Low Cost Lab Equipment Implementation of a Machinery & Controls Course in Engineering Technology

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Abstract

Existing lab facilities were inadequate and out of date for teaching a sophomore course on electrical machines and their control. Many of the existing lab experiences were faculty demonstration oriented rather than hands on student labs. The limited number of matching and working pieces of equipment caused difficulty in developing meaningful lab experiences. A further hindrance was the availability and location of available three phase power outlets. The existing situation necessitated a low cost method for delivering laboratory experiences in a required Associate of Applied Science Degree course, titled Machinery & Controls. Packaged educational machinery systems were investigated but were determined to be cost prohibitive leading to the development of customized lab systems.

This paper will walk through the incorporation of three-phase power to the lab and the purchase of up to date equipment found in modern industrial environments. The initial equipment implementation is focused on induction machines with plans to incorporate, synchronous, single phase, brushless DC and stepper motors as funding for additional purchases becomes available. The design process, purchase and installation of laboratory three-phase induction motors, loads and control equipment is discussed. The controls equipment included in the lab facilities is intended to give the student a practical exposure to the actual control items found in industry including variable frequency drives and solid-state soft starters. The lab equipment is designed to be supplied by a 208Y/120, 3 phase source and as such up to date electrical safety considerations according the NFPA 70E are emphasized in the course. Student feedback on the learning experiences during the first course offering with the new equipment will be included.

Keywords

Low Cost   Industrial Grade Equipment   NFPA 70E/IEEE 1588   Custom Designed

Modular

Description of Class

Machinery & Controls is an introductory class to topics of basic electromagnetics, DC machine operation and control and three phase induction motor & single phase motor operation and control. Basic electromagnetics takes on an approach as needed for the creation of electromagnetic fields in electrical machines. The method of magnetic circuits is introduced and utilized to explore the topics of magnetomotive force, magnetic field intensity and flux density that are needed to create fields in a variety of types of iron & steel cores as well as air gaps.

An introduction to the basic components of DC machines including the shunt field, armature, series field and the identification of the leads. Basic commutation, commutators, brushes and basic permanent magnet motors are explored.

Three phase induction motor topics including the synchronous field and speed are explored as well as the rotor speed and slip including the need for slip as required to create torque in and induction motor. Output power is identified and calculated. Split phase motors are then introduced and the need for the main and run winding investigated along with the concepts that reveal the need for starting and running capacitors in single phase motors.

The course continues with control components starting with the control power transformer, calculation of available fault current and identification of the items to understand Flash Hazard. From a safety standpoint, the Shock Hazard and Flash Hazard are discussed. The class then focuses on the components to investigate “two wire” control, “three wire” control, HOA control on three phase induction motors. Time delay relays are explored. The application of Variable Frequency Drives, Soft Starters and their control are then thoroughly investigated.

Existing Course Lab Experiences

The course as found in the Fall of 2015 was modestly equipped with devices to investigate DC Machines and transformers. The equipment was rather old but basic dc machine operation has not changed much since the equipment was obtained. The building that houses the lab rooms for this class was built in the 1960’s and has three phase power available but it was not available in the lab rooms. With this in mind even if there was reasonable three phase equipment available, there was no power supply for such equipment. In addition, there was a very limited amount of control equipment available for students to be able to investigate controls elements in practical laboratory experiments. As a result, there was a lot of demonstration type lab experiments provided.

Concerning some other outlying matters with the existing course; neither standard motor starters nor electronic soft starters were available. There was one variable frequency drive and one three phase induction motor that was used for demonstration purposes only.

The book that was being used was a very good for illustrative purposes on a very wide range of subjects in the field. It handled basic controls fairly well but because it was so wide ranging it offered a lot of information on a lot of topics not covered in the class. For the amount of material that it provided for the class it was rather expensive as well.

Rationale for Equipping Lab with Three Phase Power

Electronic Engineering Technology students with an emphasis in the Power & Utility area continue to see a strong market for graduates with Associate and Bachelor degrees. The

College of Applied Science & Technology at the University of Akron houses the Electronic Engineering Technology program that offers both an Associate of Applied Science and Bachelors of Science Degree in Electronic Engineering Technology. Through guidance from the program industrial advising committee there is an effort under way to provide the opportunity for those students to mold their Bachelor degrees with courses that provide instruction in this area through electives of their choice.

