Employing the Servo Trainer in Expanding the Frontiers of Polytechnic Education in Control Engineering

Adetona[1], Z. A. and Ojo[2], B.A.

[1,2]Electrical Engineering Department

Federal Polytechnic, Ilaro

[1]zachadetona@gmail.com, [2]babajideojo1978@gmail.com

Abstract

The objective of technical polytechnic education in Nigeria is to ensure that learners are imparted with adequate technical knowledge that will prepare persons for employment in a recognized occupation. Such area of study is electrical engineering with specialization in control and instrumentation. This paper describes some useful experiments that can be adopted into the curriculum of Electrical Control Engineering as a course to be taught in the Polytechnic. The experiments have been carried out using the Servo Trainer equipment. Since Control engineering relies on a strong background and a good control laboratory, the Servo Trainer equipment has been utilized to demonstrate how the barrier to knowledge in electrical control engineering in Nigerian polytechnics can be widened. When such experiments performed are used in training students it will help in preparing them for the possibility of getting employed in an industrial setting where the knowledge of automatic control and instrumentation is required or in areas of designing new engineering systems.

Keywords: Polytechnic education in Nigeria, Electrical Control Engineering, Science and Technology Education for Post – Basic (STEP – B), Servo Trainer, automatic control and instrumentation, control laboratory experiment.

1.0 Introduction

The primary purpose of polytechnic education as a form of technical education is to produce graduates with necessary requisite knowledge that will make them employable or become employers of labour in the future. The objective of technical polytechnic education in Nigeria is to ensure that learners are imparted with adequate technical knowledge that will "prepare persons for employment in a recognized occupation" [1]. Technical education has been defined as "a planned program of courses and learning experience that begins with exploration of career options, supports basic academic and life skills, and enables achievement of high academic standards, leadership, preparation for industry-defined work, and advanced and continuing education" [2]. In view of this definition technical education can be seen as a form of specialized "education designed to develop occupational skills" [3].

The National Board for Technical Education (NBTE) is "a principal organ of Federal Ministry of Education specifically created to handle all aspects of Technical and Vocational Education falling outside University Education". NBTE has a mission, among other functions, "to promote the production of skilled/semi-skilled technical and professional manpower, to revitalize, and sustain the national economy, reduce unemployment and poverty…" [4]. Many vocational/technical institutions in the country have tailored their goals and objectives to reflect the general objectives of the NBTE. The Federal Polytechnic, Ilaro, as an example similar to other technical institutions in Nigeria, focuses on the "production of technical manpower to meet the needs of the nation; and production of sound and competent graduates that can compete at the global level" [5]. This is part of the objectives of the institution with strategic plan whose general objective is to "provide technical and practical oriented training to meet the manpower requirements for the industrial, agricultural, commercial and economic development of Nigeria".

As part of its aim of production of technical manpower to meet the needs of the nation, the Federal Polytechnic, Ilaro, offers four engineering programmes targeted at technological development. These programmes are:

- Civil Engineering
- Computer Engineering
- Electrical Engineering
- Mechanical Engineering

These programmes are fully accredited by the NBTE both at the National Diploma (ND) and Higher National Diploma (HND) levels. The courses are taught from the NBTE approved curricula. At the HND level, students are required to choose a particular area of specialization in the programme of study. For instance, the Electrical Engineering programme of the polytechnic has two areas of specialization namely:

i. Power and Machines and
ii. Electronics and Telecommunications.

There are other areas of specialization in the Electrical Electronic Engineering field offered in Nigerian Universities which include but not limited to:

- Solid state electronics
- Electronics engineering
- Electrical Instrumentation
- Electrical Control Engineering
- Computer Engineering
- Computer with Electronics

Some of the above-mentioned options of electrical engineering are readily available in Nigerian higher institutions of learning while others are not. The reasons for this can be attributed to a

number of causes. One prominent reason is a lack of manpower. Another is unavailability of modern technological infrastructure to go along with the training. Control engineering for instance is not offered as an area of specialization in many of the Nigerian polytechnics including the Federal Polytechnic, Ilaro. The same can be said of other areas of specialization such as Solid State Electronics, Electronics engineering, Electrical Instrumentation, etc.

