Enhancing the Student Learning Outcomes in Electric Drives and Control by Integrating the Core Courses Through PBL Approach.

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Abstract: In recent years Power Electronics and Drives has gained much importance in the Electrical Engineering domain, owing to the growing need for industrial applications, such as Motor Drives, Switched Mode Power Supplies (SMPS) and Electric Vehicle. Electric Drives and Control course is delivered for Electrical and Electronics Engineering junior year students at K.L.E Technological University, India. The course derives the knowledge from the core courses of the program like Electrical Machines, Power Electronics and Control Systems. It is challenging to facilitate the integrated learning experience to students at the junior year with conventional teaching pedagogy. Problem Based Learning (PBL) approach is known to be a fascinating, problem-centered teaching/learning process, that helps the student for a more in-depth understanding of the concepts and to strengthen the application of the knowledge gained by students in theory classes. This paper presents the experience of faculty team adopting a PBL in delivering Electric Drives and Control course for junior year level at K.L.E Technological University. An open-ended problem in Electric drives and Control laboratory was floated as a PBL activity to integrate the learnt concepts of three courses (Electrical Machines, Power Electronics and Control Systems). Through this approach we are able to increase learning outcome of a student such as applying fundamental knowledge of electrical science, theoretical and practical understanding of a subject, use of modern engineering tool to solve complex problem and to validate the simulation and practical results.

Keywords: Electric Drives and Control, PBL.

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1. Introduction

Electrification process is opening up more opportunities for Power Electronics and Drives in the field of power train for the electric vehicle, DC- charging stations, motor drives, and its control, etc. It’s a challenge for any academia to equip students to current industry requirements in the area of Electric Drives. The traditional “*chalk and board pedagogy”* in delivering Electric Drives and Control course are trailing in reaching out industry demands. The pre-requisite knowledge for Electric Drive and Control course is core courses of the program like Power Electronics, Electrical Machines, and Control Systems. It is a challenging task to facilitate integrated experience to students in the junior year with current teaching practices. This paper presents how the Problem Based Learning approach has helped in the eradication of traditional pedagogy barriers in Electric Drives and Control course. The Centre for Innovative in Teaching and Learning (CITL), Illinois describes, that problem based learning or teaching is motivating that can improve the quality of engineering education and helps the students in long term retention of knowledge, reinforcement in the subject matter.

Recently the Technical University of Denmark has adopted delivering Power Electronics course with PBL approach [1], which emphasizes peer evaluation and peer learning, which reflects the quality of work done by the students. The paper includes assessment method, course teaching plan, and student feedback. Fernando Martinez-Rodrigo discus, in his article how PBL approach is used to improve educational outcomes in power electronics course by addressing topics on choppers, controlled rectifiers, etc. [2]. The outcome was measured by comparing the previous year results. The results have shown an improvement in educational outcomes and student satisfaction.

This paper presents the experience of faculty team adopting PBL method in Electric drives and Control course. An open-ended problem in Electric Drives and Control course is floated as a PBL approach to integrate the concepts of three core courses viz. Electrical Machines and Control systems and power electronics course.

This paper describes the structure of the course in brief, pedagogy followed in delivering the course. Rubrics framed for student assessment, followed by attainment of program outcomes and comparison of results with and without PBL approach is also discussed.

This paper is organized as follows — Section-1 introduction. The process for course delivery is discussed in Section-2. PBL methodology followed in Electric Drives and Control course will be discussed in Section-3. Results are discussed in section-4. Finally paper wraps up with the conclusion.

2. Course delivery process

Course contents is organized in three units, where Unit I is dedicated to DC Drives and its control, Unit II comprises of AC Drives and its control and Unit III consists of Special machine drives like Switched Reluctance Motor, Permanent Magnet Synchronous Motor and Brushless DC Motor.

The structure of the course is L-T-P: 2-0-1 which means two lecture hours per week followed by two hours laboratory session.

