The Experimental Set for 3-Phase Induction Motor Drives by Using Modern 32-bits Microcontroller

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***Abstract*-Industrial motor drives and control course is often complicated to teach the students both in experiment and in theory. The objective of this research was to design and implement an experimental set, lesson plans, tests, laboratory sheets and evaluation sheets for teaching industrial motor drives and control course. After the experimental set was designed and constructed, it was experimented with 8 fifth-year undergraduate students (experimental group) enrolling in Bachelor of Engineering (Electrical Power) at Technological University (Dawei), Myanmar. The result showed that 5 experts opinion on the experimental set for 3-phase induction motor drives by using modern 32-bits microcontroller was at very high level. The satisfaction of experimental group was at very high level and also posttest scores were better than the pretest. In conclusion, the results demonstrated that with a proper step by step instruction, the students can easily see real equipment of the experimental set and quickly practice their essential skill to achieve this course.**

Keywords: Experimental Set, 3-Phase Induction Motor, 32-bits Microcontroller, Experiment and theory teaching

I. BACKGROUND AND PROBLEM STATEMENT

Industrial motor drives and control course (EP-5028) is fifth-year of Bachelor of Engineering (Electrical Power) at Technological University, Dawei (TU Dawei). TU Dawei situated at Dawei District, Taninthayi Region in Republic of the Union of Myanmar. Bachelor of Engineering of undergraduate degree program is sixth-year (full time). This course is an important part of the respective engineering curriculum and include many different field of study such as electrical machine, power electronics and control strategies.[1]

Industrial motor drives and control course is often complicated to teach students both in experiment and in theory such as open-loop and closed-loop control system. We could not use the experimental set better than demonstration for the students. They were not seen real equipment of hardware system setup. Also, the students are not familiar with software as MATLAB/Simulink. Consequently, the students are not easy to understand of precision and information in the control strategies. Some engineers and researchers used to solve this problem, comprises a virtual power electronics and drives laboratory for undergraduate electrical power engineering degree programs and practicing engineers, also known as a virtual laboratory [2]. According to a virtual laboratory setup, the students gained a better understanding of the main forms of modeling, simulation, and hands-on experimentation for electrical drives [3]. In this paper, the experimental set for 3-phase induction motor drives was used to treat open-loop volts per hertz (*V/f*) control by using modern 32-bits microcontroller. The experimental set has been rather as a necessary advanced education and understanding tool.

AC motors are now employed in variable speed drives, also due to development of semiconductor converters employing thyristors, power transistors, IGBTs and GTOs, linear and digital ICs, and microcomputers have made the control characteristics even more flexible. The controls for power modulator is built in control unit which usually operates at much lower voltage and power levels. In addition to operating the power modulator as desired, it may also generate commands for the protection of power modulator and motor. Input command signal, which adjusts the operating point of drive, forms an input to the control unit. And, sensing of certain drive parameters, such as motor current and speed, may be required either for protection or for closed-loop operation.

An inserted microcontroller controls generally the operation of AC motor controller. However, the disadvantage of the microcontroller can show hard to understand estimation, such as coordinate transformations, field estimation algorithms and controller algorithms [4].

In this paper, modern 32-bits microcontroller confirmed with the help of the softwares, such as MATLAB/Simulink, Code Composer Studio (CCS) and controlSUITETM. The aim of this research was to design and implement the experimental set, experiments & theory teaching for industrial motor drives and control course. Finally, it has designed and constructed a need for more educated and better trained students.

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II. LITERATURE REVIEW

The experimental set is 3-phase voltage source inverter (VSI). A voltage source inverter is commonly used to supply a variable frequency variable voltage to a 3-phase induction motor in a variable speed application. The induction motor applications are very wide spread from centrifugal pump, compressor, punching presses, elevator and many more [5]. The inverter switching techniques such as pulse width modulation (PWM), sinusoidal PWM and space vector PWM are explained in [6] and [7]. PWM drives are more efficient and typically provide higher levels of performance. Pulse width modulation is a technique to generate pulses with a certain rules and goals through supplying DC voltage for inverter to obtain variable speed drive operations.

In general, there are two basic types of inverters: voltage source inverter (VSI), employing a DC link capacitor and providing a switched voltage waveform, and current source inverter (CSI), employing a DC link inductance and providing a switched current waveform at the motor terminals. CSI are robust in operation and reliable due to the insensitivity to short circuits and noisy environment. VSI are more common compared to CSI since the use of pulse width modulation (PWM) allows efficient and smooth operation. Furthermore, the frequency range of VSI is higher and they are usually more inexpensive when compared to CSI drives of the same rating.

