Multifunction Hardware Experimentation Laboratories

Khaled ARFA                             Gilles Roy                         Georges-Émile APRIL
khaled.arfa@polymtl.ca                 gilles.roy@polymtl.ca              georges-emile.april@polymtl.ca
Département de génie électrique
École Polytechnique de Montréal

Abstract: The electric machines laboratory, now under development at École Polytechnique de Montréal for our electrical engineering department, is presented as an example to illustrate the pertinence of physical experimentation laboratories and therefore as the justification for the considerable investments they require.

Keywords: laboratory, electric machinery, test bench, experimentation, simulation.

1. INTRODUCTION

In recent years, higher education establishments, especially those involved with engineering have been leaning more and more towards the use of software based simulation as opposed to the use of actual machines of a size commensurable with those found in industrial applications. This is easily understood since simulation has the potential of being ultimately more powerful than the use of actual, meaning real, machines. In particular, simulation allows one to test conditions that would be out of the reach of classical laboratories, the latter being mostly limited to steady-state, mostly static conditions. The future modern engineer needs to be exposed to more complex situations; including dynamic and transitory conditions that can greatly impact real design situations. It seems, however, that the main reason for the popularity of simulation tools is the fact that they require little initial capitalization, at least in the short run, and very little infrastructure.

If a place is to be kept for laboratories using actual machines, these will have to be conceived in such a way that they will be safe to use, and allow experimenting at power levels commensurate with real world situations while being versatile enough to be used in many domains, which would allow their admittedly high cost to be spread amongst many domains and serve many fields of study. Furthermore, such laboratories should be very durable, and allow new technologies to be tested as they become available. These laboratories must also integrate sustainable development concepts in both their design and use.

2. PROTOTYPE OF THE TEST BENCH

The electrical engineering department of École Polytechnique de Montréal has recently undertaken the development of a new laboratory dedicated to the study of electromechanical systems. To this aim, we intend to install ten (10) work stations. Each work station will be equipped with a test bench made up of three industrial type electric machines, coupled to command, monitoring and measurement console. In order to verify the feasibility of the project, and to get a grip of the required budgetary envelope, it was decided to first construct a prototype of the test bench, bar far...
the most expensive single component of the workstation. This prototype has been assembled and can be seen in one of our laboratories. It is currently being used to validate the design choices that were made.

A number of considerations had to be addressed at the various stages of the prototype design:

2.1. **Safety**:  
The test bench must meet all current norms relative to operational safety for students using it as well as for personnel installing and maintaining it;

2.2. **Realism**, (for lack of a better word) :  
The test bench should use machines of a size and power commensurate with typical installation students are likely to encounter. Fractional horsepower machines produce unrealistic results. On the other hand, full size machines, in the megawatt range are, by necessity, eliminated due mostly on their cost, but also on their space and power requirements;

2.3. **Long life expectancy**:  
Long lasting equipment will compensate the high cost of the installation as compared with the cost of simulation. It should be borne in mind that high end simulation software is far from cheap and must constantly be updated;

2.4. **Multifunctionnality**:  
In a further attempt to make the cost more palatable, the equipment should allow itself to be used in a multitude of environments, meaning it should be relevant to more than one subject matter;

2.5. **Attention to current concerns**:  
The test bench must respect current concerns about the environment both from the point of view of its operation and its life cycle.

2.6. **Attractiveness**:  
The test bench should incorporate the most recent communication technologies modern students have come to expect matter of factly for their attractiveness and efficiency.

3. **LABORATORY SET-UP**

3.1. **Simulation vs. experimentation**:  
Computer hardware performance is constantly increasing, as is the degree of sophistication of simulation software and the power of computer assisted design tools. This has already brought about profound changes in engineering education.

For example, it is now possible to study the operation of electromechanical machinery, say an induction motor drive, in a entirely virtual environment and to get results surprisingly close to the performance of real machinery. This has real and important consequences, inasmuch as it allows one to test hypothetical situations that would be dangerous or destructive were they to be tested on real machinery.

However no amount of software realism and sophistication can develop in the future engineer the sensibility to physical phenomena that can only come from exposure to same, be it noise, air displacement, vibration etc. Sensitivity to such things is a must for any conception process.

For an institution that aims to a rightful pride in the superior value of the formation it offers, experimentation and simulation must go hand in hand.