Laboratory experiments were planned to run concurrently with the topics covered in theory course. As discussed in the introduction section, to get a complete understanding and operation of electrical drive, one should have the knowledge of courses Electrical Machines, Control System and Power Electronics which were thought in fourth and fifth semester respectively. Experiments were designed according to the block diagram referred in Fig.1 [5]. Source for the power modulator may be AC or DC supply. Based on the type of load, power modulator block modulates the flow of power, selects the mode of operation of the motor and limit the current well within safer limits. Control signals for power modulator are generated from control unit. Sensing of motor parameters like current and speed are required for closed loop operations is done by Sensing Unit.

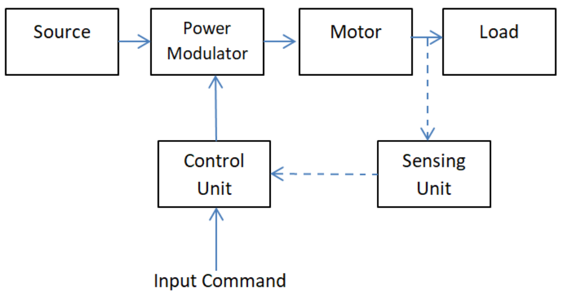

Fig.1 Electrical Drive Components

As we know, any electrical system nowadays is controlled through embedded systems. Keeping this concern in mind as one of the opportunities, the first few laboratory sessions were dedicated for hands-on training on usage of sT-Embed tool provided by Altair, which is considered as one of industry-standard modern engineering tool for developing embedded systems. This tool facilitates Frequency Domain Analysis and Linearization, generalized reduced gradient method of parameter optimization, model-based development, etc. In recent days model-based development is gaining importance in design of complex control systems, hence we faculty have designed all laboratory experiments using model-based development approach.

Fig.2 DSP Processor (TMS320F28069)

Control signals are generated through sT-Embed tool using TMS320F28069 DSP processor as shown in Fig.2 the strength of these control signals are not sufficient to trigger the switches of the power modulator circuit. So these signals are amplified to required voltage level through level shifter circuitry using 7417 IC as shown in Fig.3.

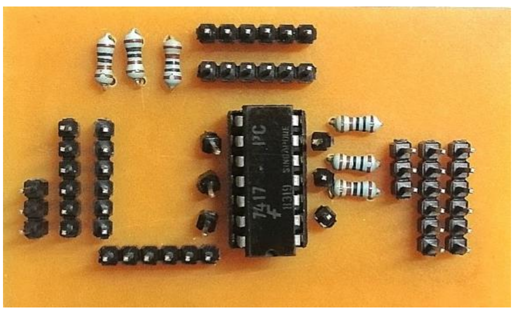

Fig.3 Level Shifter Circuit Using 7417 IC

Once the control unit block is ready, then the student is given the task of realizing the power converter module, knowledge of which was acquired from power electronics course. Control unit and power modulator block (Refer Fig.4) prepared in hand, the next exercise is given to the student is to verify the drive operation. For this exercise, prior knowledge of electrical machines is necessary.

Fig.4 Power modulator block

3. PBL approach in Electric Drives and Control Course

As discussed in the Course delivery process, after completing all the experiments, students were given with open ended problem statement as a part of lab assessment, for which students have to arrive at the solution as per understanding of course. *Open Ended Problem* statement floated among students is given below:

The state-space model of a separately excited DC shunt motor with name plate specification: 220 V, 3kW, 1500 rpm are given in equations (1) and (2).

$$\frac{di_a}{dt} = -\frac{R_a}{L_a} i_a - \frac{K_{bt}}{L_a}\omega_a + \frac{V}{L_a} \qquad (1)$$

$$\frac{d\omega_a}{dt} = -\frac{B}{J_m}\omega_a + \frac{K_{bt}}{J_m} i_a - \frac{T_L}{J_m} \qquad (2)$$

where,

V : Voltage applied to armature in Volts
i_a : Armature current in Ampere
R_a : Armature resistance in Ohm
L_a : Inductance of the armature in Henry
T_L : Load torque in N-m
ω_a : Mechanical speed of the motor in rad/sec
B : Damping coefficient
J_m : Moment of inertia of the motor
K_{bt} : Machine coefficient

Design a closed loop speed control of DC motor given for 50% of the loading conditions.
Data: Damping coefficient=0.023Nm-s, Moment of inertia=0.08735 kg-m^2, Machine coefficient=1.1607V-s/rad

After floating this open ended problem statement, students were asked to identify the challenges they may face during implementation.