The most common AC drives today are based on sinusoidal pulse width modulation (SPWM). Pulse width modulation systems are relatively new development as far as widespread industrial applications are concerned. They enable variable speed induction motor drives ranging from zero speed and up. Their appearance in the marketplace is directly due to the availability of high speed switching devices such as IGBTs. PWM is accomplished by computer control of the gate triggering. Also, the Texas Instruments AC motor development kits and software are used to develop the program, and produce control signal in real time [8].

In this project, the LAUNCHXL-F28027 kit features all the hardware and software necessary to develop applications based on the F2802x microprocessor. The LaunchPad is based on the superset F28027 device, and easily allows users to migrate to lower cost F2802x devices once the design needs are known. It offers an on-board JTAG emulation tool allowing direct interface to a PC for easy programming, debugging, and evaluation. In addition to JTAG emulation, the USB interface provides a UART serial connection from the F2802x device to the host PC.[9]

III. RESEARCH METHODOLOGY

A. Experimental System

In this section, the experimental set involved three necessary parts: 1.) implemented inverter, 2.) DC link, and 3.) induction motor.

1) Implemented Inverter

The power of 3-phase voltage source inverter was 1 kW. A 1 kW inverter comprised of DC bus, gate drive circuits [10], modern 32-bits microcontroller and IGBT inverter module [11]. Fig. 3 shows system description of 3-phase voltage source inverter.

The control part consisted of a TMS320F28027 board, made by Texas Instruments (C2000 LaunchPad XL), as shown in Fig. 1. It is assumed that the student will be educated in digital system processors subject, using also this board.

The control board has the following features:

- USB debugging and programming interface via a high-speed galvanically isolated XDS100v2 emulator featuring a USB/UART connection.
- Superset F28027 device which allows applications to easily migrate to lower cost devices.
- Nibble (4-bit) wide LED display.
- Two push buttons for user feedback and device reset.
- Easily accessible device pins for debugging purposes or as sockets for adding customized extension boards.
- Boot selection and USB and UART disconnect switches.

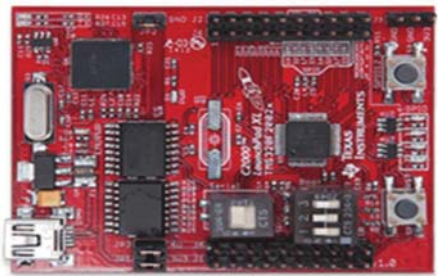

Fig. 1. Experiment kit TMS320F28027 (C2000 LaunchPad XL)

2) DC Link

The inverter converts the DC link to an AC output. The topology of a drive with a DC link varies depending upon the power rating of the drive. In this research, at lower voltage (<300 V_{dc}) and powers, the DC link stage typically only has a capacitor (1000MF 450V DC) to support the voltage for 1 kW inverter.

3) Induction Motor

The motor converts electrical energy into mechanical energy. Induction motor of rated power 0.25 kW specifications used in hardware implementation as shown

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in Fig.2. Here we have used it in star connection. For the specified of 3-phase squirrel cage motor is as follow:

TABLE I.
SPECIFICATION OF 3-PHASE SQUIRREL CAGE MOTOR

Parameters	Value
Power (kW)	0.25
Voltage (V)	230/400
Frequency (Hz)	50
Current (A)	1.47/0.85
Connection	Delta/star
cosϕ	0.78
Rated speed (rpm)	1350

Fig. 2. Three-phase squirrel cage motor [12]

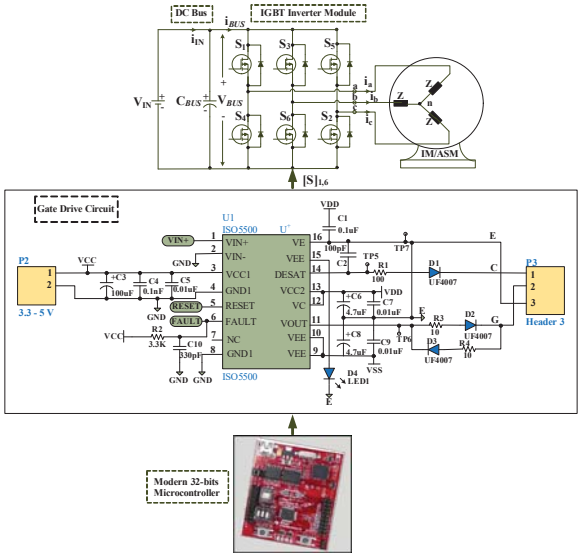

Fig. 3. System description of 3-phase voltage source inverter

The C2000 launchPad is used to generate pulses to open-loop *V/f* control the frequency and voltage magnitude of the 3-phase voltage source inverter output. Fig. 4 shows photograph of the complete designed experimental system.

