

Low Cost Real Time Centralized Speed Control of DC Motor Using Lab View -NI USB 6008

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ABSTRACT

DC motors are an outstanding portion of apparatus used in automotive and automation industrial applications requiring variable speed and load characteristics, due to its ease of controllability. Creating an interface control system for multi DC motor drive operations with centralized speed control, from small-scale models to large industrial applications is in much demand. By using Lab VIEW (laboratory virtual instrument engineering workbench) as the motor controller, we can control a DC motor for multiple purposes using single software environment. The aim of this paper is to propose the centralized speed control of DC motor using Lab VIEW. Here, Lab VIEW is used for simulating the motor, whereas the input armature voltage of the DC motor is controlled using a virtual Knob in Lab VIEW software. The hardware part of the system (DC motor) and the software (in personal computer) are interfaced using a data acquisition card (DAQ) -Model PCI-6024E. The voltage and Speed response is obtained using Lab VIEW software. Using this software, the speed of a group of motors can be controlled from different locations using remote telemetry. The proposed work also focuses on controlling the speed of the individual DC motor using PWM scheme (Duty cycle based Square wave generation) and DAQ. With the help of the DAQ along with Lab VIEW front panel window, the DC motor speed and directions can be changed easily in remote way. In order to test the proposed system the laboratory model for an 80W DC motor group (multi drive) is developed for different angular displacements and directions of the motor. The simulation model and experimental results conforms the advantages and robustness of the proposed centralized speed control.

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1. INTRODUCTION

The DC motors were invented in mid-nineteenth century, its impressive characteristics like speed control over wide range, high starting torque, quick starting, stopping, reversing and acceleration, etc. have helped this motor to exist in today's generation. Because of its various good characteristics, it finds application in various automotive industries, agricultural industries, in electric vehicles etc. Since it is used in various industries, it becomes very important to keep a check on performance, efficiency and running status [1]. Using traditional methods lowers the production and increases the possibility of errors, so it is eventually eliminated. Although there were many significant attempts made to make things easier there are still many limitations [2]. In order to make things automated, the use of virtual instrument and computer technology can be of great help [3].

Virtual instrumentation is basically a combination of software and hardware setup system. This system works on a specific design which is given or already designed by the user. Virtual instrumentation has significantly grown since its inception in 1970s. In recent years, commonly used simulation software's are Pspice, Protel and Matlab. Lab VIEW, compared with other computer software is created based upon the language along the text lines of code, Lab VIEW graphical programming language-G language. The resulting program is shown in block diagram form [4]. Lab VIEW is also a perfect simulation, debugging tool such as setting breakpoints, single step and so on. With Lab View's dynamic continuous tracking mode, the process of data and changes can continuously and dynamically be observed, hence it is more convenient and effective than any other language development environment. The actual motor parameters can be measured, controlled and modified directly, which will greatly facilitate simulation [5]. The better response of the system can be obtained To control the speed of motor and display the changes of rotational speed of motor. The NI USB-6008 [6] data acquisition (DAQ) card scratches the data of D/A converter to transmit the signal in real time to PC to be the speed response of DC motor real-time supervision. Because the DAQ card has the capability of data storage and calculating, analysis and A/D, D/A conversion matches with the Lab VIEW virtual instrument characteristic applying to detect the revolution of DC motor. This mode can substitute the traditional instruments, for instance, oscilloscope, signal generator, power etc. and the test operation is convenient [7]. However, National Instruments increases the productivity of engineers and scientists in developing test, control, and design systems by providing software products for a wide range of functionality [8-10]. NI Lab VIEW is a graphical development environment for creating flexible and scalable test, measurements, and control applications rapidly and at minimal cost. Based on the above discussion, the VI platform gives enhanced performance to control a motor in real time. Very few research papers are available to test the VI based real time DC-motor control, particularly low cost DAQ based DC-motor real time control.

