PLC Based Closed Loop Speed Control Of DC Shunt Motor

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Abstract: In industries, it is very much required to maintain speed of DC motor accurately or precisely for some applications like drills, lathes, spinning and weaving, elevators, cranes etc. This is possible only by taking feedback of speed from DC motor and control the speed according to required accuracy. PLC and DC Drive makes major role in maintaining the speed of DC motor. PLC gets feedback signals form motor by means of encoder pulse or analog signals, it sends correction factor to PLC then it will direct to dc drive to correct the speed by changing armature voltage. PLC can accept either pulses or analog signals from encoder which will monitor the gating pulses to check the speed, where function blocks are available in PLC to convert these gating pulses to speed of motor. Then PLC can send analog output to DC drive to change the speed, where DC drive can convert this analog signal to corresponding change in armature voltage to DC motor.

Keywords: DC Motor, PLC, DC Drive, Ladder Logic

I. INTRODUCTION

In today's industries demand process automation in all sectors, because automation results in better quality, increased production and reduced costs. The variable speed drives which can control the speed of AC/DC Motors, are indispensable controlling elements in automation systems. Depending on the application some of them are fixed speed and some of them are variable speed drives.

Direct current (DC) Motors have been used in variable speed drives for a long time. The versatile characteristics of DC motor can provide high starting torque which is required for drive application. Also, the control of its speed over a wide range can be easily achieved. The methods of speed control of DC motors are simpler and less expensive than those of alternating current (AC) Motor.

Due to the fast performance of DC motors, these motors are regulated in a wide range of speeds and can be used in many applications. The main advantage of using DC motors in today's world is the ability to easily control the speed and angle of the motor. This project is about controlling the speed of DC motor by using Programmable Logic Controller. The controller has more advantages than conventional control circuits. The benefits can be noted such as reducing the size of the control panel, very low energy consumption, Durable Equipment, Proper operation in the worst cases. Using PLC for controlling industrial systems is initiated in 1968 and, its development has been greatly accelerated in recent years.

II. SPEED CONTROL OF DC SHUNT MOTOR:

The speed of the shunt motor is independent of the shaft load. As the load to the motor increases, the speed of the motor slows down instantaneously. Slowing down the speed reduces the back EMF, which in turn increases the current in armature branch. This results in the increase of the motor speed.

On the other hand, if load is decreased, then motor speed will rise instantaneously. This in turn will increase the counter EMF, thus reducing current to the motor. Gradually the motor will reduce it's speed. As a result, the DC shunt motor is capable of maintaining a constant speed irrespective of load changes. Because of this feature, this motor is used for automotive and in industrial purposes where fine precision of the motor speed is required.

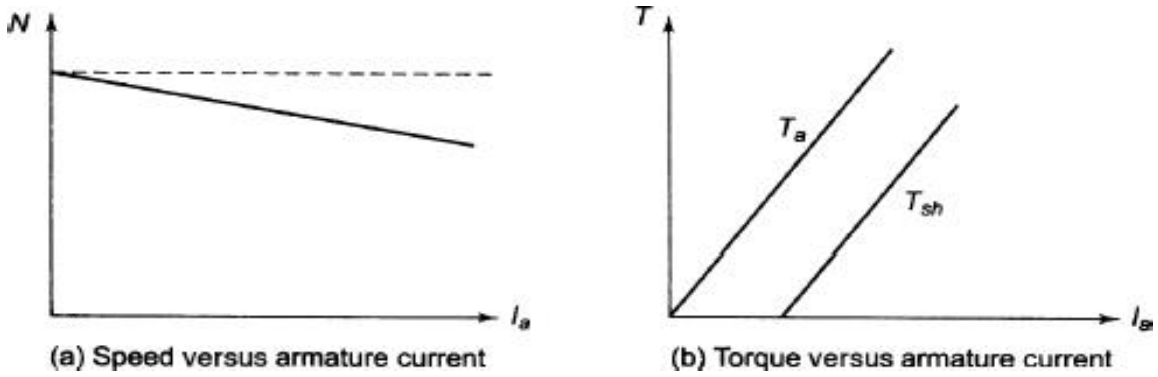


Figure: 1 Shows speed control characteristics

Speed of dc shunt motor is controlled by the following methods

A) Field Control of DC Shunt Motor

By this method speed control is obtained by any one of the following means

i. Field rheostat control of DC Shunt Motor: In this method. speed variation is accomplished by means of a variable resistance inserted in series with the shunt field. An increase in controlling resistances reduces the field current with a reduction in flux and an increase in speed. This method of speed control is independent of load on the motor. Power wasted in controlling resistance is very less as field current is a small value. This method of speed control is also used in DC compound motor

Limitations of this method of speed control:

- Creeping speeds cannot be obtained.
- Top speeds only obtained at reduced torque
- The speed is maximum at minimum value of flux, which is governed by the demagnetizing armature reaction on the field.

ii. Field voltage control: This method requires a variable voltage supply for the field circuit which is separated from the main power supply to which the armature is connected. Such a variable supply can be obtained by an electronic rectifier.