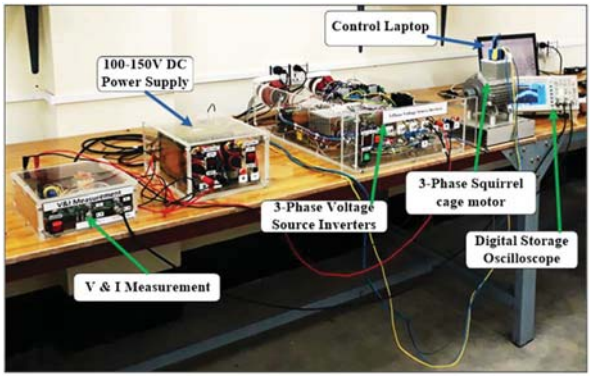

Fig. 4. Photograph of the complete designed experimental system

B. Experiments and Theory Teaching

The experiments and theory teaching were implemented using 3-phase voltage source inverter (VSI). These consist of lesson plans, tests and implement 2 laboratory sheets as shown in Fig.5. The lesson plan in this research has been prepared for 3-phase VSI and open-loop V/f control based on the traditional learning model. And, implement 2 laboratory sheets have been comprised 1.) How to set-up softwares + simple Simulink + PWM, and 2.) Open-loop V/f control of 3-phase induction motor.

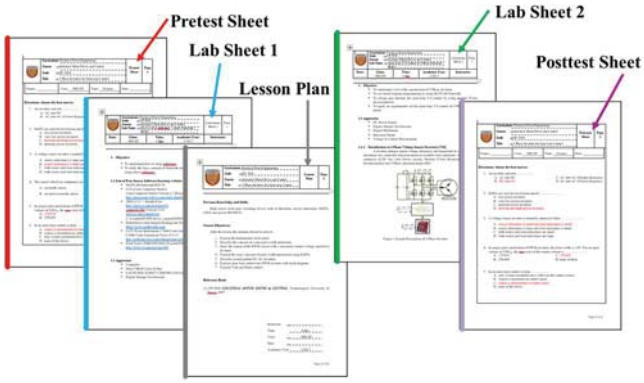

Fig.5. Experiments and theory teaching sheets

1) Lab-1: how to set-up softwares + simple Simulink + PWM

A software control panel that enables the user to configure the actions in an application, operating system or the hardware. The objective of this lab is to understand how to setup softwares and study the basic concept of Simulink & pulse width modulation (PWM) by using softwares, as shown in Fig.6. This lab included types of software application such as MATLAB/Simulink R2015b, CCS, 2802x C/C++ Header Files, controlSUITE, Embedded Coder Support Package for Texas Instrument C2000 Processors, C2000 Code Generation Tool and TM320F2802x Piccolo ™ Flash API.

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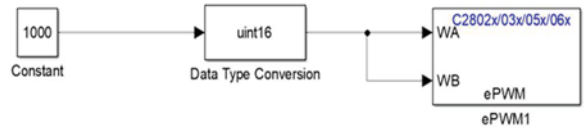
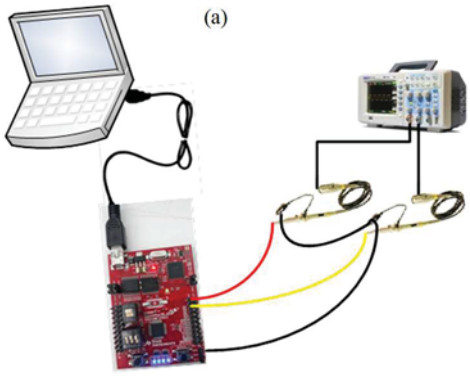


(a)



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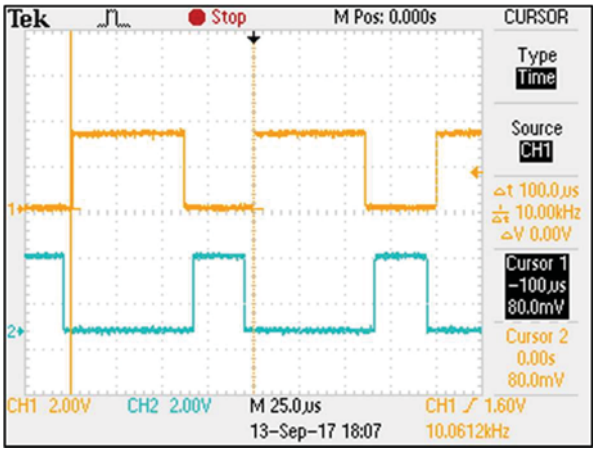

