Design and Implementation of PLC based Computerized Monitoring in Dip Coating System

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ABSTRACT
The present study is about the design and implementation of dip coating system based on Programmable Logic Controller (PLC) technology. The PLC correlates the operation parameters control required by the user and monitors the system during normal operation and under dipping conditions. Tests of dip coating system driven by DC motor driver and controlled by PLC prove a higher accuracy in regulation as compared to manual human works. The implementation of the hardware and software for control system and results obtained from tests on dip coating performance is provided. Thus, PLC is proved as a versatile and wide effective tool in industrial control of electric drives.

General Terms
Programmable logic controller (PLC), Printed circuit Board (PCB), Toggle switch.

Keywords
Dip Coating, DC motor, L293D Driver Circuit, Programmable Logic controller (PLC), Computer, Slide and Vessel.

1. INTRODUCTION
With the rapid changes on industries and information technologies in recent years, some traditional bulk electronic appliances have to be monitored for a long time. All of their control devices such as communication interfaces gradually enter the Internet information era. Control of all equipments has been performed through the use of computers. Most equipment uses PLC (Programmable logic controller) to connect with computer to monitor consuming devices. PLC's are widely used in industrial fields because they are inexpensive, easy to install and very flexible in applications. A PLC interacts with the external world through its inputs and outputs. Since technology for motion control of circuit drives became available, the use of PLC with power electronics in electric machine applications has been introduced in the manufacturing automation [1].

Dip coaters are robust computer controlled instruments for precise thin film deposition. We provide solutions for the dip coating of small to large samples in either single or multiple vessels which is suitable for both simple and complex vessel sequencing [2].

Since technology for motion control of electric drives became available, the use of PLC's with power electronics in electric machines applications has been introduced in the manufacturing automation [3&4].

Many applications of DC motors require besides the motor control functionality, the handling of several specific analog and digital input/output signals, home signals, forward command, reverse commands and on/off [5].In such cases, a control unit involving a PLC must be added to the system structure. This paper presents a PLC-based monitoring and control system for Dip Coating. It describes the design and implementation of the configured hardware and software. The test results obtained on DC motor performance show improved efficiency and increased accuracy in time constant controlled operation. Thus, the PLC correlates and controls the operational parameters to the time set point requested by the user and monitors the DC motor system during manual operation and under automatic conditions.

2. PLC AS A SYSTEM CONTROLLER
PLC is a microprocessor-based control system, designed for automation processes in industrial environments. It uses a programmable memory for the internal storage of user-orientated instructions for implementing specific functions such as arithmetic, counting, logic, sequencing, and timing [6&7]. A PLC can be programmed to sense, activate and control industrial equipment, incorporates a number of I/O points, which allow electrical signals to be interfaced. Input devices and output devices of the process are connected to the PLC and the control program is entered into the PLC memory (Fig 1).

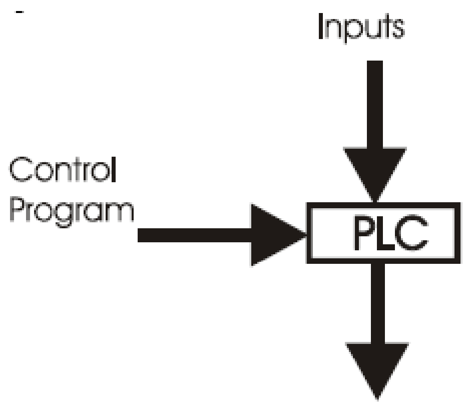

Fig 1: Control Action of a PLC (source [1-8])

In our application, it controls through analog/digital inputs and outputs the varying load-constant speed operation of an induction motor. Also, the PLC continuously monitors the inputs and activates the outputs according to the control program. This PLC system is of modular type composed of specific hardware building blocks (modules), which plug directly into a proprietary bus: a central processor unit (CPU), a power supply unit, input-output modules I/O and a program terminal. Such a modular approach has the advantage that the initial configuration can be expanded for other future applications such as multi machine systems or computer linking [8].