Hence, this paper deals with the speed of a DC motor in Lab VIEW real time platform using low cost hardware structure including virtual Knob in Lab VIEW software a DAQ -Model PCI- 6024E. The proposed work also focuses on controlling the speed of the individual DC motor using PWM scheme (Duty cycle based Square wave generation) and DAQ. With the help of the DAQ and Lab VIEW front panel window, the DC motor speed and directions can be change easily in remote way. In order to test the proposed system the laboratory model for a 15W DC motor group (multi drive) is developed for different angular displacements and directions of the motor. The simulation model and experimental results conform the advantages and robustness of the proposed centralized speed control.

2. DC MOTOR SPEED CONTROL FUNCTIONAL BLOCK DIAGRAM

2.1. Speed Control of DC Motors

This work uses a separately excited DC motor, which is often used for the velocity tuning and the position adjustment. The proposed DC motor control is by using the armature voltage control method, where the field voltage maintaining constant. The equivalent circuit of the DC motor using the armature voltage control method is shown in Figure 1.

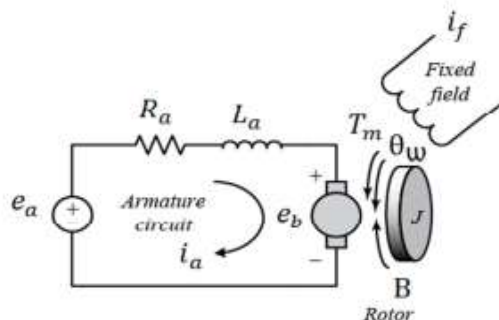


Figure 1. DC motor equivalent circuit

Armature resistance (Ω)

Armature inductance (H)

Armature current (A)

Field current (A)

Input voltage (V)
 Back electromotive force (EMF) (V)
 Motor torque (Nm) ω
 Rotor inertia (kgm) B
 Friction constant (Nms/rad)
 Torque constant (Nm/A) K_T
 EMF constant (Vs/rad) K_b

The equivalent armature voltage control functional block diagram of a DC motor armature voltage control system is shown in Figure 2, in which control parameter is supply voltage (given through DC to DC converter)

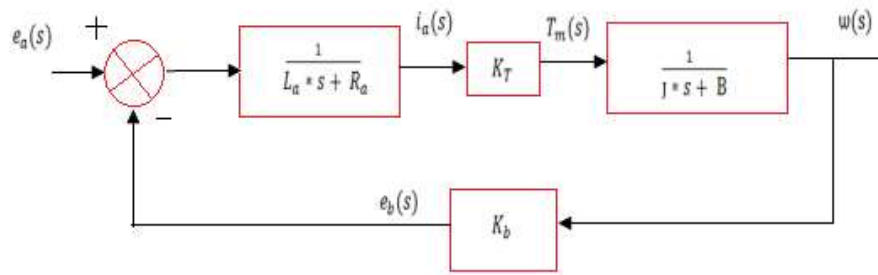


Figure 2. DC motor armature control system block diagram.

3. PROPOSED DC MOTOR SPEED CONTROL IN LAB VIEW ENVIRONMENT

The first step to scheming a closed-loop controller is to discover a mathematical illustration of the system to create a model. Many types of systems can be modeled, including mechanical systems, electronic circuits, analog and digital filters, and load system (mechanical load). For this trial, we have created a model for a DC motor through VI, based on the transfer function (Figure 2). The DC motor can be best represented by a transfer function. A transfer function provides a mathematical description for how the inputs and outputs of a system are related. In our case, the input to the system is voltage (V_m) and the output from the system is angular velocity (Ω_m). We can use the equation below to represent the model of our DC Motor, where:

k_m = Motor back-EMF constant (V/ (rad/s))

R_m = Motor armature resistance (Ohms)

J_{eq} = Equivalent moment of inertia ($kg \cdot m^2$) (Assume that $J_{eq} = J_m$ (Motor armature moment of inertia))

Model of the DC Motor represented in the Lab VIEW Math Script Node as shown in Figure 3.