(c)

Fig. 6. (a) The basic concept Simulink model of ePWM (b) Photograph of the complete designed ePWM (c) Output waveform of ePWM

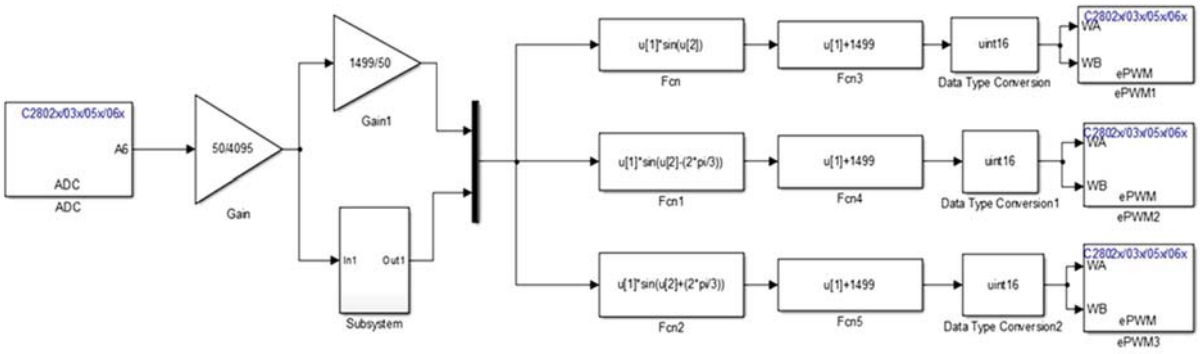

Fig.7. Simulink model of open-loop V/f control for 3-phase VSI

C. Population Groups

The population groups divided 5 experts (3 experts from KMUTNB & 2 experts from TU Dawei) and experimental four groups of fifth-years of Bachelor of Engineering (V.BE-EP) students. Firstly, 5 experts evaluated the quality of experimental set and experiments & theory teaching. As for the students, they were divided into four groups (2 students in each group) and were asked to rate their satisfaction level upon the using of the students were collected and analyzed.

IV. RESEARCH RESULTS

The results of the research include three parts: 1.) the experts' results satisfaction, 2.) the satisfaction level results of experimental group, and 3.) the learning achievement of experimental group.

Lab-2: open-loop V/f control of 3-phase induction motor

In this lab-2, the open-loop *V/f* control has been implemented using modern 32-bits microcontroller with MATLAB/Simulink library. It has been modified and consequently adapted to work with the experimental platform. Fig. 7 shows Simulink model of open-loop *V/f* control for 3-phase VSI.

The laboratory sheet 2 is the objective of practiced skills as following:

- To understand view of the construction of 3-phase inverters.
- To use block diagram programming by using MATLAB/Simulink.
- To design and simulate for open-loop *V/f* control by using modern 32-bits microcontroller.
- To apply an experimental set for open-loop *V/f* control of 3-phase induction motor.

A. The experts' results satisfaction

The 5 experts evaluated results of experimental set and experiments & theory teaching (lesson plans, laboratory sheets and tests) as shown in Table II and Fig.8. The experts' evaluation items according to the following:

1) Usability

- Design and implement of an experiment set
- Layout of an experiment set
- Design and implement for information sheets & lab sheets
- Impression for using

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- Duration for lab experiment
- Operating procedure

2) *Functionality*

- Set-up softwares and simple Simulink + PWM
- Lab sheets for experiment set
- Simulink block diagram programming for open-loop *V/f* control
- Procedure for setting up lab system
- Manageable for experimental lab

3) *Performance*

- Operating steps for 3-phase induction motor lab
- Designation of an experimental set for industrial motor drives and control course
- Open-loop *V/f* control for 3-phase induction motor practice
- Experimental set for students
- Reduced for industrial motor drives and control course lab
- Application of an experimental set/3-phase voltage source inverters (VSI)

TABLE II.
RATING SCALES (1-5) OF 4 EXPERTS' EVALUATION OF SATISFACTION
(5=EXCELLENT, 4=VERY GOOD, 3=GOOD, 2=FAIR, 1=NEED IMPROVE)

