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Student Training for Motor Performance Assessment in Industry

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Student Training for Motor Performance Assessment in Industry.

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Introduction

The Industrial Assessment Centers is an organization of about 35 universities scattered throughout the country and funded by the Department of Energy Office of Energy Efficiency [1]. One of the Centers is the ST-IAC, located at the University of Texas Rio Grande Valley (UTRGV), where the authors work

An essential objective of the Centers is to conduct energy and water usage diagnostics, promoting energy efficiency. A team of faculty and students will complete these assessments with no charge to the local medium-sized industries. The ST-IAC team visits the manufacturing industry in question during one or two days. Once the data has been gathered and the recommendations outlined, the ST-IAC will write a report, which must be approved by the Field Managers of the Centers before being released to the customer [2].

A second primary objective of the Centers is to train the students (usually graduate and undergraduate engineering students) in the discipline of energy (and water) efficiency. Topics for electrical engineers are Energy efficiency in electric motors, energy-efficient lighting, and Energy management

The paper's objective is to report our efforts and results in training students to conduct motor performance assessments. We have based our training on a report published by DoE about 25 years ago [3]. Since the energy assessments conducted by our team must be completed in one day, the student-faculty team should evaluate in a fast way the performance of several motor systems. Therefore, previous training is indispensable for a successful energy diagnostic, and we will now describe the experience of the Electric Machines course imparted in the Fall semester of 2021. The Lab operation was video recorded for the students, who could not meet face to face because of the pandemic restrictions. At the end of the practice, students answered a questionnaire about the contribution of the experiment to their knowledge base, about the impact of the experiment on their interest in the subject, and the appropriateness of the tools and workspace under which they worked.

Motivation of the Lab

Induction motors are the most popular and economical electric motors, especially the squirrel cage type. According to DoE, electric motors consume more than 50 % of all electrical energy in the USA and more than 85 % of electrical energy used for industrial production [4]

We asked students to imagine themselves in an industrial environment where all things and people are running in a rush, time is precious, and they don't have all the information required for the best analysis, nor the best instruments, as in a laboratory setting [5]
Motors running at nominal load (load = 100 %) offer their best efficiency and hence consume the least energy. Underloaded (load < 100 %) motors run at lower efficiency and at lower power

factor, contributing to the increase of losses and operating costs. To quickly find those performing motors, students must know and trust their instruments

Lab Objectives

- To determine the load of a motor, This is the percentage of power being consumed, with respect to the rated power of the machine
- To use three methods for this task:
  1) Direct input power
  2) Line current measurement
  3) The slip method
- Compare the precision methods 2 and 3 with respect to method 1

Nominal Machine Ratings

Our low-power Lab is equipped with Hampden Engineering rotating machines and accessories. Typically we run a 1/3 HP squirrel cage three-phase motor, manually controlled by a prony brake. We have used hand held (Fluke), tabletop (Voltech) power meters, plus a digital tachometer. The nominal ratings of the squirrel cage motor are 1,725 rpm, 1.7 Amps. and 1/3 HP = 248.7 W (mechanical). For the wound-rotor motor these are 1,750 rpm, 1.7 Amps and 1/3 HP. All lab induction machines run at 60 Hz, have 4 poles, hence n_{synchr} = 1,800 rpm. The prony brake used to load the motor and to measure torque has a radius of 3" = 7.62 cm

The three diagnostic methods

Method 1- Direct input power measurements, with two wattmeter configuration
Connect the PM 300 as in the top of the following schematics. Notice that the instrument uses TWO amp-meters and TWO voltmeters. Hence, it is called the two-wattmeter connection. It is more economical than the other two methods, which use three pairs of meters. All power meters must also measure the current-voltage phase difference