A basic requirement for working in the Power & Utility field is a solid understanding and comfort with basic three phase power utilization. The modification of this course and lab space provided the perfect opportunity to give the program practical exposure to this resource and the requirements, such as the Electrical Safety requirements, for working in and around a three phase power source and loads.

A 480Y/277 V utilization supply is a very common source of three phase power in industry because it provides a nice solution of reducing the current to distribution panels, motor control centers and motors, which decreases the physical size of motors and the conductors required to serve these item. It is however, from an Electrical Shock Hazard standpoint, more dangerous than lower voltages. A 208Y/120 V system is not as common as 480 in an industrial setting, however it is still usually necessary to be available to supply standard 15 A and 20 A receptacles as well as commonly being used for lighting. Lower voltage distribution systems however, can be counter intuitive as it relates to Flash Hazard. In some situations, unlike in a typical home, the lower voltage system can be fed from a large transformer, say 1000 KVA or 1500 KVA. When this occurs there is a tremendous amount of fault current available to drastically increase the ability to feed an arcing fault causing a flash hazard to the system users.

With both sources available, it was decided to provide the lab space with a three phase, 208Y/120 volt supply. Any potential Flash Hazard would be mitigated with the use of current limiting fuses and control transformers. In addition, the new lab equipment panels are equipped with chords and plugs and all wiring is done in a denergized state. Also, each receptacle is equipped with a fused switch with 5 amp fuses and the control transformers are fused at 1 amp primary and secondary to limit student shock and flash hazards to maximize student safety.

After installation of the three phase supply, a good conservative estimate of the actual Flash Hazard in the lab space has been calculated. It has been found to have a Flash Boundary of 1.7” in each switch and 0 cal/cm^2 at a working distance of 18” from a part in each switch. The actual Flash Labels and system are shown below in Figures 1 & 2.

