DC MOTOR SPEED CONTROL DEVELOPMENT SYSTEM (DCMSCDS)

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ABSTRACT

This project is about building a low cost education aid for teaching electrical drive laboratory experiments as well as useful output load for power electronics subjects. Dc Motor Speed Control Development System is used for Dc motor driver and control system. This block of system only consists of the dc machine and speed indicator. The controller or drive is not included, to allow the user to design and construct the drive based on the specifications defined. This is the idea of this research, to enhancing creativity of the students in laboratory activities instead of constructing a circuit by referring the lab manual or just connecting the circuit by using jumper if involving the training module. This kind of laboratory training, student would only know how use jumper without knowing the function of every components in the circuit. They will not appreciate the important reading data sheet before running the lab work. Therefore, this project will give an encouraging scenario in teaching and learning techniques and in solving problems to be more innovative and creative in learning electric drive. The student will be able to appreciate more in designing and constructing. Moreover, this education aid also can be used by PSM student is speed control research area of Dc motor because of its flexibility of input and output. Not forget to mention low cost teaching aid for electric drive experiments.

KEYWORDS

DC motor speed controller, Speed controller development system

1. INTRODUCTION

Motor drives constitute a vast, complex and interdisciplinary subject that has gone through rapid technological evolution during the last four decades [1]. This gives a challenge to academic area to synchronize with modernization of the electric drives technology. The subject is largely application-driven but draws from a broad knowledge base including basic circuits and electronics, control systems, power systems and semiconductor devices. The study of electric drives requires practical demonstration so that students learn the significant of every elements of electric drive system. The study of electric drive systems involves controlling electric motors in the steady state and in dynamic operations, taking into account the characteristic of mechanical loads and the behaviors of power electronic converters [2]. A modern electric drive system has five main

functional blocks a mechanical load, a motor, a converter, a power source and a controller. Practically, in industrial scenario, usually modification wills happens at converter, controller and motor blocks. Power source and mechanical load is depends on the nature of the industry. However, in academic arena, students have to have knowledge on every types of electrical motor. Therefore, the motor will be provided for them instead.

1.1 Educational Challenge

[3] discuss about advantages and disadvantages of available educational equipments. Built it self laboratory work need extensive background effort and have potential source of frustration because spending several weeks in the laboratory preparing the circuits. In order to overcome this drawback, Black-box approach: students assemble experiments using pre-built function modules was introduced. This approach is common among commercial vendors of electric drives laboratory equipment. It can lead to rugged, sophisticated units that can perform high-level power conversion functions.

This kind of laboratory work, will save time and the experiments are guaranteed success, but from the students point of view. Do they learn? Does the training module available same as at the factories? Can they apply that kind of training in real machine? The obvious drawback of a black-box approach is that without access, it is difficult for students to understand the inner workings-the heart or real electric drive systems.

Most of the trainers, they do not shows the whole connection. Some connections such as the motor to converter or power supplies to converter are hidden in casing. They only show the built in controller circuits, which are ready to be connected by the students. Often, this controller will be like a card that is going to be inserting into base trainer. Therefore, in the first place, students have to study the training module by study the manual. If lucky, the manufacture will provide the schematic drawing of the trainer. If not, does the student allow to dissectible the expensive training module? It is save time?

In terms of creativity, the kind of trainer that had been explain above, student are unable to shows their creativity. They have no change to build or to design.

"It's okay to make mistakes. Mistakes are our teachers -- they help us to learn." John Bradshaw - How are the students going to makes a mistake if they only connect the circuit according to manual not constructing them. If they have chance to design, they will do mistakes, then they will learn. The questions why, how or what will come out. Only then they learn to analyst and solving problem. Yes it takes a lot of time, but in terms of quality the student will be a good product. Same problem occurs to instructors. The manual binds them. They discouraged to be creative and innovative. Unknown, what inside the casing, instructors unable to design their own drive circuit enable suite the topic.

1.1.1 The Need To Enhancing Creative Thinking

"The most important developments in civilization have come through the creativeprocess but ironically most people have not been taught to create" [4]. Based on journal by Caroline Baillie, enhancing creative in engineering student are important. In recent years, industry and in particular the engineering industry has begun to focus on the lack of creative thinking and innovation in graduates. Employers are looking for more than adaptive recruits; they are looking for transformative employees, i.e., people who can use higher level skills, such as analysis, critique, synthesis and multi-layered communication to facilitate innovative teamwork and employees who can use their abilities and skills to evolve the organization.