Methodology followed by students to solve the above problem

1. Identify and determine required data experimentally.
2. Mathematically model separately excited DC shunt motor using state space equations given in equation (1) and (2), simulate the same using MATLAB/Simulink.
3. Experimentally validate the results.
   a. Develop a model for control signals in sT-Embed and export the developed model on to DSP launch pad TMS320F28069M.
   b. Control signal tapped from DSP launch pad are of 3.3V in magnitude.
   c. The power circuit in power modulator module requires control signal of magnitude 15V, which is not provided by DSP launch pad TMS320F28069M alone.
   d. An additional circuitry is required to boost the amplitude of the control signal to 15V from 3.3V, which is achieved by level shifter.
   e. The output of Level shifter is given to switches of power modulator, which supplies controlled input to the motor.
   f. Closed loop control system is designed with PI controller as per block diagram shown in Fig.5

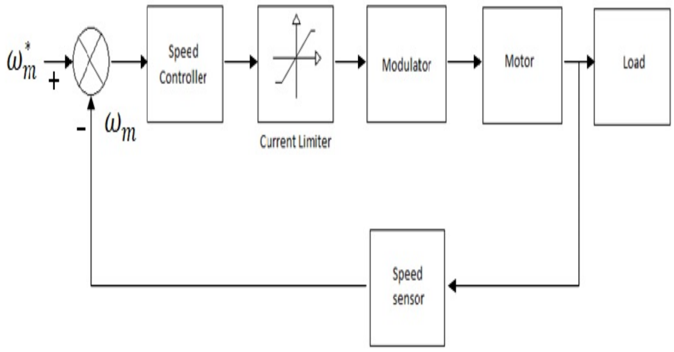

Fig.5 Closed loop control system

   g. Integrate all individual blocks as per Fig.1 and its verification carried out experimentally as shown in Fig.6

Fig.6 Experimental set-up

A. Student Assessment:

In a semester, students are assessed for four internal events which include two In Semester Assessments (ISA) through mode of theory examination and one with laboratory and last activity through assignment or quiz through *Moodle*. Evaluation scheme is as shown in Table.1

Table-1 Evaluation Scheme

Assessment	Weightage in Marks
In Semester Assessment-1	15
In Semester Assessment-2	15
Electric drives and control laboratory	15
Assignment/Quiz	05
Total	**50**

PBL approach was followed majorly in Electric Drives and Control laboratory and its assessment rubrics are discussed in Table.2

Table-2 Evaluation Rubrics for EDC lab

Assessment Parameters	Excellent	Good	Poor
Evaluating unknown parameters	* Student is able to clearly identify the data which is required solve a given problem and evaluate them. * Student is able to recognize unknown which need to be derived either through calculations by applying basic engineering knowledge or through any experimentation (2 Marks)	* Student is not clear about which all data need to be considered to solve a given problem * Student has identified the unknown data which is required to solve the given problem, but lack in knowledge how to acquire at those data.(1 Mark)	* Student has no knowledge in identifying data in problem statement. * Student is not able to identify there is data missing in problem statement which is required in the process of solving the problem. (0 Mark)
Design or development of solutions	Student is able to apply the prior knowledge in the process of developing the solution and implement the same. (3 Marks)	Student is able to arrive at solutions after faculty intervention (2-1 Marks)	Student is not able to arrive at solution even after faculty intervention. (0 Mark)
Mathematical modelling	After obtaining all the data which is required to solve problem student is able to demonstrate its mathematical model of a system or subsystem and validate the results through simulation and experimentation. (4 -3 Marks)	After obtaining all the data which is required to solve problem student is able to demonstrate its mathematical model of system or subsystem with faculty intervention and but lack in validating the results through simulation experimentation. (2-1 Marks)	Student is not able to model at least any of the subsystem (0 Mark)

Modern tool usage	Student is able to choose appropriate modern engineering tool to demonstrate the possible results virtually and draw conclusion from the all the results obtained. (6-5 marks)	Student is able to choose appropriate modern engineering tool to demonstrate the possible results virtually but lack in drawing conclusion from all the results obtained. (4-2 Marks)	Student is able to choose appropriate modern engineering tool with the help of faculty intervention but lack in demonstrating the usage of it for solving the given problem. (1 Mark)

B. Students Learning Outcome during various stages of problem solving:

Assessment rubrics were designed in such way that each student should be able to gain few competencies or skills. This section describes how aimed competencies were achieved through various reviews.