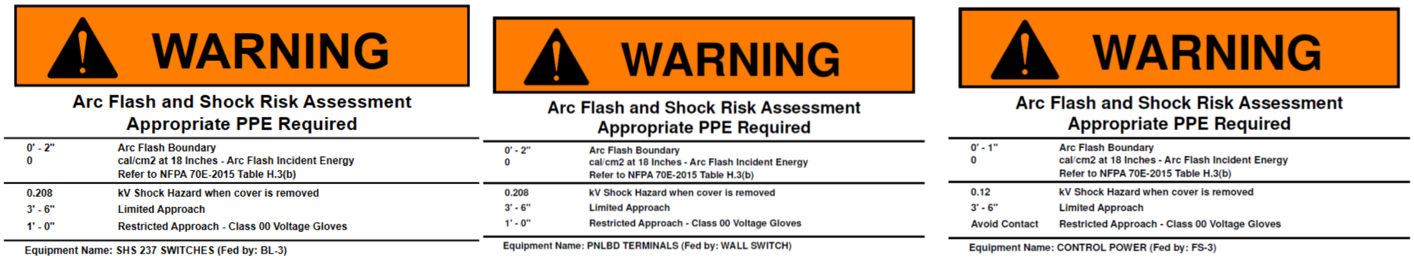

Figure 1

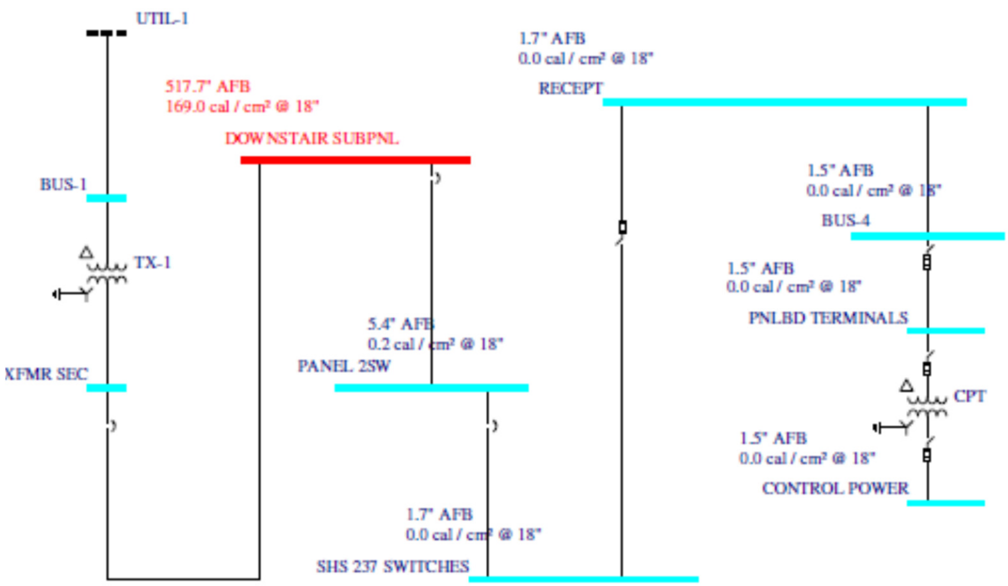

Figure 2

Rationale for Industrial Grade Equipment Purchased:

Graduates of the EET program are employed in a wide variety of positions in the region. The employment opportunities range from surface mount circuit manufacturing to the power utility industry with a large number of students working in advanced manufacturing environments with a heavy dependence on automation and equipment control. In the recent past, the EET program was heavily focused on courses in digital electronics, communications and industrial control. The changing industrial environment which includes jobs associated reshoring of manufacturing facilities and the region's industry base of power utilities, steel processing and automotive manufacturing guidance from the program industrial advisory committee has driven the development of new courses and the updating of existing courses that address the industrial needs. Examples of new courses developed to meet the demands include a third year courses utilizing data acquisition using LabVIEW software, a course covering topics of National Electrical Code NFPA 70, and an industrial control panel building course. In addition to these new courses revisions to the Machinery and Controls class presented an opportunity to improve student learning by increasing the number and scope of student lab exercises.

With these items in mind, it was concluded that the opportunity presented itself to equipped a lab with three phase power and the knowledge of cost effective control equipment could be capitalized on to provide students with an excellent hands on controls laboratory experience. The total cost of the project is shown below and itemized lists of the control panel items and Hampden equipment are attachments at the end of this paper.

Project Cost			
Item	Qty	Price Each	Item Total
Provide Three Phase Power to SHS237	1	$ 12,500.00	$ 12,500.00
Control Panels	6	$ 719.47	$ 4,316.82
Hampden Motors & Prony Brakes	6	$ 2,704.00	$ 16,224.00
		Project Total:	**$ 33,040.82**

Educational Motor Console

The concern with the inability for students to experiment with three phase induction motors was investigated to determine how students could gain experience with appropriate lab equipment. Hampden Engineering is one of companies that provides motor training consoles for lab instruction in a variety of motor configurations. This equipment is in widespread use but has two significant drawbacks the cost of the consoles exceeds the available equipment budget coupled with the large physical size of the consoles. The available lab room is used for both lab and lecture courses and is not physically large enough to house a sufficient number of consoles for students to use of lab purposes. In addition to the consoles companies like Hampden manufactures, they also supply mounting bedplates to accommodate a variety of motor types for coupling loads on the bedplate for testing. It was determined that the physical space requirement could not accommodate multiple consoles but would allow the use of six mounting beds with prony bakes.

Development of Labs

With the purchase of the above reference equipment and past DC equipment, the class now is largely driven by the available lab equipment to provide the student with a very practical hands on experience with equipment that will be found in industry.

The lab experience begins with exposure to DC motor connections and operation, and three phase motor connections and operation including the loading of the motors with the prony brake. The lab experience then moves through the new panelboards beginning with a hands on approach to the 24 VDC power supplies and Control Power Transformers (CPT's) by collecting the manufacture's data on those items and calculating theoretical available fault current. The labs then continue on with basic I/O items, relays & motor starters.

Another important aspect of utilizing the new lab equipment and introducing newer aspects of the equipment is the control of variable frequency drives and soft starters. The students not only operate the drives and soft starters, but the lab experience also walks them through designing control schemes incorporate some of the introductory aspects of remote control of the these items. The labs lead the student right up to the point of being able to interface such items as start-stop control & speed set point with more advanced controls systems such as Programmable Logic Controllers & Distributed Control Systems.

Observations & Conclusions

The finished Panelboards and lab room three phase power installations are shown below in figure 3 & 4, respectively.