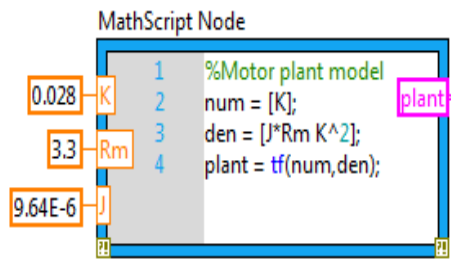


Figure 3. Model of the DC Motor represented in the Lab VIEW Math Script Node

The next step is to choose a control method and design a controller. When designing a controller it is best to fully understand the plant, in our case, the DC Motor. This understanding comes from the analysis of specialized graphs, such as Bode, and root-locus, which build perception of how the plant will perform. Graphs in the time domain, such as the step response, offer instantaneous feedback on the perfect performance of the system, such as rise time, overshoot, settling time, and steady-state error. (Due to the page constraint the behaviors of the motor is not given). Model of the DC Motor represented in schematic of a Closed-Loop Control system as shown in Figure 4.

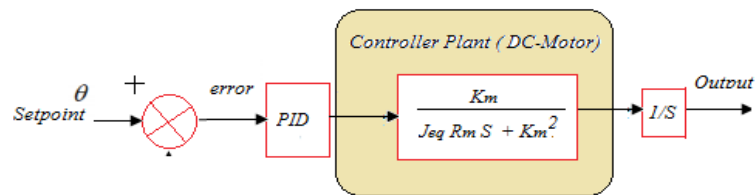


Figure 4. Model of the DC Motor represented in Schematic of a Closed-Loop Control System

For this experimentation, a well designed PI controller is used for the DC motor using the Lab VIEW Control Design and Simulation module. The Simulation Loop, which includes a built-in ODE solver for handling integrals and derivative terms, can be found in the Control Design and Simulation palette under Simulation. To control parameters of PI controller the following steps to tune is worn: Begin with gains set at: $K_p=1$ and $K_i=0$ Increase Proportional Gain (K_p) to get preferred rise time to increase integral gain (K_i) to decrease steady-state error if necessary. While the rise time looks good with our proportional gain, k_p set to 1, the plot shows a small amount of steady-state error, which is represented by the gap between the desired speed data and the estimated speed data. It can reduce this steady-state error by increasing our integral gain, k_i . On increasing the integral gain, k_i , to 10, the system response goes much better. Closed-Loop PI Controller performance as shown in Figure 5.

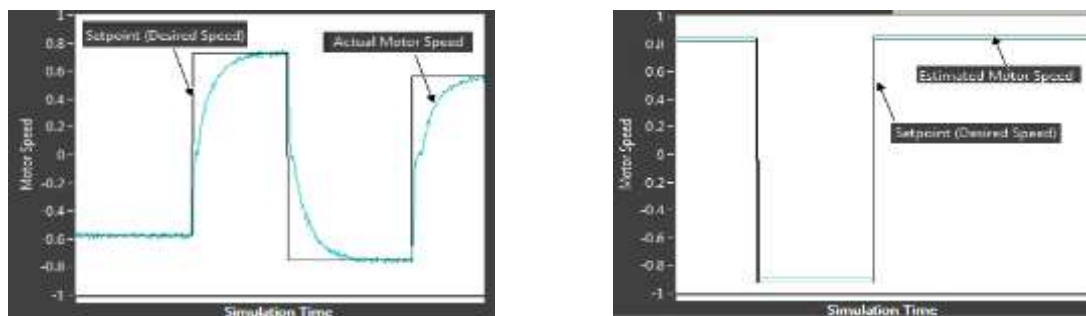


Figure 5. Closed-Loop PI Controller performance

For the tuning and verification simulate both our controller and the response of the DC motor, it follows an iterative process to optimize designed controller as shown in Figure 6. It will tune the controller parameters from the Lab VIEW front panel while verifying the system routine. Closed-Loop PI Controller with DC Motor TF as shown in Figure 7. The block diagram of start-stop VI as shown in Figure 8 and designed Lab VIEW front panel in Figure 9.