1. During review 1: It was expected from the students that to identify any data missing which is required in the process of solving the problem.
   a. It is observed from the problem statement that it is essential to have the data regarding armature resistance R_a and inductance L_a.
   b. Students conducted a laboratory experiment to determine the unknown data with the prior knowledge of Electrical Machines which students studied in 4th semester.

   Learning outcome gained by the student through this activity was **applying fundamental knowledge of electrical science.** .

2. After gathering all required data students modelled the electric motor mathematically with the given specification and they were expected to verify the results through simulation. With the aid of this activity students were able to **draw conclusions** from the various results obtained in MATLAB/Simulink competency gained through this activity was the **usage of the modern engineering tool.**

3. To control the motor for given application through power modulator, next task for students was to design an appropriate controller for power modulator unit which was available in laboratory.

4. Designing of closed loop controller was implemented using PI controller. With the course Linear Control System learnt in 4th semester students designed PI controller, arriving at appropriate values of proportionality constant and integral constant. In the process of designing particular controller students gained the competency of **applying discipline specific knowledge**

5. During review 2 expected work to be done from the students was to integrate the designed controller, power modulator unit and electrical motor. Competency gained through this activity was **theoretical and practical understanding of a subject, by integrating the skills acquired through fundamental courses.**

4. Results and Discussions:

To conquer 21st-century grand engineering challenges, any engineering student should possess specific graduate attributes given by Washington Accord. Here in our department, the faculty team tried making students attain a few significant Program Outcomes (PO) through various assessment events. Comparison of PO attainment for the academic year 2017-18 with chalk and board pedagogy, 2018-19 with PBL approach as shown in Table.3

Table-3 Comparison of PO attainment

Program Outcomes (POs)	Academic year 2017-18	Academic year 2018-19
PO1	✓	✓
PO2	✓	✓
PO3		✓
PO4		✓
PO5	✓	✓
PO9		✓
PO10	✓	

Besides enhancing the student learning outcomes, there is a significant improvement in the performance of the students in End Semester results. The bar graph shown in Fig.7 is a comparison of End Semester Assessment results for two consecutive academic years 2017-18 and 2018-19. It can be observed from the graph that there is an improvement in the percentage of students obtaining ‘S’ grade. Also, there is an improvement in the cluster of students shifting from ‘C’ grade to ‘B’ grade through the PBL approach.

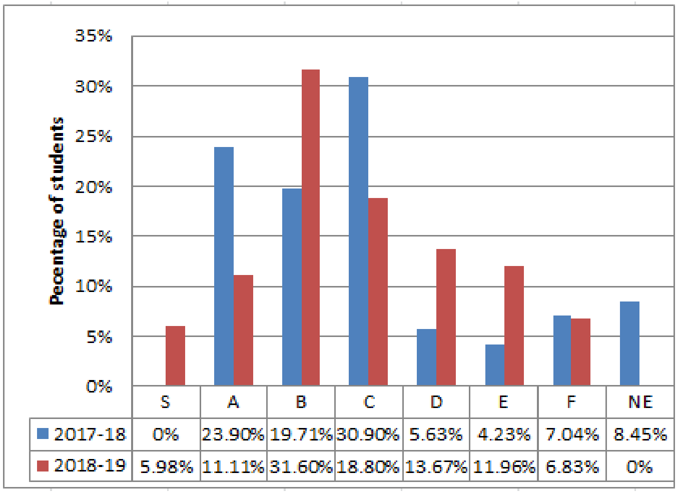

Fig.7 Comparison of Grades Obtained

5. Conclusion

The paper presented here is an attempt made by authors to enhance the learning of students in Electric drives and controls course through problem based learning approach. As discussed in the paper it was witnessed that through PBL approach, authors could make the students to enhance their learning outcomes and competencies by integrating the courses.

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