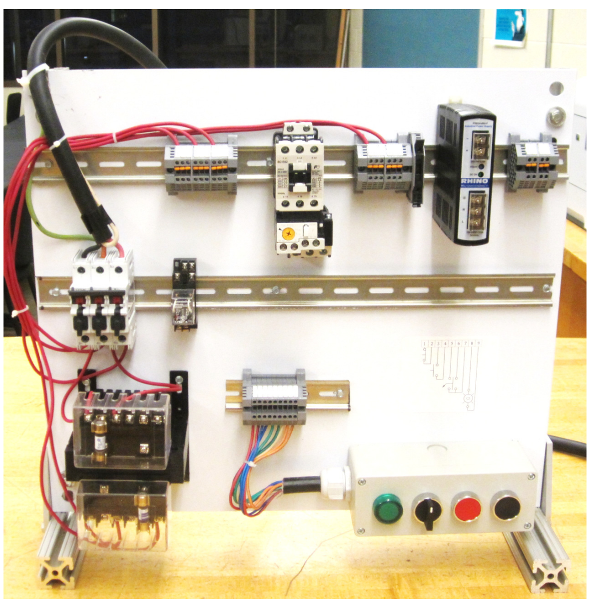

Figure 3

Figure 4

At the time of the writing of this paper, students have performed approximately 6 labs in two lab sections for a total of about 24 students utilizing this equipment. Preliminary performance of these labs has been very satisfactory. This equipment has provided an obvious, cost effective improvement and extremely practical exposure to real world industrial grade equipment. End of the semester student feedback will be included at the conference presentation.

Concerning performance of the collective equipment, several observations have already been made. Most notably, several protective fuses have been found in a “blown” or operated condition. These fuses were the control power transformer fuses which indicates a very satisfactory fuse coordination, meaning that fuses closest to the load operated and not the wall mounted switch fuses, nor the single pole 20 amp circuit breakers in the panel feeding the lab. Also, there appears to have been no apparent operation of these fuses indicating that whatever condition existed to operate these fuses, the result was a very safe and satisfactory operation with no observable flash apparent. Also, very notable from a student safety standpoint is the chord and plug nature of the equipment. Wring is performed after the wall mount switched has been turned off and the plug removed from the receptacle.

In addition, the amount of equipment that was able to be purchased and assembled facilitated small lab groups, commonly two students to a group and very positive student feedback has already been observed. This equipment has created a very positive hands on lab experience for the students taking this course.

References

1. Automation Direct, Online catalog, https://www.automationdirect.com/adc/Home/Home.
2. Easy Power Software, Easy Power, LLC
3. Hampden Engineering, Online catalog, retrieved from http://www.hampden.com/product-category.php?catid=199.
4. Lobsiger, D, Giuliani, PR, & Rexford, Electrical control for machines, Cengage, Boston, MA, USA : 2016.
5. Wildi, T, Electrical machines, drives, and power systems, Pearson/Prentice Hall , Upper Saddle River, 2006.

Gregory Harstine

Gregory Harstine is an Associate Professor of Practice in Electronic Engineering Technology program at the University of Akron with 18 years teaching power type classes in Electrical and Electronic Engineering Technology programs.. Greg has extensive experience in the power utility industry. He has an MBA from Ashland University and is owner of an electrical engineering consulting firm providing consulting services in the electrical power distribution and controls field. Have assisted several local companies in implementing electrical safety plans and modifying electrical safety plans to include the latest requirements of the NFPA 70E.

Andrew Milks

Andrew Milks is an Associate Professor of Electronic Engineering Technology at the University of Akron. Before joining the University of Akron, he worked in the process control industry, and continues to consult in the area.