Caroline Baillie highlights several techniques to help enhance the creativity of engineering students but one that motivated this research, is it by use of unblocking technique. It allows students to use convergent and divergent thinking and enable students to bring their own personal approach to the problem setting.

This research is to give alternative to instructor in order to provide better training and skill to the students.

2 GOALS OF THE PROJECT

This project is based on the concept of blue box introduced in [5]. Blue box, differs from a black box in that the internal subsystem are studied prior to use and they are simple enough to understand its basic functionality without having to ignore elements. The blue box approach has been used successfully for more than ten years. Dc Motor Speed Control Development System however is not blue box. It only provide electric motor block of electric drive system not entire subsystems. This laboratory module is completed of connection points as well as speed indicator. It allows the user to design their own drivers. It is alternative training equipment in order to produces a creative, innovative and well skill engineering student. Another goal of this project is to build low cost laboratory training module. Of course this project focused on electric drive as well as power electronic subjects.

To date several papers have been proposed education aid or teaching method of dc machine and power electronics subject [6:8]. Power electronics and motor drives are appropriate subjects for an advanced undergraduate or beginning graduate course. The subject is largely application-driven but draws from a broad knowledge base including basic circuits and electronics, control systems, power systems and semiconductor devices. For many students, a power electronics laboratory can provide an early experience in synthesis, requiring them to use knowledge across their full curriculum with close attention to detail. It is well known that issues such as wiring configuration, circuit layout and device selection can dominate the performance of the converter. Similarly, the study of electric machines requires practical demonstration so that students learn power flow and energy conversion concepts intuitively. This suggests that laboratory instruction has great value as a component of a power electronics and electric machines curriculum.

This Dc Motor Speed Control Development System is base for dc motor driver and control system. This block of system only consists of the dc machine and speed indicator. Instructor as well as students is allows

modifying what kind of control system they want to use. They will learn about specification of electric and eventually free to design they own drive.

2.1 Dc Machine

Dc machines [2],[9:10] have traditionally dominated the domain of drive systems. Even now most industrial drives use dc machines. The dc motor is popular due to its simple operation and control. The starting torque of dc machines is large, which is the main reason for using it in several traction applications. For this research dc shunt motor will be use. There are many method of dc motor speed control [2].

The speed of dc motor may be varied by

i) Resistance in armature circuit. When a resistance is inserted in the armature circuit, the speed drop, $\Delta\omega$, increases and the motor decrease.

ii) Terminal voltage (armature). Reducing the armature voltage V_t of the motor reduces the motor speed.

iii) Field flux (or field voltage). Reducing the field voltage reduces the flux, ϕ, and the motor speed increases.

Above are fundamentals drives. There is variety of drive types, such as, Pulse width modulation chopper, Semi-converter phase controller, Full-converter phase controller and Dc voltage source. However in this project, Dc voltage source control or also called as armature voltage control and speed controlling by adding resistance have been chose as a drive block in this Dc Motor Speed Control Development System.

2.1.1 Armature Voltage Control

Armature voltage control is the type most commonly used in dc drives [2],[9]. This method is highly efficient and stable and is simple to implement. Based on equation (1)[2], when the armature voltage is reduced, the no-load speed ω_0 is also reduced.

$$\omega = \frac{V_t}{K\phi} - \frac{R_a I_a}{K\phi} = \omega_0 - \Delta\omega \qquad (1)$$

Moreover, for the same value of load torque and field flux, the armature voltage does not affect the speed drop $\Delta\omega$. Therefore, in this research, armature voltage method of control is going to be used.

1.1.2 Controlling Speed By Adding Resistance

Resistance is added into armature circuit. In general, by adding resistance into armature circuit, it will decrease the subscribed voltage to the motor armature. Therefore, same concept of armature voltage control, speed of the motor will decrease as value of the adding resistance increasing.

$$\omega = \frac{V_t}{K\phi} - \frac{(R_a + R_{add})I_a}{K\phi} = \omega_0 \quad \Delta\omega - \qquad (2)$$

2.2 The Design

Dc Motor Speed Control Development System, Figure 2.0, consists of dc shunt motor and speed indicator. This simplest design was meant to be that way, so that it will allow the user to design the drives. This system provides the electric motor for electric drive system. Speed indicator is for the user to determine the speed.

In this project, 12 V dc motor was chose (Figure 2.0). The specification, please refer appendix. This motor is suitable for laboratory equipment specifications. Furthermore, the purpose of this system was developed is for electronic field. The dc voltage range that usually used is less than 30V.