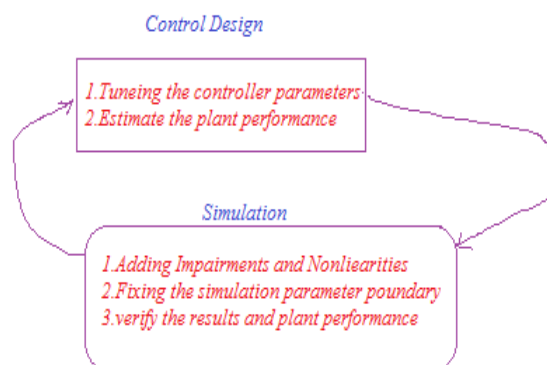


Figure 6. Iterative Process Controller

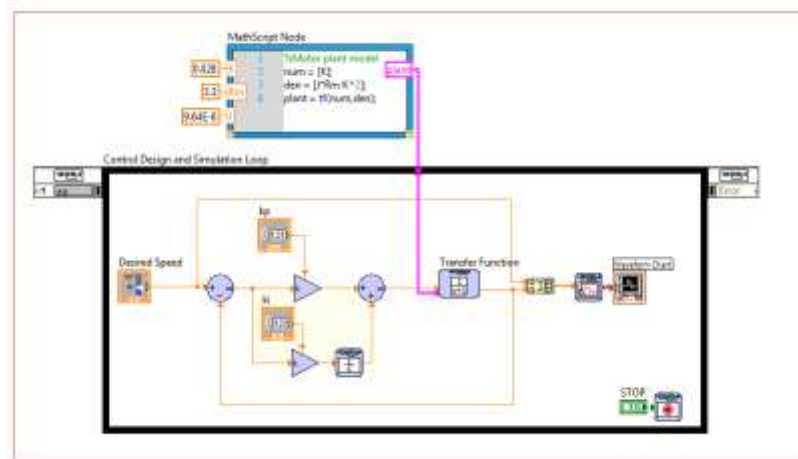


Figure 7. Closed-Loop PI Controller with DC Motor TF

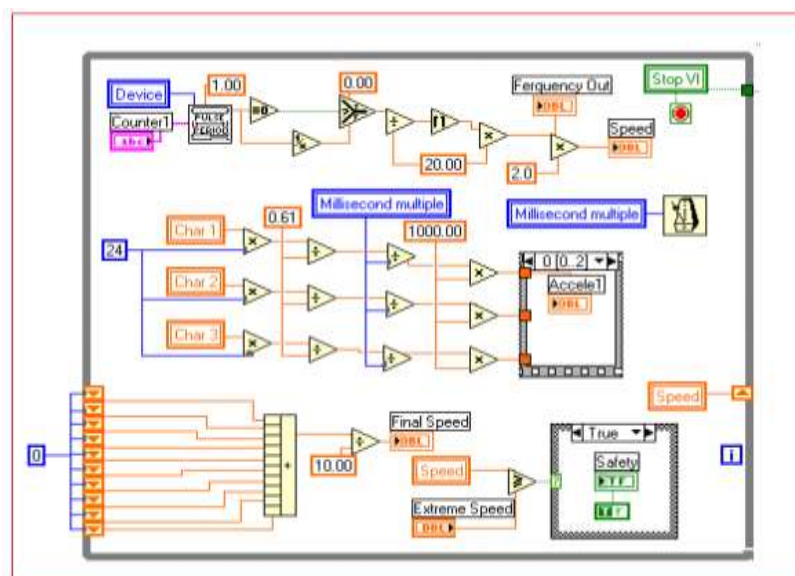


Figure 8. Sub-VI for DC motor armature control

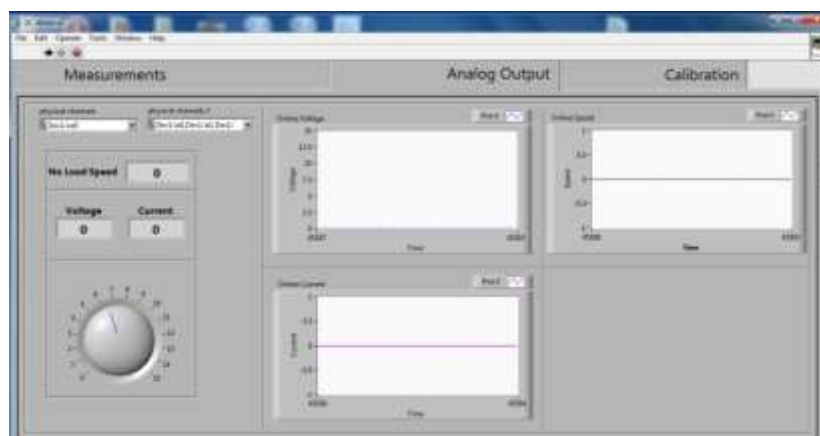


Figure 9. Designed Lab VIEW front panel

4. HARDWARE SYSTEM AND RESULT DISCUSSION

4.1 Structure of Hardware System

One of the main instruments that are used is national instrument USB 6008. It is a low cost multifunction data acquisition device (DAQ) that provides the data acquisition for some applications of portable measurement. It is compatible with software's like Lab view, .NET, Mat lab etc. With recent bandwidth improvements and new innovations from National Instruments, USB has evolved into a core bus of choice for measurement applications. The NIUSB-6008 and USB-6009 are low-cost data acquisition (DAQ) devices with easy screw connectivity and a small form factor [17-19]. With plug-and-play USB connectivity, these devices are simple enough for quick measurements but versatile enough for more complex measurement applications. DAQ software is needed for the DAQ hardware to work with a PC. The device driver performs low-level register writes and reads on the hardware, while exposing a standard API for developing user applications. A standard API such as COMEDI allows the same user applications to run on different operating systems, e.g. a user application that runs on Windows will also run on Linux [20-21]. Figure 10 illustrates the experimental setup of Opamp- V and I amplifier. NI USB 6008 as shown in Figure 11, A class 'C' 80 WDC motor in Figure 12. DAQ and NI USB 6008 interface Sub-VI as shown in Figure 13.