B) **Armature Control of DC Shunt Motor:**

Speed control by this method involves two ways. These are,

i. Armature resistance control: In this method armature circuit is provided with a variable resistance. Field is directly connected across the supply so flux is not changed due to variation of series resistance. This is applied for dc shunt motor. This method is used in printing press, cranes, hoists where speeds lower than rated is used for a short period only.

ii. Armature voltage control: This method of speed control needs a variable source of voltage separated from the source supplying the field current. This method avoids disadvantages of poor speed regulation and low efficiency of armature-resistance control methods. The basic adjustable armature voltage control method of speed d control is accomplished by means of an adjustable voltage generator is called Ward Leonard system. This method involves using a motor –generator (M-G) set. This method is best suited for steel rolling mills, paper machines, elevators, mine hoists, etc.

III. VARIOUS METHODS USED TO CONTROL SPEED OF DC SHUNT MOTOR:

- ***Speed control of DC shunt motor using Fuzzy logic:***

The speed of DC shunt motors can be adjusted within wide boundaries so that this provides easy controllability and high performance. DC Shunt motors used in many applications such as still rolling mills, electric trains, electric elevators, electric vehicles and robotic manipulator requires speed controllers to perform their tasks. Speed control of DC shunt motor is carried out by means of voltage control in 1981 firstly by Ward Leonard. The regulated voltage sources used for DC shunt motor speed control have gained more importance after the introduction of Thyristors as switching devices in Power electronics. Then Semiconductor components such as MOSFET's, IGBT's, GTO's have been used as electric switching devices.

In general, the control of systems is difficult and mathematically tedious due to their high non-linearity properties. To overcome this difficulty, Fuzzy logic controller can be developed. The best application Fuzzy logic controller are the time-variant systems that are non-linear. One of the most important fuzzy logic controller applications in real life is the metro system in the city Sendia of Japan in 1987. Now a day, Fuzzy logic controller applications are successfully used in many field including automatic focus cameras, House hold materials such as dish wash and in automobile industry.

The speed response of the DC shunt motor exposed to fixed armature voltage was investigated for both under loaded and un loaded operating conditions. The first, DC shunt motor was operated for a required reference speed under loaded and unloaded operating conditions using PI control method. Then, to make performance comparision, the speed of the system was controlled using Fuzzy logic controller. The Fuzzy logic controller system designed for operating at fixed speed under different load conditions are simulated at MATLAB/SIMULINK environment, in this study Chopper circuit acts as motor drive

- ***DC shunt motor velocity control through DC-to-DC power converter:***

The proposed feedback controllers use step, ramp and constant functions as reference trajectories for the specifications of the desired angular velocity profile.Conventionally, DC motor drives have widely employed thyristorbased phase controlled rectifiers which supply adjustable terminal voltage for speed control. We note that DC-to-DC converter can be operated at much higher switching frequencies (above 50 KHz) and may be designed to supply continuous armature current under all load conditions.

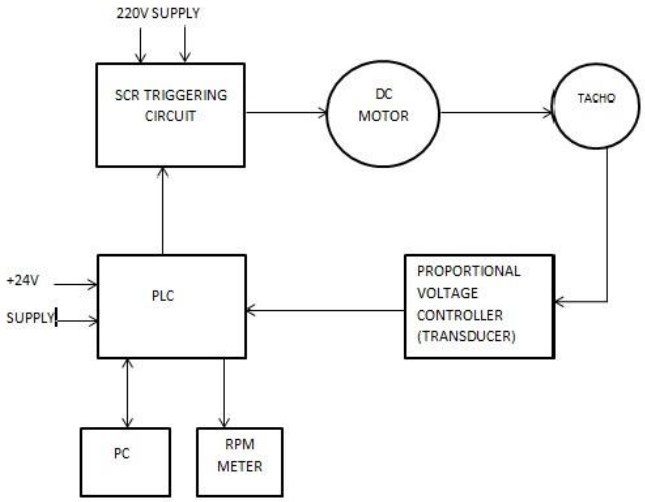
By using DC-to-DC power converter of the "buck" type as an "electronic starter" for the machine operation initiated at rest conditions towards a desired final constant reference converter input current, the proposed scheme results in a "sensorless" feedback controller. The starter control input is designed so that a smooth trajectory is followed by the motor angular velocity.