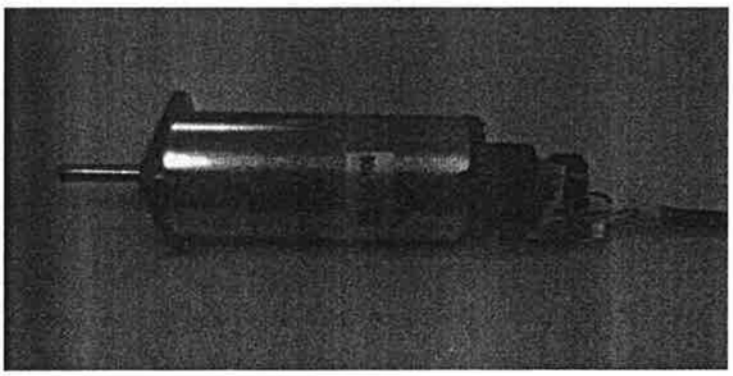

Figure 1 : Dc shunt motor

3 METHODOLOGY

This research was all about the alternative way of training for electric drive subject as well as power electronic subject. These proposed experiments, which will be explained in the next chapter were easy to conduct, clearly shown the concept of experiments and flexible to do any enhancement or adjusting in order to proportionate to the subject.

This work began with conducting a survey. The target group was 4th year Industrial Electronic student (4 BENE) of Kolej Universiti Teknikal Kebangsaan Malaysia. Then, the survey's result was analyzed. The Dc Motor Speed Control Development System was firstly designed using the SIMULINK and then transferred to hardware. The system was tested by using to types of drive, which were controlling by adjusting the armature voltage and by adjusting the armature resistance. The details of the methodology will be explained in the next parts.

3.1 Survey

The survey was conducted on 14th October 2005. The target group was the user itself which was 4th year Electronic Industrial students of Kolej Universiti Teknikal Kebangsaan Malaysia. In their 4th year subjects, one of them is Electrical Drive (BENE 4133). In this subject they were learnt about how to control a dc and ac motor using fundamental drives or using power electronics circuit. To date they using the trainers that only needs to be connected by jumpers to operate. This discouraged the students to design and most important is to learn the details connection of the circuit. It is because the circuit is not fully shown on the trainer, where as, in this subject how the drive is connected to the dc motor is important to be highlighted. Therefore the survey questions are about :-

a) how the current trainers help them in understanding the topic ?
b) what is important to have so that will make them easier to learn this subject?
c) are the available trainers enough to master the subject? Why?
d) would they like to have the elements of design in the topic?
e) If the Projek Sarjana Muda has something to do with electric motor, would they like if the electric motor as well as the speed indicator is provided, therefore they only focus on drive?

From the survey, 70% of them were agreed that to have a design types of training. They love application type of experiments. They want to learn how to choose the best specification of electric motor, how to calculate the right value of components for the driver or the main question is how to design. Those questions could help them for Projek Sarjana Muda.

80% of them 70% students have difficulty to gain knowledge from available trainers. From the student's point of view, some trainers are too complicated to understand. Extra times are needed to study the trainer in order to understand every part. Of course, sometimes instructor is will give a briefing, but due to time constraint, students have to execute the experiments with a little knowledge of the trainers.

Experience proves, trainers are not proportioned and tally to the subject. Every instructor or universities have their own style of training objectives. Some available trainers, sometimes not suitable for certain topics or idea of training. As a result, experiments have to be adjusted so that the trainers can perform the meaning training. However sometimes is it hard to execute and seldom not possible. This is one the reasons students can become confuse. As a result, they might become not interests in the subject.

3.2 The Hardware

The design was mounted on the protoboard. The dc shunt motor is fit with encoder. It fitted to the rear output shaft of each motor. This encoder can give 1 pulse per motor revolution. Actually, user can already use it, but it will hustle to determine the speed from the oscilloscope. Would it be better if we can get value directly, from the meter for instance? Therefore, the dc motor is then attached to frequency to voltage converter and then the output is connected to meter.

3.3 Speed Indicator

The signal from encoder is connected to frequency to voltage converter circuits. The circuit, Figure 2 use LM331 chip. When the input frequency waveform has a negative-going transition, LM331 is driven momentarily lower than the 13V threshold voltage at pin 7. (Please refer to appendix for LM331 specifications).