Figure 10. Experimental setup-Opamp- V and I amplifier



Figure 11. NI USB 6008

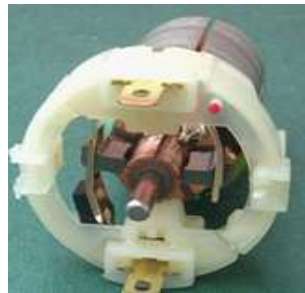


Figure 12. A class 'C' 80 WDC motor



Figure 14 (a) shown below depicts low speed of 1840 rpm, high current of 0.86 A and voltage of 7.56 V where two parameters go out of specification. All failure modes can be preloaded into the programming and can be prompted to the testing person to intimate the production line as a quality alert. Figure 15 shown below depicts the no load performance characteristics of a particular DC Motor. The no load speed of the motor is 2370 rpm, current is 0.21 A, and voltage is 5.29 V which highlights it is working under normal condition. All relevant parameters are monitored in terms of numerical values and graphical representation. One of the advantages of the Graphical Programming is to visualize all the parameters online. As the numerical values keep on changing, one cannot track the changes if the sampling speed is higher. Figure 16, shown depicts the load performance characteristics of a particular DC Motor. The curve obtained, for torque, current, voltage, power and speed, when the motor is under load condition, is also shown. All relevant parameters are monitored in terms of numerical values and graphical representation. Advantage and

flexibility of Lab VIEW is exploited here and load profile is clearly monitored online. Calibration of the DC motor can also be done with the help of Lab VIEW software.

