The Rebuilding of The Electrical Power Lab and Electrical Power Program At The University of Memphis

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Room 202, Engineering Technology Building

The Electrical Power Lab at The University of Memphis is in room 202 of The Engineering Technology Building. The building was dedicated in 1971 and the lab was equipped with static and rotating equipment at about the same time. The basic equipment is listed on an inventory at the end of this paper. The only addition to the original equipment were 4 variable frequency drives which were added in 1996. One of my first assignments, when I arrived at The University of Memphis in 2002, was to teach the electrical power class in The Engineering Technology department. The assignment was pretty simple; teach the junior and senior students about electrical power, use my imagination, and have fun. The lab itself is used by Electrical Engineering for energy conversion classes and by Engineering Technology for its electrical power and machines class. Since the two departments shared the lab, neither had taken the initiative to keep it organized, or to modernize it. In the summer of 2003 I was encouraged to, and given some support in an initiative to bring the lab into the 21st century, and in the process make it more user friendly. One of the instructions that was given was; 'Don't do anything that would require moving walls or cutting concrete'. The next instructions were; ', Do not throw away anything that could be conceivably be used for anything and to spend little or no money'. This turned out to be a real challenge.

The first problem was getting permission to move the existing equipment into a more logical arrangement. In a room where very little had been changed for 30 years, and in an institutional setting, this required more than a little diplomacy. To accomplish that, each piece of existing equipment was measured and inventoried. The first thing that was noticed is that it would be possible to have 4 complete setups, each suitable for a maximum of 4 students at a time. Each lab set up would consist one of each of the following:

1. Hampton Model # H-REM_120C-MP Universal Lab Machine
2. Hampton Model # HTT3-M Transformer Bench
3. Hampton 2 kva inductor panel
4. Hampton 2 kva capacitor panel
5. Hampton 2 kva resistor panel
6. Hampton Model # H-VFD 300A variable speed drive
7. Hampton Series 100 fractional horsepower test bench each equipped with a variety of motors, generators, loads, and brakes

There was also existing a collection of meters and other equipment that needed organized and inventoried. A copy of the complete inventory is attached. The only major pieces of equipment that were missing, that would be needed to make a complete lab, were 1 inductor bank, 3 resistor banks, and 3 small induction motors. The university purchased this equipment for a total investment of approximately $13,000. There was an additional expense of less than $500 for miscellaneous small parts.

The equipment was moved to new locations. It was now easily accessible. Some of the equipment wheels broke because the larger pieces of equipment hadn't been moved in years. The replacement wheels were a small expense. With the major pieces of equipment moved, there were four workstations. The arrangement turned out to be very convenient as many experiments simultaneously used parts on 2 or 3 of the 3 major pieces of equipment As an example, the meters on the Universal Lab Machine and Series 100 Test Bench could be used on the transformer experiments. Also, if a meter on a particular bench was inoperable, the meters on the other benches could be used. With 30 year old equipment, this has turned out to be valuable at times.

After the basic equipment was in place, hundreds of jumper wires had to be organized. Enough unused wall space was found to install wire hangers on both sides of the room. These wire hangers were another small expense. The only source that was found was Pomona. The model numbers used for this project were # 1508 for holding wires up to .201 inches in diameter and # 4408 for holding wires up to .320 inches in diameter. The wires were categorized according to length and function. Where before, the students were always searching for the right type and length of wires, the wires were now easy to find. As an added benefit, the wires were always returned to where they belonged, and the students developed a sense of responsibility for taking care of the lab. As a matter of fact, the morale and attitude of the students improved. The students did not have any more equipment available than before the re-organization, but now it could be easily found.

Another thing that happened was that four, five foot by six foot work tables were arranged into one big table ten foot by twelve foot. This made for a not too efficient arrangement of the tables, and they were therefore not utilized very well. As a matter of fact, no one ever used them for anything, except for storing stuff that wasn't being used anyway. These tables were connected to the electrical distribution system with flexible conduit connected to conduit embedded in the concrete floors. Since the places where the conduit exited the concrete floor were fixed, and the length of the flexible conduit was fixed and short, there was very little ability to move these tables anywhere. Therefore, the flexible conduit connecting the tables to the floor first had to be made longer. Since this flexible conduit didn't stretch very easily, another way was found to make it longer. Four of a type of electrical fitting called a 'C' were purchased. This is a straight fitting that has female threaded ends and an opening in the middle where wires can be connected. The opening can be covered after the wire connections are made, to meet National Electrical Code requirements. With these pieces, some flexible conduit, some electrical connectors and a few feet of wire the connecting cable that ran from the floor to the bottom of the tables was lengthened. This enabled the tables to be moved into a position where they were much more usable. The university purchased these fittings and flexible conduit and a local electrical supply store supplied the wire. As an unintended benefit, the stool type chairs that were stored in the room were now able to be placed around these tables so that the students would have usable work space.