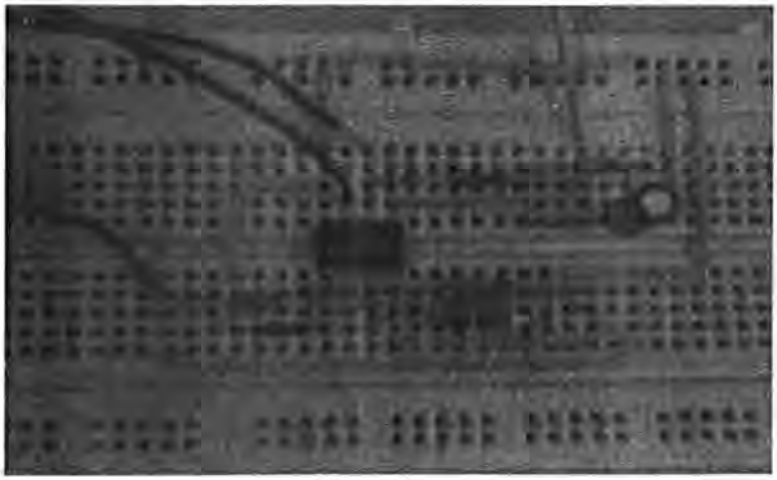

Figure 2 : Frequency to voltage converter

This initiates a timing cycle controlled by the R_t and C_t at pin 5 and also causes a transition from +5V to 0V at pin 3 which is usually left unused in F-to-V operation. During the timing cycle ($t=1.1 \times R_t \times C_t = 75\ \mu s$) a precision current source $i=1.9\ V/R_s$ flows out of pin 1 of the LM331.

By calculation, output voltage can be obtained from equation 3;

$$V_{out} = f_{in} \times \left(\frac{R_L}{R_S} \right) \times (1.9V) \times (1.1R_tC_t) \qquad (3)$$

With the development of power electronics, the drive system is becoming more and more complex and sophisticated in order to realize high performance. Furthermore, they constitute a vast, complex and interdisciplinary subject that has gone through rapid technological evolution during the last four decades. Could it more beautiful if education synchronous with the development of the technology?

Following parts show the various types of experiments that can be execute by using this Dc speed motor development system, especially for electric drive subject.

4 PERFORMANCE WITH A DC VOLTAGE SOURCE DRIVE

Figure 4 shows voltage-speed characteristics for motor driven from a DC voltage source, calculations being carried out with 2, 4, 6, 10 and 12 Volts. The characteristics are virtually linear and equally spaced. From equation 1, it proved that speed is proportionally to dc voltage.

From appendix 1, shows the technical specification of the Dc shunt motor of this trainer. Before this experiment will be carrying out, the user has to aware the specification of the motor. This is to avoid any overvoltage or overcurrent that can damage the motor. Dc motor can not been supply with voltage over 10 percent of it rated voltage. A point that important to know, rated value is not the minimum amount of voltage that must be provided to the motor, but the maxima value. Also, the user has to know the starting current that must be supply to the motor. Dc motor would not operate if there is not enough current supplied to it.

Instructor, designing an experiment is not complicated because they only have to aware the voltage and current values. As for student, learning the specification before running the experiments or designing a driver is a good practice. This kind of training, teach them the important of knowing of technical specification of the components of the experiments. This element of training sometimes has been forgotten in today experiments.

Although this experiment is look simple, it is clearly shows the operation, result and also indirectly teach the user the elements of designing.

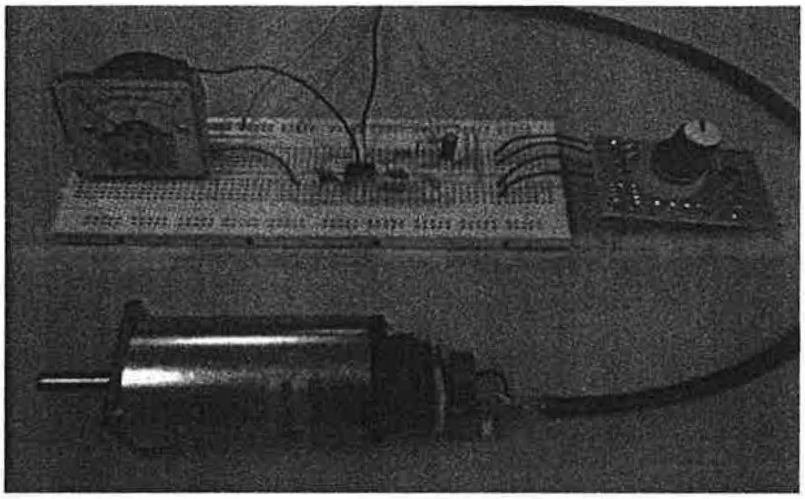

Figure 3: The connection of voltage control experiments

This experiment shows how speed of the motor can be varies by adjusting the armature voltage value. The results of the experiments was plotted on graph