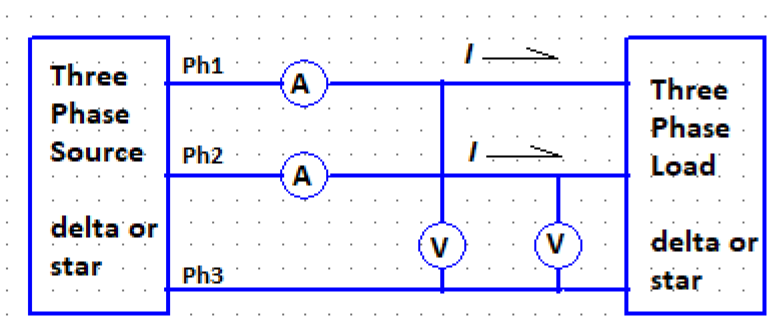

Figure 1- Voltech power meter PM-300 connection diagram of the three phase-three wire method

The two-wattmeter connection delivers active power P_1 and P_2. From these, we can calculate

$$P_{3-phase} = P_1 + P_2 \qquad\qquad Q_{3-phase} = \sqrt{3}(P_1 - P_2)$$

and hence $S_{3\text{-phase}}$ and power factor. P_{mech} is calculated by multiplying the torque and the angular speed data [6]

P_{ir} is the input reference electric power. It is obtained from the reference (nominal plate) data of the motor,

$$P_{ir} = {0.747\ HP}/{Efficiency} \qquad\qquad Percent\ Load\ (power) = 100\frac{P_{3-phase}}{P_{ir}})$$

Method 2- Line current measurements

I_r is the reference current. It is obtained from current data taken at the nominal speed (1725 rpm). I is the measured current in Figure 1. Therefore

$$Percent\ Load\ (current) = 100\frac{I}{I_r}$$

Method 3 The slip method

$Slip_r$ is the reference slip. It is machine's slip at reference speed (1725 rpm). Therefore

$$Percent\ Load\ (slip) = 100\frac{slip}{slip_r}$$

Procedure for data analysis

During the course, students are presented with a modified version of Table 1. The cells colored in gray are empty. Cells fall into three categories: measure (yellow), nominal or reference (pink), and calculate (gray). The assigned tasks to the student were to:

1) Populate the calculate cells inserting the formulas and reproduce the correct values (now shown)
2) Insert excellent quality graphs of current, electrical, and mechanical power.
3) Write conclusions of the Three method outcomes: for load >= 100 percent, and <= 70 percent. Split the data into high-speed and low-speed regimes. Indicate which regime is worse

Squirrel Cage		calculate		ELEE 4372 Electric Machines Fall 2021						
		measure	Volts	Nominal = Plate values						
R [cm]		nominal	avg	1725 rpm	1.7 Amps	1/3 HP =	248.7 W			
7.62			208.79							
rpm	% slip	Torque	P mech	Amps	P1	P2	P elect	Q		eff
1698	5.67	1.19	212.4	2.28	173	461	634	498	249	33.5
1700	5.56	0.97	172.8	2.31	172	460	631	500	249	27.4
1725	4.17	0.75	134.9	2.1	108	377	484	466	249	27.9
1725	4.17	0.75	134.9	2.09	104	386	490	489	249	27.5
1750	2.78	0.56	102.6	1.65	41	299	340	448	249	30.2
1775	1.39	0.26	48.6	1.54	-24	244	220	464	249	22.1
1790	0.56	0.01	1.4	1.31	-84	187	104	469	249	1.3

Table 1- Experiment's nominal and measured data released to the students. The calculated data is not released. It is their job to find and write it on the table

	Three Methods			Analysis of Variation		
	Power	Current	Slip	with respect to Power		
rpm	Percent Load			Power	Current	Slip
1698	131	109	136	0.0	22.2	5.0
1700	130	110	133	0.0	20.1	2.9
1725	100	100	100	0.0	0.2	0.0
1725	101	100	100	0.0	1.4	1.2
1750	70	79	67	0.0	8.5	3.6
1775	45	74	33	0.0	28.2	12.0
1790	21	63	13	0.0	41.1	8.1

Table 2- Analysis of Variance (with respect to Power)

From Table 2, the numbers of the last two columns show that the slip method measurements are closer to the power data. In conclusion, during an assessment, after the power data, we will trust the slip method more than the current method.