Having this background, this paper is put together to propose the possibility of giving student learners the area of specialization of Electrical Control Engineering as an option of specialization. It is being used to demonstrate some of the practical experiments that can be adopted into the curriculum of the Electrical Control Engineering course in Nigerian tertiary institutions.

2.0 Objectives of Control Education

Virtually every activity in daily life is influenced by some control system [6]. Examples of devices using automatic control system include electric iron, generator, toilet tank water level control, and hot water heater [7]. Thus it is necessary to train people in control systems design and maintenance. Control and instrumentation engineering as a course is designed to train persons to design and maintain automation and control system in the industry and to present a detailed control education to others. According to Kheir et al (1991) the main objectives of control education are [8]:

i. to provide the basis for the future control engineer to be able to deal with the design

   of control systems for different plants and

ii. to establish and maintain high standards in the presentation of the main concepts of control.

Learners are expected to be made acquainted with the latter through preliminary courses in control engineering. The former, which relies on a strong background, can only be achieved with the help of a good control laboratory. It is well accepted that a good control laboratory must not only illustrate the concepts introduced in the theoretical course but have to be realistic as well [9].

With the foregoing, we wish to demonstrate some laboratory experiments with the aid of some newly acquired servomechanism and control equipment (Servo Trainer[1] shown in Fig. 1). The equipment was supplied to the Electrical Engineering Department of the Federal Polytechnic, Ilaro by a World-Bank-assisted Programme tagged Science and Technology Education for Post – Basic (STEP – B). Such modern control equipment is rarely available in the polytechnics and universities in Nigeria. This is the more reason why the few institutions that have benefitted from the World Bank programme should develop practical manuals and integrate the equipment into the current curriculum.

[1] The Servo Trainer equipment is designed and manufactured by TecQuipment Ltd, United Kingdom.

3.0 Highlight of Some of Experiments Developed

In an effort to integrate the newly-acquired equipment into the curriculum, a number of experiments are developed using the Servo Trainer (ST). Four of these experiments shall be highlighted. Some of the practical experiments developed are:

i. Calibration of Input Actuator for Speed Control System
ii. Output Gain Characteristics of Servo Motor for Speed Control System
iii. Proportional Control of Servo Trainer Speed
iv. Angular Position Control: Proportional Control
v. Non-Linear Characteristics of Control System
vi. Proportional plus Integral Control of Servo Trainer Speed
vii. Etc.