3. CONTROL SYSTEM OF DIP COATING MODULE

The following configurations can be obtained from this setup. PLC's programming is based on the logic demands of input devices and the programs implemented are predominantly logical rather than numerical computational algorithms. The programmed operations work on a straight two-state "forward and reverse" basis and these alternate possibilities correspond to "positive polarity or negative polarity" (logical form) i.e. "+12v or -12v" respectively. In (Fig 2), the block diagram of the experimental system is illustrated.

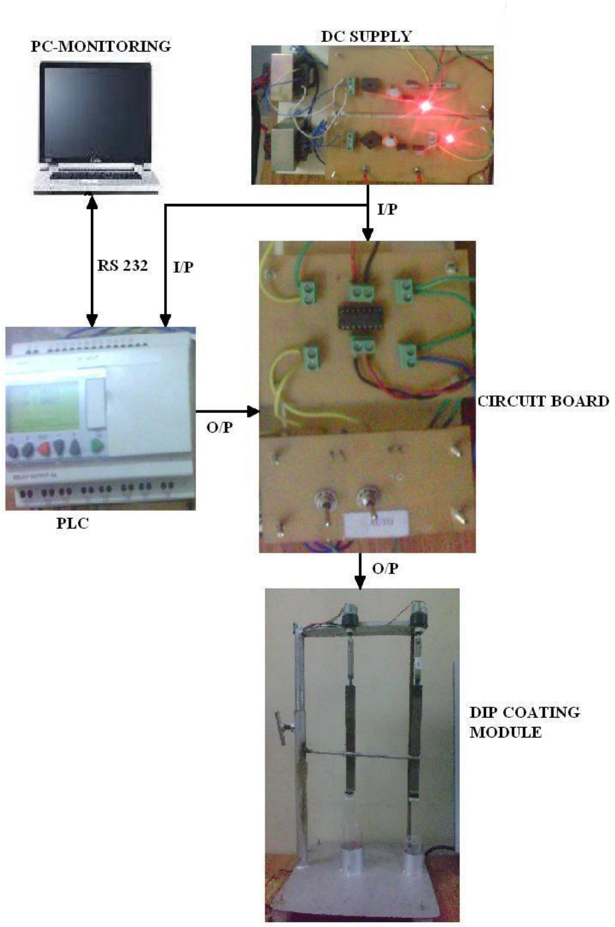

Fig 2: Experimental Setup

The following configuration can be obtained from this setup.

A. Personal computer for monitoring the status of dip coating.
B. PLC- programmable logic controller is programmed with ladder diagram and communicates with PC through RS232 [9].
C. AC 230V, 50 Hz convert to DC Power supply, simultaneously gives 24V-12AMPS for PLC, 12V and 5V 12 AMPS for L293d driver to operate the function (SMPS) [10&11].
D. Circuit board contains L293D PCB (Printed circuit board) design along with controller switch to operate auto and manual [12&13].
E. Dip coating model has 12"×12" square steel sheet, 12" rod, 10" angle, 2 numbers of slide clamper and vessels clampers.
F. The automatic process can be controlled the system of Dip coating module by Auto and Manuals switch are placed inbuilt in the circuit board.

4. HARDWARE DESCRIPTION

DC motors run on direct current from a battery or DC power supply. Direct current is the term used to describe electricity at a constant voltage. AC motors run on alternating current, which oscillates with a fixed cycle between a positive and negative value. Electrical outlets provide AC power, when a battery or DC power supply is connected between a DC motor's electrical leads, the motor converts electrical energy to mechanical work as the output shaft turns [5&20].

These are high quality low cost motors. This motor has a plastic gearbox shell which accommodates metal gears that ensures longer wear and tear. High quality grease is applied inside the gearbox for providing frictionless rotation of the gears [5]. DC motor technical specifications shows in Table 1.

Table 1. DC motor technical Specifications

Connection	Range
Input voltage	12vdc
Output current	500-600mA
Rated speed	150rpm
Torque of motor	5.5kg-cm
Shaft Length	2.4cm
Diameter of shaft	6mm
Weight of the motor	150gms
Mounting Diameter	14mm

L293D is a dual H-Bridge motor driver IC L293D can interface two DC motors which can be controlled in both clockwise and anti clockwise direction. L293D has output current of 600mA and peak output current of 1.2A per channel. Moreover for protection of circuit from back EMF output diodes are included within the IC. The output supply (VCC2) has a wide range from 4.5V to 36V, which has made L293D is a best choice for DC motor driver [14].A simple schematic for interfacing a DC motor using L293D (Fig 3).