Joshua Boley

Joshua Boley is a senior engineering technician for the Engineering and Science Technology Department at the University of Akron. He is responsible for department computers, equipment and the design/construction of laboratory equipment facilities.

item	mfg	part #	qty	cost each	item total
sub panel	Automation Direct	N1P2024	1.00	$ 24.5	$ 24.50
iec motor starter	Automation Direct	SC-E02-110VAC	1.00	$ 15.0	$ 15.00
din rail, 35 mm 10 pk, 1m lengths	Automation Direct	DN-R35SAL1	0.17	$ 36.0	$ 6.12
motor protector 30 A, Fusible Disconnect	Automation Direct	CFS-3PM30	1.00	$ 61.0	$ 61.00
CPT, 208-120, 250 VA	Automation Direct	PH250MGJ	1.00	$ 97.0	$ 97.00
CPT terminal covers	Automation Direct	FG3	2	$ 4.0	$ 8.00
terminals, 20A, 100 pk	Automation Direct	DN-T12-A	0.50	$ 42.0	$ 21.00
terminal ends, 50 pk	Automation Direct	DN-EB35	0.20	$ 39.5	$ 7.90
fused terminals	Automation Direct				$ -
CPT HV fuse, 1A, primary fuse only, 10 pk	Automation Direct	MOL1	0.20	$ 14.0	$ 2.80
dsiconnect fuses, UL Midget Fuses, 5A, Fast Acting, 10KA, 250 Volts	automation Direct	MOL5	0.30	$ 14.0	$ 4.20
CPT Fuse holder	Automation Direct	PFK2	1.00	$ 6.0	$ 6.00
DC power Supply 120 VAC - 24 VDC, 2.5 amp	Automation Direct	PSB24-060-P	1.00	$ 28.0	$ 28.00
overlaod blcok	Automation Direct	TK-E02-120	1.00	$ 25.0	$ 25.00
Structure, 80/20® 1515-97 1-1/2" X 1-1/2" T-Slotted Profile, 97" Stock Bar, http://www.globalindustrial.com/p/storage/struts-and-framing/8020/151597-112-x-112-tslotted-profile-97-stock-bar	Global Industrial		1.00	$ 56.0	$ 55.95
misc wires and connecters for strut ect.					$ -
with					$ -
soft start, 5 amp	Automation Direct	SR22-05	1.00	$ 119.0	$ 119.00
VFD	Automation Direct	GS1-20PS	1.00	$ 117.0	$ 117.00
pilot light, 120 volt, LED, green light	Automation Direct	GCX-1232-120L	1.00	$ 15.5	$ 15.50
3 pos selector, w/ 2-NO contact blocks & 2-NC contact blocks	Automation Direct	GCX-1320-22	1	$ 19.0	$ 19.00
black Mom. PB, w/ NO contact	Automation Direct	GCX-1100	1	$ 6.5	$ 6.50
Red Mom. PB, w' nc contact	Automation Direct	GCX-1101	1	$ 6.5	$ 6.50
start stop pb Box	Automation Direct	SA110-40-SL	1	$ 13.5	$ 13.50
Faceplates					$ -
FEM3T timing relay	Allen Bradley	FEM3T	1	$ 60.0	$ 60.00
				total cost	$ 719.47

Hampden® ENGINEERING CORPORATION

QUOTATION

TO: UNIVERSITY OF AKRON
AKRON, OH 44325-3905
ATTENTION: GREG HARSTINE

DATED: OCTOBER 6, 2015
NUMBER: 15-1325
EMAIL: GPH@UAKRON.EDU
FAX:
PHONE:

MAIN OFFICE AND FACTORY:
99 SHAKER ROAD
PO BOX 563
EAST LONGMEADOW, MA 01028-0563
TEL: 413-525-3981
800-253-2133
FAX: 413-525-4741
Email: sales@hampden.com

SUBJECT: QUOTATION REQUEST

Dear Greg,

We are pleased to quote you on the following:

1 – Hampden DYN-100A-DM – Dynamometer Bulletin: 255H	Unit Price:	$ 4,518.00
6 – Hampden IM-100 – Induction Motor Bulletin: 250-1H	Unit Price: Total Price:	$ 1,336.00 $ 8,016.00
6 – Hampden MGB-100-DG – 2 Machine Bedplate Bulletin: 256K	Unit Price: Total Price:	$ 365.00 $ 2,190.00
6 – Hampden PB-100A – Prony Brake Bulletin: 253J	Unit Price: Total Price:	$ 1,003.00 $ 6,018.00

Terms: Net 30 Days (Subject to Credit Approval)
Delivery: 90 Days ARO (After Receipt of Order)
FOB: Shipping Included to Akron, OH

Quote Valid: 90 Days

Respectfully,

Jon Dominik
Regional Sales Manager

JD:kal

Note: No state or local sales or use taxes included in above quotation

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