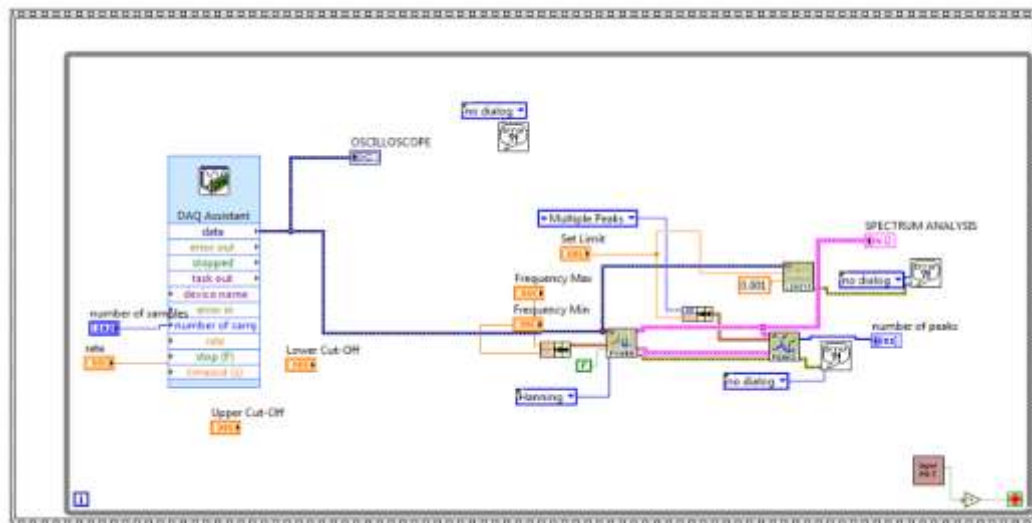
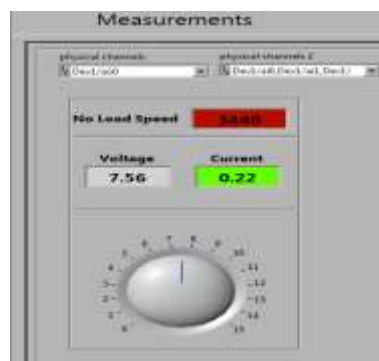
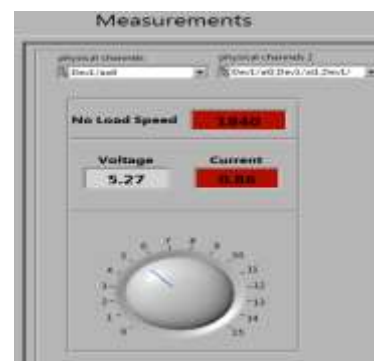


Figure 13. DAQ and NI USB 6008 interface Sub-VI



(a)



(b)

Figure 14. Lab VIEW front panel (a) Low speed and low current, (b) Low speed and high current

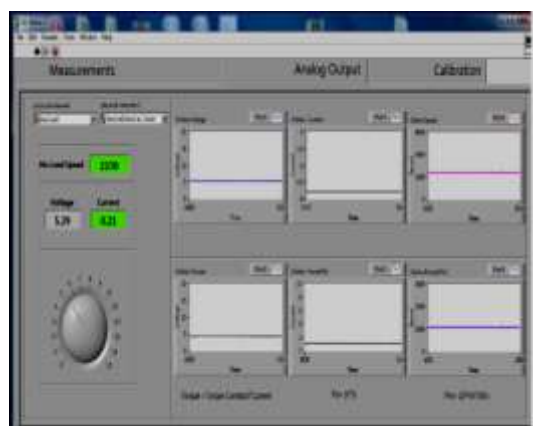


Figure 15. No load performance

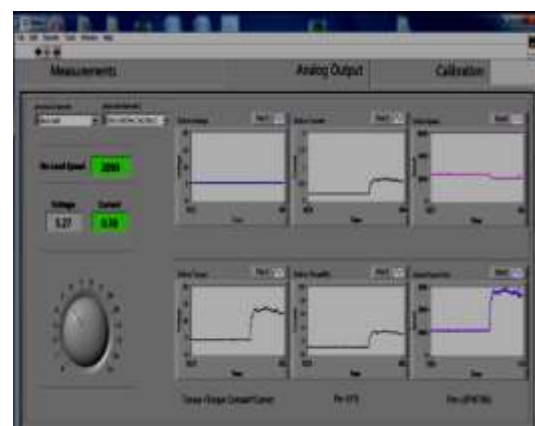


Figure 16. Load performance characteristics

Table 1 shows the different experimental results for various conditions of DC motor. The performance of the motor was also tested in different load conditions from no-load to full load as shown in Figure 17. Based on that, it could be understood that, the proposed Lab view based low cost platform also proves the performance in steady state and transient condition. During the transient condition the PI controller tuning their constants and performing the motor in close to the desired speed input. Transient state response (motor loaded condition) as shown in Figure 18.