Three pins are needed for interfacing a DC motor (A, B and Enable). For enabled connect 5v VCC to enable pin another 2 pins needed from controller to make the DC motor works.

As per the truth table Table.3 mentioned in the fig.3 it's fairly simple to program the PLC controller. It's also clear from the truth table of BJT circuit and L293D the programming will be same for both of them, just keeping in mind the allowed combinations of A and B[15]. We discuss about the programming in ladder diagram as well as functional block diagram for running the DC motor with the help of a PLC controller.

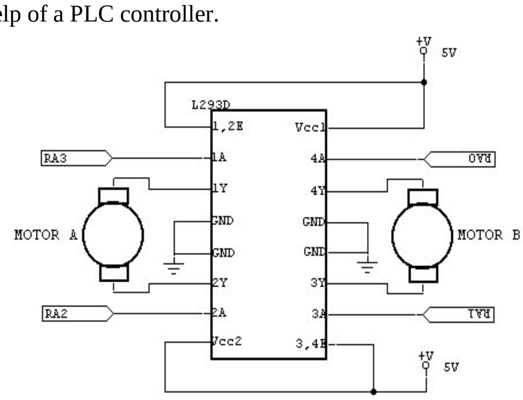

Fig 3: Schematic diagram of L293D

Table 2. Truth Table for L293D

Input			**Output**
Enable	RA2/RA1	RA3/RA0	A,B
1	0	0	Motor Brakes
1	0	1	Runs Reverse
1	1	0	Runs Forward
1	1	1	Motor Brakes

The control system is implemented and tested for a wound rotor DC motor, having the technical specifications given in Table 1. This controller is implemented on a PLC modular system. The PLC architecture refers to its internal hardware and software. As a microprocessor-based system, the PLC system hardware is designed and built up with the following modules [16].

- Central processor unit (CPU)
- Discrete input module (DIM)
- Discrete output module(DOM)
- Analog inputs module (AIM)
- Analog output module (AOM)
- Power supply

The DC motor machine drives its shaft mechanically and an output voltage is produced, the magnitude of which is proportional to the speed of rotation. Polarity depends on the direction of rotation. The voltage signal from the circuit driver must match the specified voltage range of the (0–12 V DC).

PLC external control circuits are designed using a low-voltage supply of 24 V DC. For the manual control, the scheme is equipped with start, stop push buttons, as well as with a forward and backward direction selector switch (Table 2), all of the described components: a main switch an automatic forward and backward selector through PLC module and for manual forward/backward direction of rotation switch selector as well as the PLC modules are installed in a control panel. The program is downloaded into the PLC from a personal computer (PC) using RS232 serial interface.

5. SOFTWARE DESCRIPTION

PLCs offer a flexible, programmable and alternative to electrical circuit relay-based control systems built using analog/digital devices. The programming method used is the ladder diagram method. The PLC system provides a design environment in the form of software tools running on a computer terminal which allows ladder diagrams to be developed, verified, tested and diagnosed. First, the high-level program is written in functional block/ladder diagrams [17]. Then, the ladder diagram is converted into binary instruction codes so that they can be stored in random access memory (RAM) or erasable programmable read-only memory (EPROM). Each successive instruction is decoded and executed by the CPU. The function of the CPU is to control the operation of memory and I/O devices and to process data according to the program. Each input and output connection point on a PLC has an address used to identify the I/O bit. The method for the direct representation of data associated with the inputs, outputs and memory is based on the fact of the PLC memory is organized into three regions: Discreet input (I), output relay (O), and internal memory (M). Any memory location is referenced directly using I, O, and M (Table 3).

The PLC program uses a cyclic scan in the main program loop such as periodic checks are made to the input variables (Fig 4). The program loop starts by scanning the inputs to the system and storing their states in fixed memory locations (internal memory I).