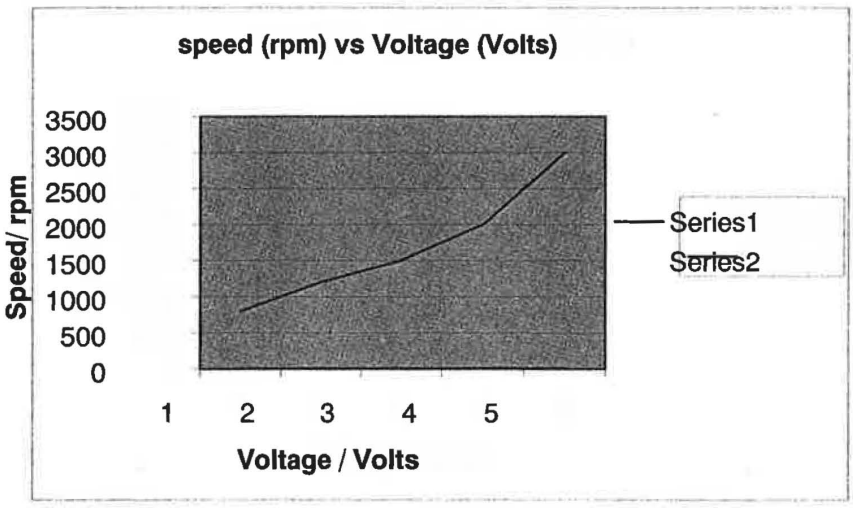

Figure 4: The results of voltage control experiments

From the equation 1, speed of the dc shunt motor is proportional to the armature voltage. This shows by the graph 1. Therefore, this Dc motor speed developments system is working properly. For experiments which to determine the speed of the dc shunt motor by varying the value of the armature voltage or supply voltage, this trainer clearly shows the operations and results. Students will understand easily as it proved the theory.

4.1 Performance with Resistance Adjusting

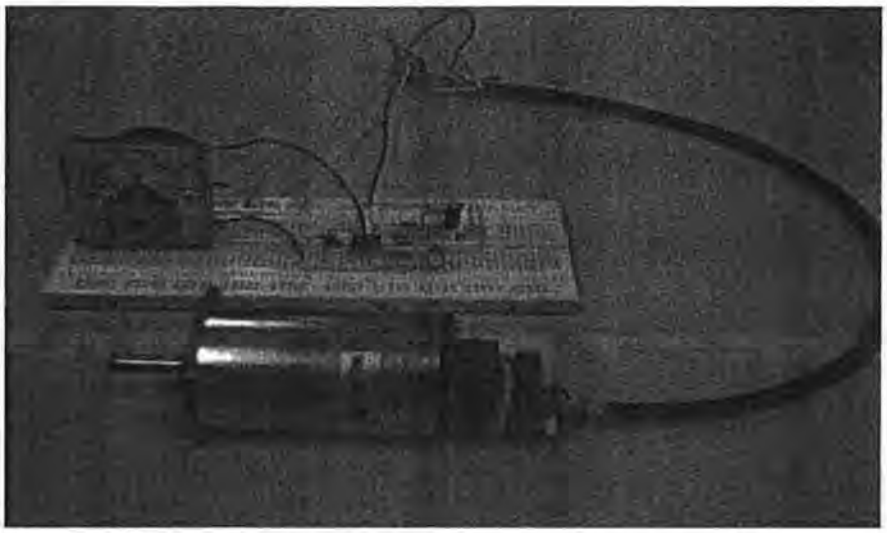

Figure 5: The connection of resistance control experiment

Figure 5 shows the connection for experiment that shows the performance of the dc shunt motor if speed been adjusted by using several of resistance value at the armature circuit. From the equation (2), adding resistance at armature circuit will reduce the motor speed. Graph shows the result if several value of resistance is use to control the motor speed.