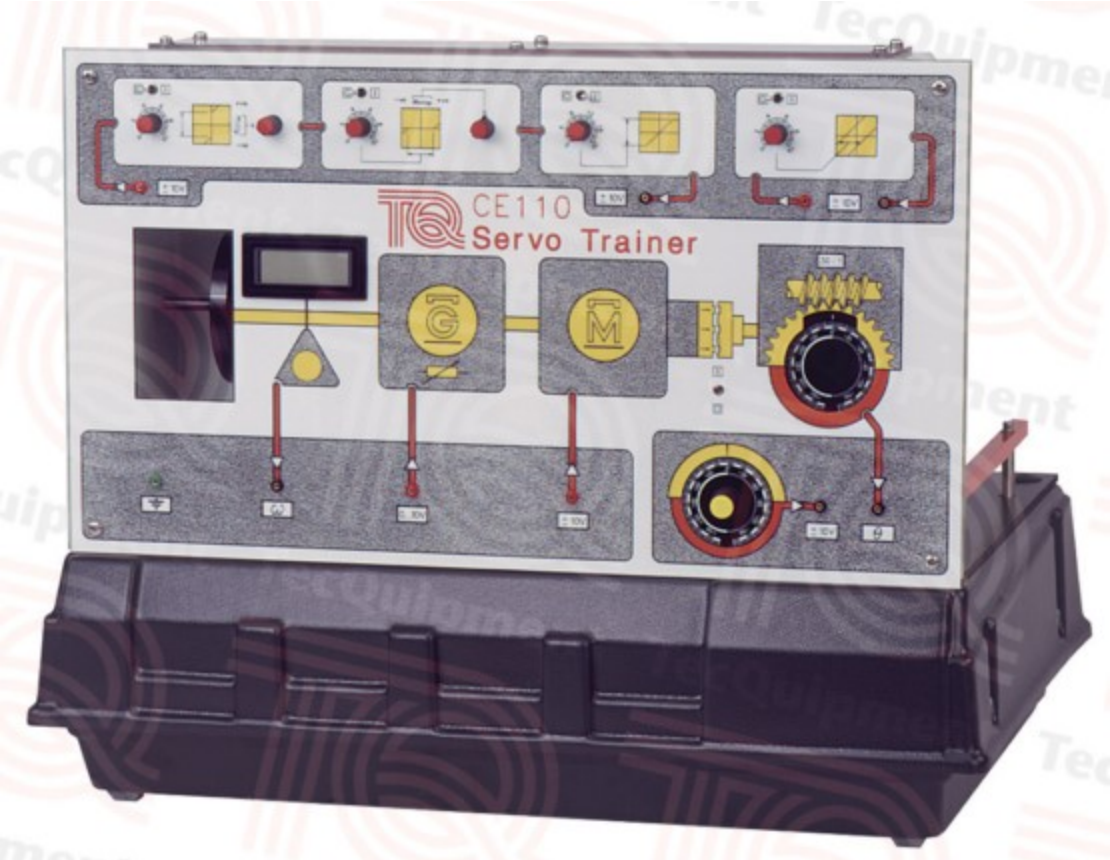

Fig. 1: The Servo Trainer (Obtained from www.tecquipment.com/Datasheets/CE110_0410.pdf with permission from TecQuipment Ltd, United Kingdom)

3.1 Experiment 1

Title: Calibration of Input Actuator for Speed Control System

Objective: At the end of the experiment the students should be able to determine the speed voltage characteristics of the Servo motor. That is, to calibrate the circuits of the Servo Trainer namely the input actuator (the motor circuit) and also the output sensors (the speed and angular position sensors).

Background theory: Servo systems occur widely throughout all branches of industry to such an extent that grounding in servo mechanism control is the regulation at a constant speed of an industrial manufacturing drive system. For example, in the production of strip plastic, a continuous strip of material is fed through a series of work stations. The speed at which the material is fed through must be precisely controlled at each stage. Similar examples exist where accurate position control is required.

Procedure: The method involves applying energy to the Servo motor in a gradual manner to monitor the portion of the characteristic where the system produces a response. A "dead-zone voltage" for which the system remains dormant until a response is extracted is meant to be obtained. Then the input energy is further gradually applied to obtain voltage-speed characteristic of the Servo. The connection diagram in Fig. 2 is employed.

The students are given a step-wise procedure to guide them in fulfilling the objectives of the experiment as given above. They are required to tabulate the results obtained.

Exercise: Simple related questions such as the following are asked to test the students understanding.

i. Plot the graph of voltage against servo motor speed and determine its slope.
ii. Explain the importance of the dead zone and the slope.
iii. What is the effect of increase in voltage on speed?