3.2. **The electromechanical platform**

Many performance criteria must be applied to the electromechanical platform, some academic, some ergonomic others administrative.

Some should be mentionned:

- It should provide an attractive and friendly environment for current and future prospective users, and more importantly, a safe environment for students, personnel and faculty, as well the occasional visitor;
It should cover, as much as feasible, the needs for laboratory experimentation of all courses offered in electrical energy;

It should minimize the amount of intervention required from personnel to ready the laboratory for a set of experiments after a different set has been performed;

It should ensure that all rules of safety and security are met, as well of all recommendations or ergonomic science for such installations;

It should be made “future proof” by allowing itself to be augmented by the eventual addition of whatever information and communication technologies may become relevant in future.

Photograph of the test bench and picture are on the last page (Fig. 1 and 2).

4. MACHINES AND DRIVES

In order to give this set-up a high level of pertinence by insuring that the students be exposed to a variety of machine types, the test bench (Fig. 1 and 2) is made up of the following:

- 1 squirrel cage induction machine rated 2.2 kW at 1175 rpm. For old timers like me, that is about 3HP;
- 1 permanent magnet synchronous machine rated 3.7 kW à 1800 rpm. This machine will be operated at 1200 rpm for compatibility with the other machines. Under those conditions, it should develop about 2.5 kW, or 3.1 HP, should you prefer the old system;
- 1 direct current separately excited machine rated 3.7 kW at 1730 rpm. This will also be operated at 1200 rpm, allowing it to develop slightly over 2.5 kW;

The presence of the squirrel cage machine needs no justification, since this is, by far, the most commonly used machine in industry.

On the other hand, the synchronous machine represents the absolute state of the art in electromechanical energy conversion, using or producing energy with a level of efficiency superior to what can be achieved with induction machines. Both AC machines are coupled to adapted speed controllers.

The direct current machine is to be used mainly as a controllable mechanical load for the AC machines, making it easier to characterize and test the latter. The DC machine is operated via a regenerative speed controller, making it a lot “greener” than any other kind of brake that could be used in its stead, since a large amount of the energy used is returned to the network.

5. OTHER COMPONENTS

- 1 Torque meter (with speed pickup);
- 2 electromagnetic clutches;
- 1 forced ventilation system;
- 1 independent centrifugal overspeed limiter.

The torque meter provides the signals necessary to measure and record the instantaneous torque on the shaft and the rotational speed, in both steady-state and dynamic conditions.

The clutches allow the operator to arbitrarily couple or decouple the machines under any condition, full speed, stopped, with or without load, allowing abrupt load variations.

The forced flow ventilation system allows the machines to be operated at full current even when running at very low speeds, without over heating. The amount of air flow is regulated by high performance variable speed fans, in response to temperature sensors located at various points on the bench, i.e. on the three motor frames, and on the bearings. These fans
are capable of delivering 600 cfm while producing only 60 dBa of acoustic noise.

For safety, an autonomous speed limiter (centrifugal switch) is connected directly to the emergency stop button, lest the DC machine field should somehow fail.

Eleven test benches will be installed in a room measuring 130 square meters (1400 square feet) which makes 6 square meters (64 square feet) for each work station. Two students will be at each work station. With ten stations in operation, we hope to keep the noise level below 66 dBa, which is no mean feat for a laboratory equipped with industrial type machines.

In order to meet that challenge, three levels of noise abatement and vibration avoidance are used:

- the massive table is placed on a multi-ply neoprene cushion ("Unisorb Titan Pad");
- this is supported by a base made of laminated wood beams ("iLevel Parallam PSL");
- the whole thing is supported by anti-vibration “feet” incorporating a synthetic rubber membrane ("Unisorb Vibralastic Mounts").

6. LABORATORY EXPERIMENTS

This work station will be able to serve the needs for experiments for a number of classes in various programs.

6.1. Electric machinery courses:

This will allow the measurement of the parameters of the three types of machines in order to create accurate models for simulation;

It will be possible to test all three machines as motors or generators;

6.2. Automation and mechatronics:

It will be possible to speed/torque/power control all three machines.

6.3. For various other courses:

Machine efficiency, power factor control, power regulation.

Improving efficiency and reliability of electromechanical processes;

Studying, and where possible improving the quality of the power supply especially in the presence of non-linear loads.
Fig. 1

Fig. 2