Evaluation items	Average	S.D.	Level
1. Usability	4.36	0.64	High
2. Functionality	4.64	0.58	Very High
3. Performance	4.63	0.50	Very High
Total Average	4.54	0.58	Very High

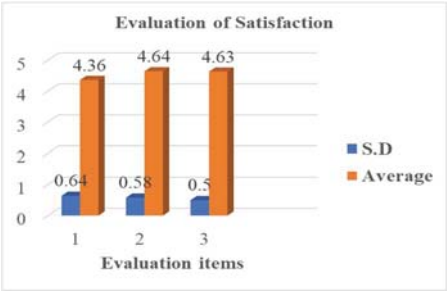

Fig. 8. The evaluation of satisfaction

Table II and Fig.8 showed results from effect of the experimental set and experiments & theory teaching from 5 experts, that the evaluation of satisfaction was at very high level as the total average score was 4.54 (S.D. = 0.58) with evaluation items taken into consideration.

B. The Satisfaction level results of experimental group

We have carried some reviews on 8 students (2 students per group) after conducting experiments and theory teaching as shown in Fig.9. Table III shows the results for V.BE-EP students on 2017.

Fig. 9. The experiment and theory teaching of experimental group

TABLE III.
AVERAGE SCORE (1-5) OF THE EVALUATION OF SATISFACTION
(1=STRONGLY DISAGREE, 2=DISAGREE, 3=NEUTRAL, 4=AGREE, 5=STRONGLY AGREE)

No.	Evaluation items	Average score	S.D.
Course Enhancement			
1	This topic exactly the requirements of industrial motor drives and control course.	4.63	0.52
2	The experiment and related topics were appropriate.	4.88	0.35
3	The experimental set was related to learning outcomes of the course.	5.00	0.00
4	It was theoretical oriented topic.	5.00	0.00
5	The topic was underpinned new knowledge and practical skill.	4.88	0.35
6	The topic requires a textbook in future years.	5.00	0.00
7	My background knowledge is sufficient to understand the topic.	5.00	0.00
	Total Average	4.91	0.17
Operating Function			
8	Using experimental set was attracted to learn.	5.00	0.00
9	Printed manual of laboratory sheets was appropriate.	4.50	0.53
10	This lab should be used with the experimental set in industrial motor drives and control course.	5.00	0.00
11	Test sheets related well to the class material.	4.88	0.35
	Total Average	4.84	0.22
Equipment Utilization			
12	The guidance gave for the topic by the lecture was useful.	4.75	0.46
13	The lectures were well organized.	5.00	0.00
14	The lectures were sufficiently prepared.	4.50	0.53
15	The lecture's use of experimental set in this class was appropriate.	5.00	0.00
	Total Average	4.81	0.25

Table III showed, according to the 8 students review, that the level of satisfaction was at very high level as the total average score was 4.88 (S.D. = 0.21) with 15

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evaluation items taken into consideration. The evaluation items 3, 4, 6, 7, 8, 10, 13 and 15 shows that 8 students of Technological University (Dawei) seem to be getting more comfortable with the idea of using the experimental set.

C. The learning achievement of experimental group

The designed lesson plans have 14 exercises, a pretest and a posttest. Student test scores were collected through the instruction. The 8 students testing scores were analyzed by comparing pretest and posttest scores as shown in Fig. 10.

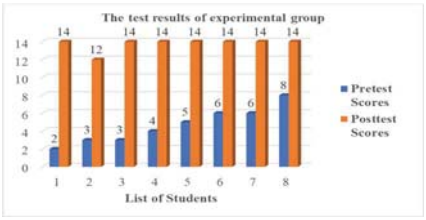

Fig. 10. The testing scores of 8 students pretest and posttest

The results are presented as shown in Fig. 10. There is enough evidence to support that posttest score is better than the pretest.

V. CONCLUSION

The implementation of the experimental set for 3-phase induction motor drives by using modern 32-bits microcontroller are presented in this paper. The experimental set and softwares were used to implement lesson plans, tests, laboratory sheets and evaluation sheets for teaching industrial motor drives and control course. The results showed that 5 experts opinion on the experimental set for 3-phase induction motor drives by using 32-bits modern microcontroller was at very high level. The satisfaction of experimental group was at very high level and also posttest scores were better than the pretest. In addition to result the experimental set both in experiment and in theory demonstrated that with a proper step by step instruction, the students can easily see real equipment of the experimental set and quickly practice their essential skill to achieve this course. In future, a good solution should be worked out closed-loop *V/f* control drives with the experimental set for industrial motor drives & control course after doing a further analysis on the causes of this research.

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