Table 3. PLC configuration

CD 20 PLC		
Pins	Available	Used
Discreet Inputs(I)	6	2
Analog Inputs(I)	4	-
Output Relays(O)	8	4
LED Display	36×72	Digital display
Data Memory(M)	368bits/200 words	

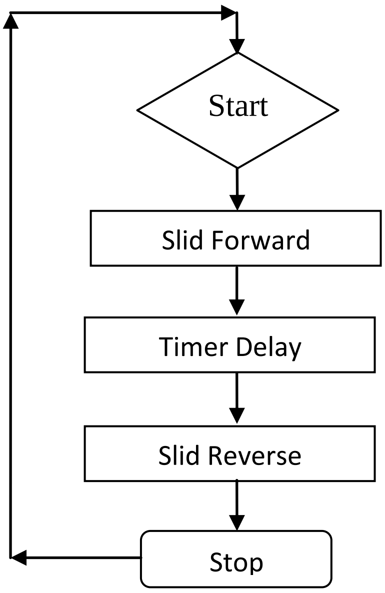

Fig 4: Flow chart of the main program.

The ladder diagram program is then executed rung by-rung. Scanning the program and solving the logic of the various functions rungs determine the output states. The updated output states are stored in fixed memory locations (output image memory O). The output values held in memory are used to set/reset the physical outputs of the PLC. For the given PLC, the time taken to complete one cycle or the scan time is 0-20 ms (Input acquisition time +1 to 2 cycle times) and with a maximum program capacity of 350 blocks /200 words [18]. The development system comprises a computer (PC) connected via an RS232 serial port to the target PLC. The computer provides the software environment to perform file editing, storage, printing, and program operation monitoring. The process of developing the program to run on the PLC consists of: using an editor to draw the source ladder diagram program, converting the source program to binary object code which will run on the PLC's microprocessor and downloading the object code from the PC to the PLC system via the serial communication port. The PLC system is online when it is in active control of the machine and monitors any data to check for the correct operation [19].

6. RESULTS

The system was tested during operation with test on Dip coating control performance and time period. The PLC monitoring the DC motor operation (Dip coating) and correlates the parameters according to the software. The performance of DC motor supplied from standard 12V and PLC total circuit input 24V network were measured. The experiment control system was operated forward and backward respectively +12V and -12V in the two different modes. The experiment flow chart shows in Fig 5.

The range of voltage and speed corresponds to design of the PLC hardware and software as described in the previous sections. The rotations versus voltage and time characteristics were studied in the range of 0- 200sec /12V (Table 4).

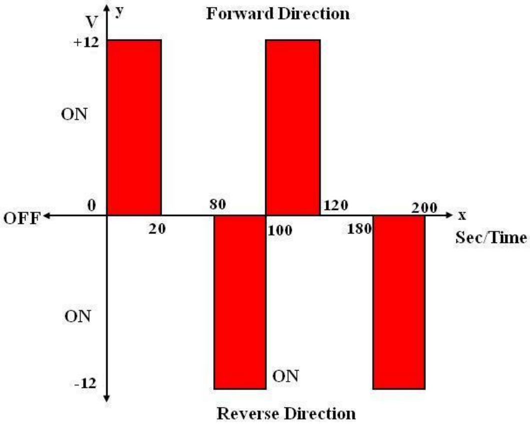

Fig 5: Experimental characteristics with PLC and L293D driver

Table 4. Description of PLC and L293D driver characteristics

Forward	Time delay (Slide in chemical)	Reverse
0 - 20s	20 - 80s	80 - 100s
100 - 120s	120 - 180s	180-200s

S- Seconds.

7. CONCLUSION

Successful experimental results were obtained from the previously describe scheme indicating that PLC can be used in automated system with L293D motor driver and control by PLC proves its high accuracy in time delay regulation at constant speed.

The present study revealed that the Dip coating effectiveness with PLC-based control system is affordable and satisfactory. The obtained Dip coating efficiency with PLC control is may be increased as compared to the other microprocessor/microcontroller. Specifically, at high speeds forward, reverse direction the efficiency of PLC-controlled system is increased up to 10-20% as compared to the configuration of the DC motor supplied from a standard network. Despite the simplicity of the control method used, this presents:

- Constant voltage
- Very good accuracy in closed-loop control scheme
- Higher efficiency
- Timing performance
- Economically low

Since, the Dip coating effectiveness with PLC proved to be a versatile and efficient control tool in industrial automation and research laboratory applications.

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