Table 1. Experimental Results for various conditions of DC motor

Parameter/performance	Speed (rpm)	Current (A)	Voltage (V)
Over speed condition	3440	0.22	7.56
Low speed high current	1840	0.86	5.27
No load condition	2370	0.21	5.29
Load condition	2090	0.58	5.27

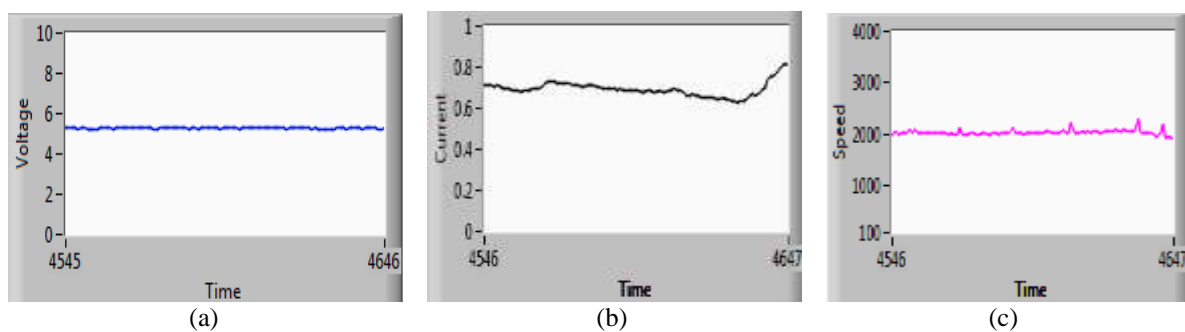


Figure 17. Steady state response (a) Supply Voltage, (b) Armature Current, (c) Speed response

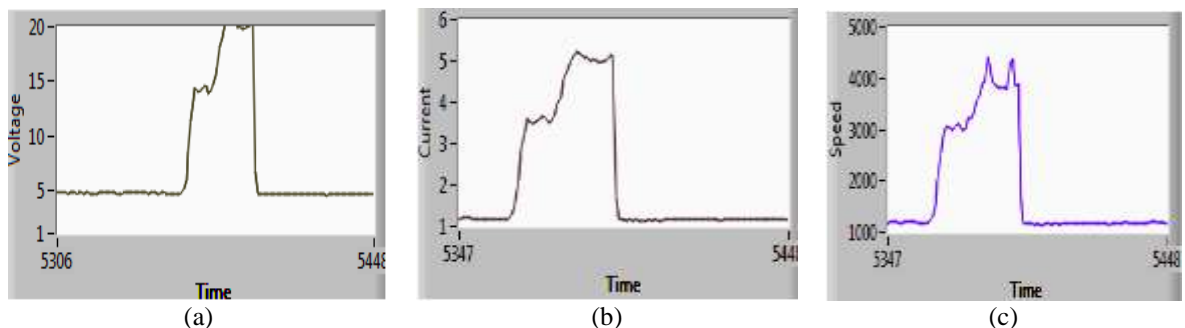


Figure 18. Transient state response (motor loaded condition) (a) Supply Voltage, (b) Armature Current, (c) Speed response

5. CONCLUSION

This paper proposes the speed control of DC motor using Lab VIEW software program and displays the real-time speed of the motor in order to obtain the system response. The real-time monitoring application can not only act as a substitute for traditional instruments, but can also monitor if the machine operation is normal. This programming system is based on a structure of the PC, and combines the DC motor supervision needed instrument, and then replaces other hardware equipments with the cheaper and more efficient method to provide operators with the graphical interface of an easy and kind operation. The development system can be set up to supervise and control the outdoor factory from the indoor office. We can supervise and control all motors in the factory or instrument equipment indoors, and also monitor the factory operational condition from the outside. In other words, this system can monitor the motor currently, and also can join all equipments that are desired to supervise and control to perform a whole supervision system in early future.

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