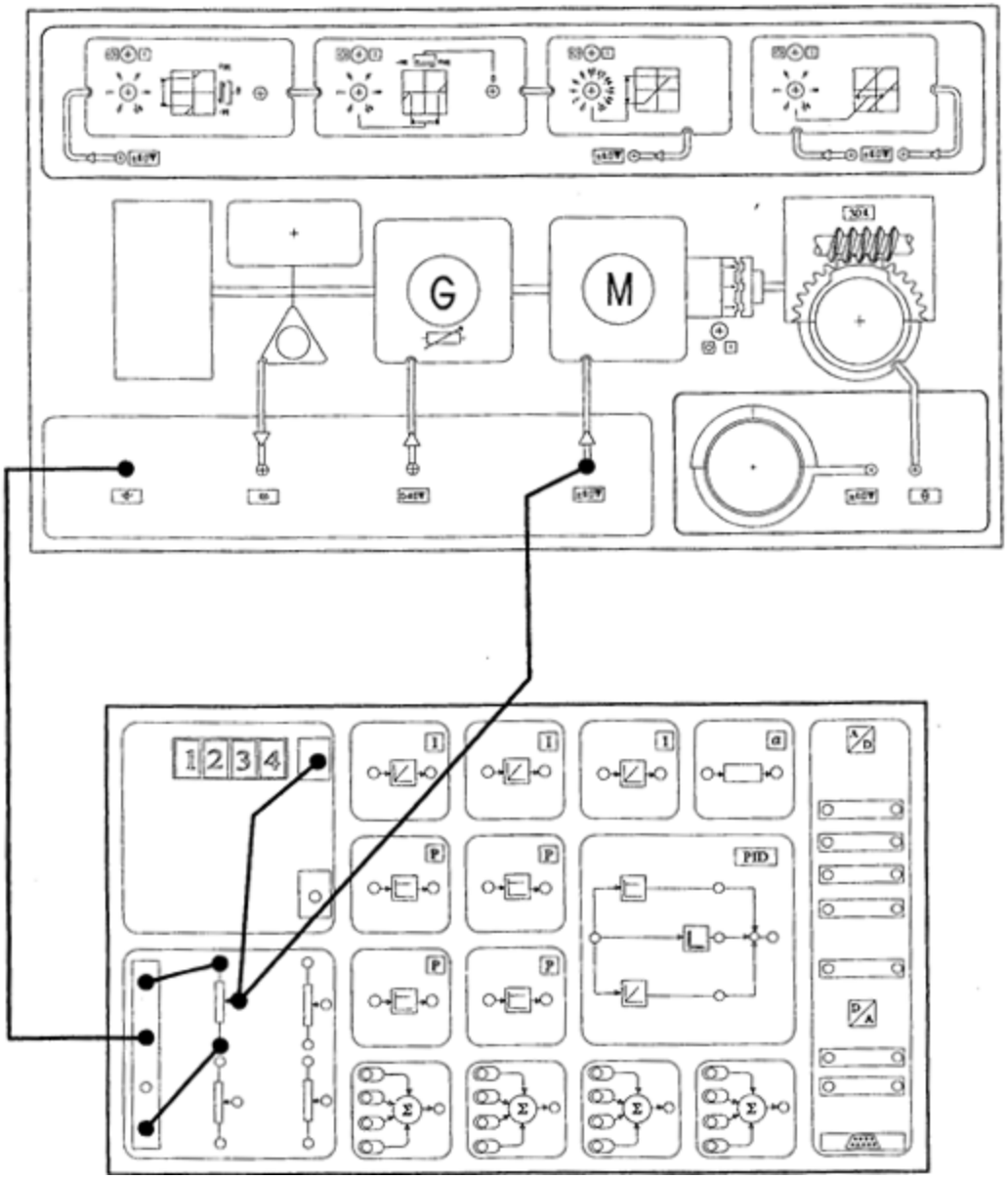

Fig. 2: The Servo Trainer Connection diagram for experiment 1 (Adapted from CE110 equipment manual with permission from TecQuipment Ltd, United Kingdom) [10]

3.2 Experiment 2

Title: Output Gain Characteristics of Servo Motor for Speed Control System

Objective: At the end of the experiment the students should be able to determine the speed voltage characteristics of the Servo motor. That is, to calibrate the circuits of the Servo Trainer namely the output sensors (the speed and angular position sensors).

Background theory: In industries, many applications often require the speed of a motor to be varied. Earlier motors tended to be over-designed to drive a specific load over its entire range. This resulted in a highly inefficient driving system, as a significant part of the input power was not doing any useful work. The speed and accuracy of stopping and reversing operations improve the productivity of the system and the quality of the product. In a feedback control system, the output must be properly sensed for accurate control. The feedback signal obtained through the transducer or sensor is then used to generate error signal to adjust the system. The block diagram of the feedback control system is represented in the manual as in Fig. 3.