- ***Speed Regulation of DC Shunt motor using Intelligent Controllers:***

Due to its excellent speed control characteristics, the DC shunt motor has been widely used in Industries even though its maintenance costs are higher than Induction motor. Thus, Speed control of DC Shunt motor has attracted considerable research and several methods have evolved. Proportional-Integral (PI) controllers have been widely used for speed control of DC Shunt motor. In order to reduce the loading effect and to minimize the time delay feed forward controller added to the PID controller.

In addition, applications of several new methods to control the speed regulation of DC shunt motor are designed. This method includes Fuzzy auto tuning, Gas based PID controller, Gas based Fuzzy PID controller, Fuzzy PID controller using neural network and Brain emotional learning based intelligent controller (BELBIC).

IV. PROPOSED WORK



3.1 SCR triggering circuit: DC drive is basically a DC motor speed control system that supplies the voltage to the motor to operate at desired speed. Earlier, the variable DC voltage for the speed control of an industrial DC motor was generated by a DC generator.

3.2. DC Shunt Motor: DC shunt motors have a rotating armature winding, in which a voltage is induced and non-rotating field winding that produces the main magnetic flux. In this type of motor the field winding are connected in parallel with the armature winding, so that the full voltage of the Motor is applied across the armature and field windings. To control the speed of a DC Shunt motor, field excitation is kept constant and armature voltage is varied.

Parameters	*Specification*
Power Rating	1 HP
Voltage	220V
Current	4.6A
Speed	1500 RPM

Motor Specifications

To control the speed of a DC shunt motor, the following components are used.

i. Tacho Generator: Tachometer generators (or tachogenerators) are electromechanical devices which output a voltage proportional to their shaft speed. They are used to power tachometers and to measure the speed of motors, engines, and other rotational devices.

ii. Transducer: It is a device which covers the tachogenerator voltage to a standard PLC voltage and it is configured as 100v corresponds to 10v.

iii. Programmable Logic Controller: A programmable logic controller (PLC) is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic to control machines and processes. It is designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the programs.

iv. Personal Computer: Personal Computer is used to provide, a user friendly graphical interface and to write the program in descriptive language and to convert the same into a machine level language which can be conceived by our PLC trainer kit. It provides the flexibility to select the mode of operation of the motor such as open loop, closed loop. It monitors the operation of DC shunt motor in operating condition. It receives the operational data such as set speed of motor, actual speed of the motor and display's the same and stores it in proper format and maintains a data base.

v. Relay: A relay is an electrically controllable switch widely used in industrial controls, automobiles, and appliances. It allows the isolation of two separate section of a system with two different voltage sources. for example, a +5v system can be isolated from a 120v system by placing a relay between them.

V. WORKING PRINCIPLE

Open loop control system: In open loop system, only speed can be monitored because there are no feedback signals. According to the input voltage given, the control voltage is developed across the motor armature and motor is driven at the constant speed.

Closed loop control system: When a supply is given to DC drive and PLC, the program should be compiled and executed, then communication between the PC and PLC has to be made. The count value which is given in the program is converted into analog in the plc using D/A converter, and at the output of PLC this analog value is converted into digital using A/D converter. This digital value is given to the DC drive. In the DC drive the field voltage is constant and the armature voltage is variable, and the drive is configured for 4000 counts=180v.This voltage is given to the DC motor the

motor will start to run. The shaft of the motor is connected to the tachogenerator, and this tacho produces a voltage of 80v.This voltage cannot be given directly to the PLC because its input is configured for -10v to +10v.A transducer has to be used to convert this 80v within 10v.This converted voltage is given to the PLC. This voltage is compared with the set value, if any correction should be made, the correction factor will be given by the program, and the whole process is repeated until we get set value.

VI. LADDER PROGRAM DISCRIPTION:

Ladder diagram is a diagram language frequently applied in automation. The ladder diagram is composed of the symbols of electric control circuit. The completion of the ladder diagram by the ladder diagram editor is the completion of the PLC program design. The control flow illustrated by diagram makes the flow more straightforward and acceptable for the technicians of who are familiar with the electric control circuit. Many basic symbols and actions in the ladder diagram come from the frequently-seen electromechanical devices, e.g. buttons, switches, relay, timer and counter, etc. in the traditional power panel for automation control.

