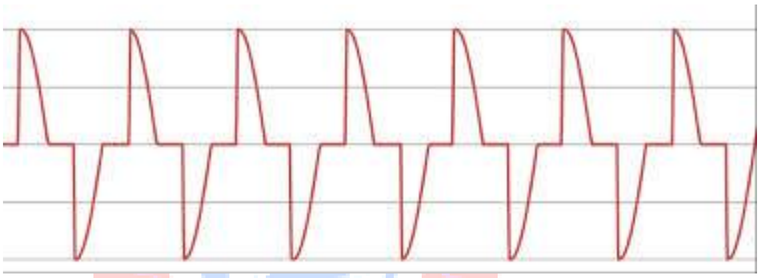

Fig. 3: Output Voltage waveforms for the DIAC-TRIAC circuit

2) Calculations:

As described before, R_C = Charging resistance
C= Capacitance Value

Also, V_S=Supply Voltage
V_C=Capacitor Voltage

i. $\alpha=(T_{ON}/T_{ON}+T_{OFF})*360$
Where T_{ON} = Duration for which the TRIAC is in the conducting state
T_{OFF} =Duration for which TRIAC is in the OFF state

ii. $V_C = V_S\ [1/1+j\omega(R+R_C)]$

iii. $V^2_{S,RMS} = V^2_{C,RMS}\ [1-(\alpha/Л)-(\sin 2\alpha/Л)]$

B. Part II: Regeneration Circuit

Implementation of the regenerative breaking circuit requires a slight modification to the basic block diagram already discussed above (Figure 1).

The required modification is the addition of a relay between the input and breaking section of the circuit. The Input section is connected to the NC (Normally Connected) terminal of the relay, while the breaking section is connected to the NO (Normally Open) terminal of the relay. The breaking signal, to be given by the user, will serve as the coil voltage for this relay.

The break signal, which is also the coil voltage for the relay, disconnects the motor from the Input section and connects it to the regenerative section.

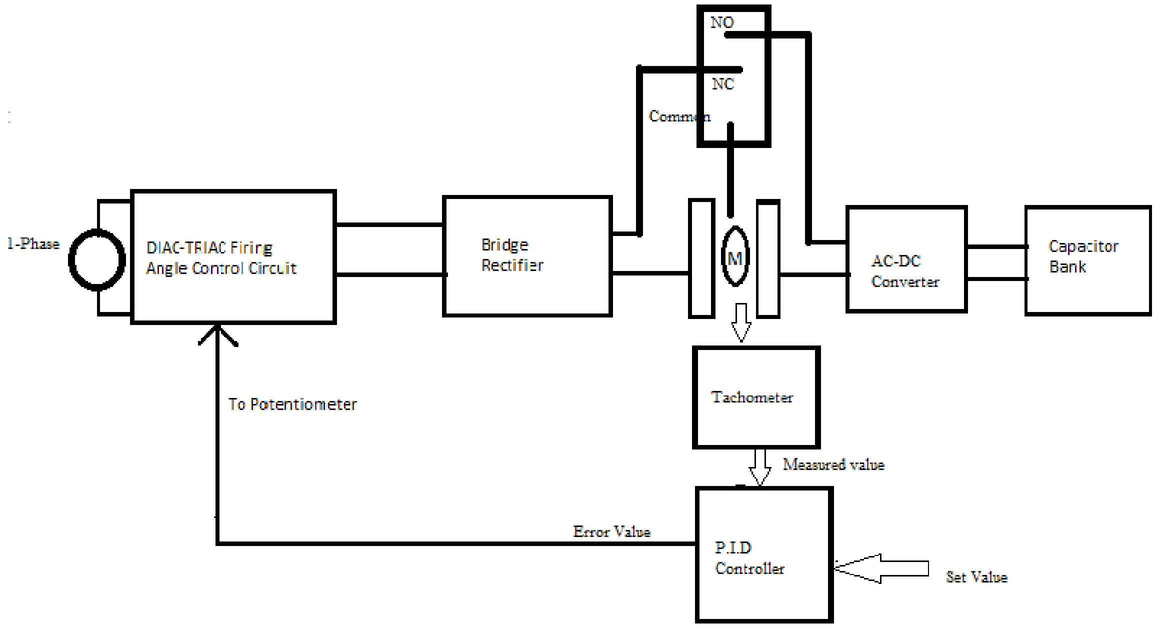

Fig. 4: Modified Block Diagram

3) Working of the Regenerative Section:

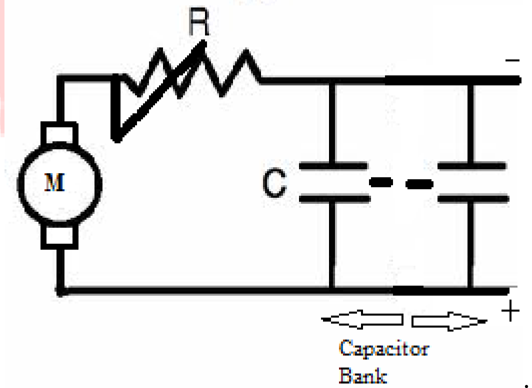

Fig. 4: Regenerative Section

As the relay disconnects the motor from the supply, the motoring action stops. The motor now works as a generator.

The Armature current direction gets reversed, so does the torque generated, The motor thus starts decelerating. The EMF generated during the breaking, by virtue of he back EMF of the motor, is stored in a capacitor bank.

4) Caution:

Here, we must address an important issue. Once the motor stops rotating and comes to a halt, the generator action will stop. The motor will now use the EMF stored in our capacitor bank, and start rotating in the opposite direction. This is dangerous and must be avoided. The relay must switch back after the motor comes to a complete halt. Also, the diode ensures there is no flow of current in the opposite direction.

5) Controlling the breaking:

The speed of the motor will continue to decrease, as the EMF transfers from the motor coil to the capacitor bank, this will happen very quickly, hence providing a very powerful breaking.

At times this may not be desired. The rate of breaking (i.e. rate of charging of the capacitor bank) can be easily controlled by adjusting the variable resistance in series with the parallel capacitor bank. The user can vary the value of this variable resistance. For example, the extent to which the break paddle is pressed in case of an electric vehicle.

C. Control Circuit

The function of this section of our system is to vary and control the values of the variable resistor, Rc, in the input section of the system.

A tachometer provides the current speed of the motor, which we will call he Measured Value. The user will input the desired speed to the controller. We will call this the Set Value.

The controller will determine the difference between these values and accordingly vary the charging resistance, altering the Armature voltage, hence speed, of the motor.

Programming of any of the available microcontrollers, and tuning a controller can do this job.

The process itself is considered outside the scope of this paper.

III. DRAWBACKS AND LIMITATIONS

- The system will work only with motors with a very high voltage rating (ideally >100V). This is because at lower voltages, we will not be able to trigger the DIAC, and hence the TRIAC, in the Input circuit (Fig. 2). For smaller motors, other methods like PWM can be applied.
- Efficient functioning of the breaking system at high speeds is limited by the size and the rate of charging of the capacitors. Large capacitor banks can get bulky.
- Breaking can fail if capacitors fail to charge. This is a real possibility in repetitive breaking, where we will apply voltage to an already charged capacitor bank. In such a situation the breaks will not work.

IV. FUTURE DEVELOPMENTS

- A system to simultaneously use the charged capacitor bank to charge a secondary battery. This maybe the same battery that is used for other peripherals in the system, for example to power the controller.
- As we have discussed above, if breaks are applied while the capacitor bank is fully charged, the system will fail. For such situations, we need a system where:
  1. The Armature voltage is dissipated elsewhere, for instance directly grounded
  2. In emergency situations, the system reverts back to conventional mechanical breaks.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

1. Power Electronics, By Techmax
2. NPTEL Series, Lecture on DC Motors
3. Physics I, Resnick, Haliday and Krane, By Tata McGraw Hill