Procedure: The method employed involved using the smallest inertia load on the Servo Trainer while the output load is disengaged. The input energy is then gradually increased from 0V to maximum while the output motor speed is being monitored. The procedure is repeated for reverse set of voltages and the motor speed likewise monitored.

Necessary procedural steps are given in a step-wise manner to fulfill the objectives of the experiment. The connection diagram for the experiment is based on a modified connection diagram in Fig. 2. The results obtained are to be tabulated.

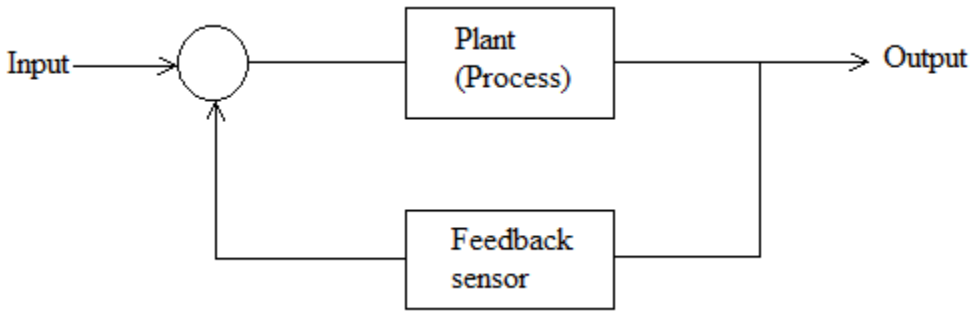

Fig. 3: Feedback control system

Exercise: The following exercise is administered to help the students make necessary conclusions on the experiment.

i. Plot the graph of voltage against servo motor speed and determine its slope.
ii. Suggest a suitable transducer for speed sensor in this experiment.
iii. What is responsible for the dead-zone increment when the clutch is engaged as observed in the experiment?

3.3 Experiment 3

Title: Proportional Control of Servo Trainer Speed

Objective: At the end of the experiment the students should be able to:

i. implement a proportional controller of the Servo Trainer;
ii. investigate the closed transient response and the steady state errors.

Background theory: In a closed-loop control system, the difference between the actual and the set speed is termed the steady state error. In a proportional control system, the output is proportional to the error input as shown in the Fig. 4. The proportionality constant is the gain of the system. If the gain of the amplifier is increased, the steady state error will reduce but not totally removed. If the gain increases too much, there is the possibility of instability in the system. Proportional control is the simplest form of control. This is illustrated in Fig. 4. The steady state error $e_{ss,}$ for a constant reference signal y_r is given by the following equation:

$$e_{ss} = \frac{y_r}{1+k_p G_1}.$$

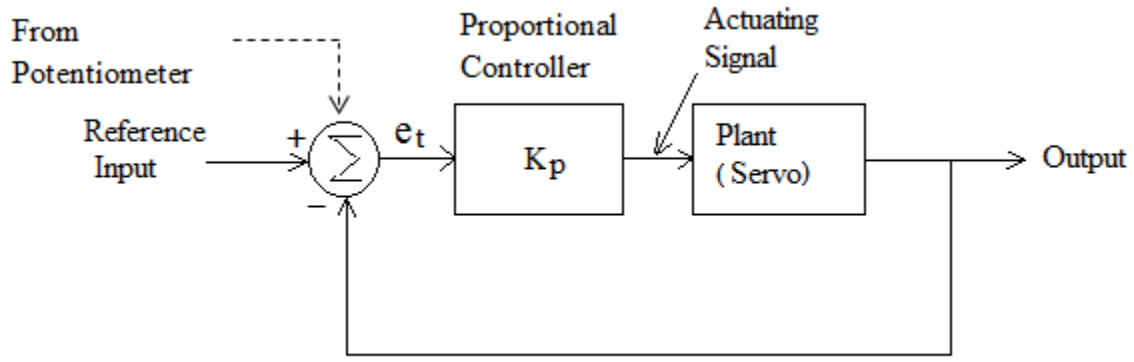

Fig. 4: Feedback control system with proportional gain

Procedure: The procedure involves using the equipment to implement a feedback control system having a proportional controller and measuring the steady state error for various values of input voltage and controller gain using applicable connection diagram. The students are expected to carry out certain measurements of angular displacements for different values of the proportional gain. These are to be tabulated.