VII. RESULTS AND CONCLUSIONS

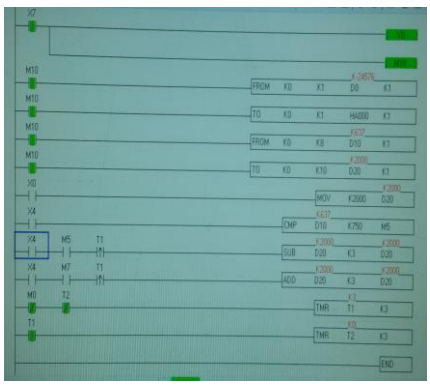
The Speed of a DC shunt motor below the rated value is successfully monitored by using a PLC with control electronic circuit, and DC shunt motor behavior in open loop operation is studied.

Without load readings:

Digital counts	Speed in rpm (set value)	Open loop speed (rpm)	Closed loop speed (rpm)	'V' across taco in volts
1000	375	300	373	29.6
1500	562	528	563	35.4
2000	750	638	750	45.5
2500	937	799	938	57
3000	1125	959	1123	67
3500	1311	1199	1313	73.5
4000	1500	1488	1499	78.5

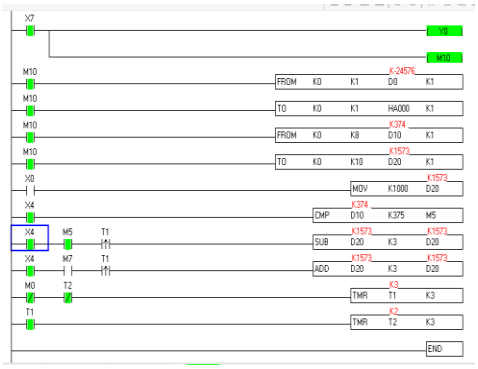
No load open loop condition:

set speed through plc=750
speed recorded by RPM meter=638



No load closed loop condition:

set speed through plc=375
speed recorded by RPM meter=373

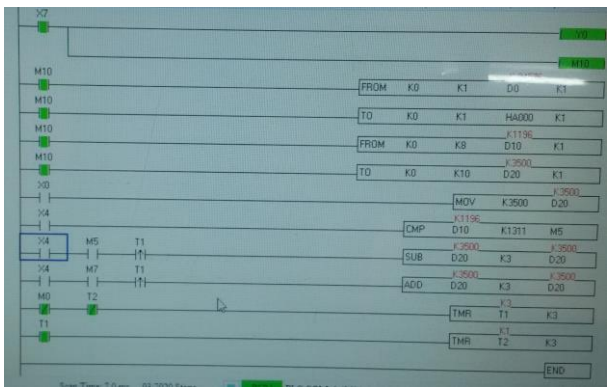


With load readings:

Load in (Kg) L1+L2	Digital counts	Speed in rpm (set value)	Open loop speed(rpm)	Closed loop speed (rpm)	'V' across tacho in volts
1.3+0.7=2.0	1000	375	329	373	29
1.9+0.7=2.6	1000	375	330	374	29.4
3.8+1=4.8	1000	375	328	375	29.4
6+1.5=7.5	1000	375	330	374	29.4

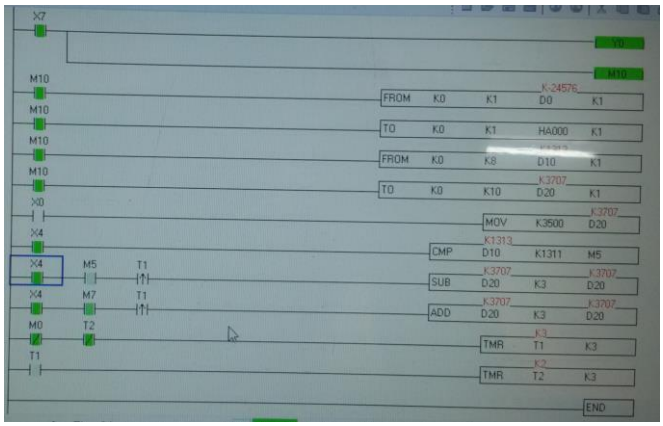
With load, open loop condition:

set speed through plc=1211
speed recorded by RPM meter=1199



With load, closed loop condition:

set speed through plc=1311
speed recorded by RPM meter=1313



VIII. CONCLUSIONS

The hardware designed using Programmable logic controller along with necessary software developed are successfully implemented to monitor the speed of a DC shunt motor. In this project, low cost and secured speed monitoring of a DC shunt motor are ensured automatically. This approach can be implemented for industrial and other practical application precisely using PLC and satisfying user needs and requirements.

Conflict of Interest: We the authors declare that there is no conflict of interest

Ethical Statement: We the authors declare that we have followed ethical responsibilities.

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