Assessment methodology

Because of the university's restriction to running face-to-face labs, these sessions were recorded on video. Each lab session was recorded and transmitted by video to the students. The authors do not have significant experience with this learning technology. At the end of the course, students completed a questionnaire in two parts: first, a survey, summarized in Table 1, based on the Likert scale from + 2 (strongly agree), +1 (agree), 0 (neither agree nor disagree), -1 (disagree), -2 (strongly disagree), designed to evaluate the impact on the students of the Lab experiments, specifically to their knowledge base, to their interest on the subject, and on appropriateness of the laboratory tools and settings. Secondly, students answered two open questions, summarized in Table 2.

		Likert	
	N = 6 students	mean	std dev
1	The purpose of two-Watt meter lab was clear?	1.00	0.00
2	The objectives were met?	1.17	0.20
3	The activity will benefit me?	1.17	0.20
4	The contents included in the activity were related to the objectives?	1.00	0.00
5	The activity increased my interest in Electric Machines	1.33	0.28
6	The activity increased my enthusiasm for the study of Engineering	1.50	0.35
7	The published videos did a good job to explain the operation of the electric machine	1.33	0.28
8	I can now explain to anybody the importance of running motors at nominal load	0.67	0.00

Table 3- Students' responses to end of course questionnaire

The response of the students to question 8 is not as assertive as the authors would like it to be, indicating that there is room for improvement.

Feedback from the open questions elicited the following responses:

Open question # 1: "What I disliked most about this activity was?
a) I would have liked to see examples of what not to do and explanations of what could go wrong
b) Not being able to actually do it
c) Not being able to do the lab with everyone
d) The instructions were at times unclear and hard to follow. They were not specific or there were no examples.
Open question # 2: "What I liked most about this activity was?
a) I liked being able to rewatch the video multiple times after reading through the Lab for a better understanding
b) Finding the equations from the given data
c) Using Excel to calculate our answers using formulas
d) See how the motors behave at different percent load
e) That a significant amount of time was given to complete the assessment

Table 4- Students' responses to open questions

Conclusions

UTRGV IAC students conducting energy assessments at manufacturing plants must be trained on standard instrumentation, with particular emphasis on their simplicity, reliability, and accuracy. They are not being trained to fill out pro-forma motor measurements. Instead, they are being trained to make the best decisions on the floor. The authors aim to write additional lab practices for the several engineering disciplines relevant to the IACs

In this paper we compared the results of method 2 (line current measurements) and method 3 (slip method) with those of method 1 (direct power input), and found that the slip method is more accurate. This is a useful result for motor performance assessments

Concerning the feedback from the students, the first thing to notice is the limited number of students responding to the questionnaire; 6 out of 12 students or 50 %.

The first four questions in Table 1 have positive responses to test the hypothesis that their knowledge increased.

Students agreed that the four questions (testing the impact of the activity on their knowledge base) were positive but not optimal. Questions 5 and 6 were designed to test their opinion concerning their interest in the topic, and the average showed agreement and strong agreement. Question # 7 encourages us about the service done by video presentations. Question # 8 shows that our methods need further improvement.

Concerning open question # 1 (what I disliked most), which is summarized in Table 2, the responses a) and d) indicate that the knowledge content of the experiments has voids and can be improved.

We have feedback about what we are doing well concerning open question # 2 (what I liked most). It is encouraging.

In conclusion, this was a successful lab because it will serve as a basis to train future IAC students for conducting energy assessments on industrial motors.

Using the slip method to assess the motor performance is a simpler, faster, easier to install method, while conserving the accuracy of measurement. We have found that for assessing the motor performance expensive and complicated equipment are not needed. This paper is about a practical and simple method to initiate the students to the electric motor behavior in real conditions.

Acknowledgement

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