Exercise: The following exercises were given to the students to make proper conclusions on the experiment.

i. Differentiate between transient response and steady state response of a control system.
ii. Distinguish between an open loop and a closed loop control system.

3.4 Experiment 4

Title: Angular Position Control: Proportional Control

Objective: At the end of the experiment, the student should be able to:

i. Examine the characteristics of the non-linear elements.
ii. Investigate the influence of dead zone and anti-dead zone input typical signals.

Background theory: In a practical servo system, a number of non-linearity occurs. The most frequently occurring forms of non-linearity are incorporated into the servo system in a block of

simulated non-linearity. The non-linear element can be connected in series with the servo motor in order to systematically investigate the influence which non-linearities have upon practical system performance.

The saturation amplifiers used in a servo motor normally works with a specified linear gain relationship between the input voltage V_i and the output voltage V_o for input in the range. A further feature of the practical amplifier is the dead-zone or dead-band where the amplifier output is zero until the input exceeds a certain level at which internal losses are overcome.

Procedure The procedure involves using the equipment to implement a simulated non-linear system and obtain the system response under a varied input supply, positive and negative, following applicable connection diagram.
Results obtained are to be tabulated and the characteristic graph of the control system plotted.
Exercise: To help the students interpret the results obtained the exercise here is included:

i. Comment on the results obtained on the table of values.
ii. Give reason(s) why the shaft moves and stops as observed in certain portions of the procedure.

4.0 Conclusions

The Servo Trainer equipment has been utilized to demonstrate how some of the newly supplied pieces of equipment can be utilized in widening the barrier to knowledge in electrical control engineering in Nigerian polytechnics. When such experiments performed are used in training students, it will help in preparing them for the possibility of getting employed in an industrial setting where the knowledge of automatic control and instrumentation is required or in areas of designing new engineering systems. The latter is one area where Nigeria is lacking. For the perennial problem of lack of technological development to be solved, Nigerian graduates have to be adequately trained and prepared for the challenges involved.

References

1. Okoro O. M. (1993) Principles and Methods in Vocational & Technical Education, University Trust Publishers, Enugu, 1993.
2. OSPI (2009) Career and Technical Education: Washington- Office of Superintendent of Public Instruction: http://www.k12.wa.us/CareerTechEd/_Acceessed 2nd November, 2012
3. www.dest.gov.au/sectors/training_skills/policy_issues_reviews/key_issues/nts/glo/utoz.htm Acceessed 2nd November, 2012.
4. NBTE (2012) http://www.nbte.gov.ng/ Acceessed 1st November, 2012.
5. FPI (2009) The Federal polytechnic, Ilaro Strategic Plan 2009-2014 www.federalpolyilaro.edu.ng/web/images/pdf/strategic%20plan.pdf Acceessed 2nd November, 2012.

6. Goyal, S. C. and Bakshi, U. A. (2008) Principles of Control Systems, seventh edition, Technical Publications Pune, India.
7. Saeed, S. H. (2012) Automatic Control Systems. Seventh edition, S. K. Kataria and Sons, Punjab.
8. Kheir, N. A., Aström, K. J., Auslander, D., Cheok, K. C., Franklin, G. F., Masten M. and Rabins M., (1991) 'Control Systems Engineering Education', Automatica, 32, 147–166.
9. Balchen, J. G., Handlykken M., and Tysso, A. (1981), 'The need for better laboratory experiments in control engineering education', in Proc. 8th. IFAC Triennial World Congress, vol. XIII pp. 42–47.
10. The Servo Trainer CE110 Equipment Manual, (2008) TecQuipment Ltd, United Kingdom.