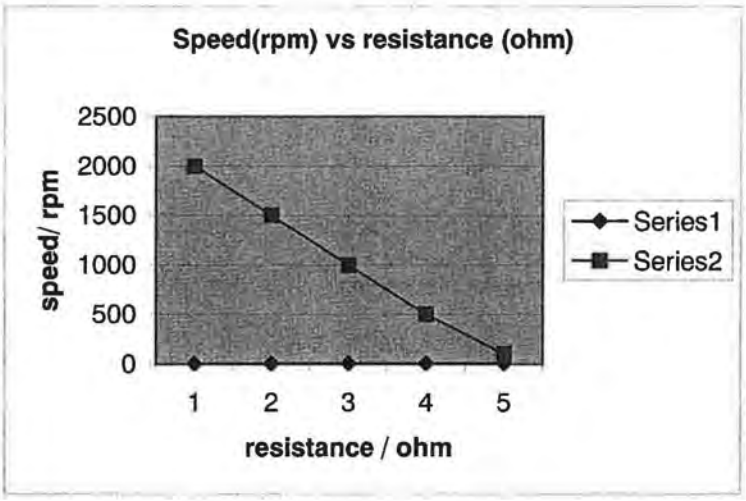

Figure 6 : The results of resistance control experiment

Students will easy to understand how resistance can be use to control the motor's speed clearly.

As for the instructors, it is easy for them create their lab manual according to the topic they teach. It is because, they can design their own drive for their lab manual freely as long as it proportionate to the specification of the DC motor.

4.2 Performance With Power Electronics Drive

In this section of the experiment, the student investigates or proves the performance of power electronics circuit to drive the dc motor. For instance, controlling the motor speed by using silicon-controlled rectifier (SCR). Variable-resistance phase control is commonly application of SCR in controlling motor or light dimming circuit. Students is required to build the drive circuit themselves and fitted to the Dc Motor Speed Control Development System. After the circuit is ready, the student can analysis the performance of the drive, by vary the injected current of the SCR.

4.3 Projek Sarjana Muda

Dc Motor Speed Control Development System can be a big help for Project Sarjana Muda. Projek Sarjana Muda that involves electric motor control is quite hard to finish it. The good project is if it presents a complete electric drive system, which consists of power source, electric converter, electric motor, controller and load. Better if the project also includes the speed indicator. It is quite hustle if student is required to include all the elements, whereas they should focus on the driver the most. Therefore, by Dc Motor Speed Control Development System, the two elements which are electric motor and speed indicator are already for them. They only need to design the driver and test it to Dc Motor Speed Control Development System.

Furthermore, electric motor is not cheap. With tide budget, students sometimes have to use the ordinary motor that used in toy car, which is obviously not provided with the specification. This is not appropriate to present the final year project, which supposes to have specific calculations and professional data.

This kind of practice is similar to working phenomena in reality. Usually the engineer is required to design the driver and controller part as well as the types of electric motor. Power supply and load is available according to the nature of the factory. Therefore, the engineer must able to associate their design to power supply and the load. However, in this project, the electric motor is available for them. Student must know how to design a driver according to the specification of the dc motor.

Thus, this is a good practice to train the students to adapt in real practical in working world.

5 DISCUSSION AND CONCLUSION

This project describes how Dc Motor Speed Control Development System can be utilized in the teaching of electrical machines and drives. The students design and test their driver to Dc Motor Speed Control Development System.

Design types of experiments are good way of develop and encourage higher level skills, such as analysis, critique, synthesis and multi-layered communication to facilitate innovative teamwork among the

students. To date, industries are looking for employees who can use their abilities and skills to evolve the organization. Therefore, student should be trained to be having all those elements.

In order to provide such training in subjects teach in universities, Dc Motor Speed Control Development System is one of alternative for electric drive and power electronics subjects. Fundamentals of electric drive, discuss the basic drivers of electric motor. Students learn effectively by proving the theories through experiments. Dc Motor Speed Control Development System is simple teaching aid that clearly shows the how the controlling works

Power electronics involves power electronics circuits that apply as driver for electric motor for instance. Dc Motor Speed Control Development System provides the electric motor and speed indicator for testing the driver. As for instructors, they are free and easy to design lab manual. Lab manual only have to suit to specification of the electric motor use in the system.

For PSM, electric motor plus speed indicator is ready for the students. Significant finding are to develop or design new driver for the electric motor.

In conclusion, Dc Motor Speed Control Development System is simple teaching aid for laboratory lesson. Provide free, easy, clear and low costs to design lab manual and learn about electric drive and power electronics. In the future, other developments system will be design by using other types of electric motor such as stepper motor or ac motor

Sometimes, simple explanation or action is the best answer

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