When a project like this is undertaken, with a minimum amount of money available, luck always plays a role. The next step was a matter of pure luck. For some reason the university was moving student desks around and there were 16 fairly good, serviceable student desks, all of the same type and color, left sitting in the hallway. After determining that they were available, they were quickly moved them into lab. There was now a functional classroom in front of the lab. Since the lab was being set up so that 16 students could use it at a time, it was quite fortunate that exactly 16 desks appeared. It never ceases to amaze me how well things work out, if a project is started with the right end in mind. The total cost of upgrading the student desks in the lab was zero. The only thing that was required was the energy of taking out the old desks and putting in the new ones.

One of the goals in this project was to bring the Power Lab into the 21st century. There's very little that can be done to bring motors and transformers into the 21st century. A transformer is a transformer and an induction motor is an induction motor. However, there is something that can be done to bring modern technology into the measurement and use of electrical power. New equipment is available to make single phase and three phase electrical power measurements easier. In the past when electrical power was measured, each wattmeter had four terminals. If single phase power was being measured, installing a wattmeter meant adding four new wires and making sure that the current coil of the wattmeter was not in parallel with the voltage source. If this were done the best thing that could happen was that a circuit breaker would trip or a fuse would blow. If you weren't so lucky the meter would blow up. Now compound this with three phase power measurements where two or three watt meters are needed to measure power, each with four connections. A real mess soon occurs. Mastering the complex of wires soon becomes the lesson, instead if learning how to measure electrical power and what the measurements mean. And since this is AC, it might be desired to know about reactive power as well as the real power that is measured by watt meters. One of the old techniques for measuring reactive power was to shift the phase of the voltage that the wattmeter was measuring by 90 degrees. Then the reactive power would be equal to the current times the 90 degree shifted voltage. Also, if the phase shift was 180 degrees out of phase, the wattmeter could read negative. Another bit of confusion occurs if the 2 watt meter method of measurement is being used to measure power in a three phase circuit. Sometimes, in normal operation, one of the 2 watt meters will read negative. So, to get reliable and accurate power and reactive power measurements in a three phase circuit, four watt meters and two 90 degree phase shifters are needed. Then, the meters and phase shifters all have to be connected correctly and then the data has to be interrupted properly. Fortunately, with modern technology, there is a way around this dilemma.

In the 1970's a new meter was developed called a power analyzer. In 1976 The Dranetz Corporation started marketing a meter called the 606 power analyzer. It was followed 2 years later by an updated version, called the 808 Electric Power/Demand Analyzer. This particular meter is still used in the industrial world. An engineering concern in PA donated a used Dranetz 808 to the Engineering Technology department. When the university needed to make some electrical measurements recently, the physical plant engineer borrowed the Dranetz 808, instead of some more modern equipment that the Engineering Technology department has. The 808 was a first generation power analyzer and was able to do the following measurements:

A. Voltages
B. Currents
C. Watts
D. Volt-Amperes
E. Volt-Amperes Reactive
F. Power Factor
G. Watt-Hours (energy monitoring)
H. Demand

The data would be in the form of a printout that consisted of a list of data printed at certain time intervals. The paper tape printout can be thought of as the memory of the Dranetz 808. Having used these meters in the 1980's, I can say that they were a real advance in power measuring techniques. However, they were difficult to use in a laboratory setting. One disadvantage that we encountered was that the standard current probes were 500 amp probes. Because of the setup of The University of Memphis Power Lab, currents of more than 20 amps are seldom, if ever, encountered. This is probably true of most university electrical power labs in the country. And when more than 20 amps flows, it's usually a student testing the circuit breakers and fuses. Fortunately, the circuit breakers and fuses usually work. Using the 500 amp current probes caused measurement errors, since the measurements that were being taken were at the low end of the scale. A real advantage is that the current probes can measure current by being connected around existing wires. After a circuit is built no connections are broken to take current, voltage, and power measurements. Another disadvantage that was encountered was that the 808 was really designed for industrial applications, with readings taken over a period of time. Also, if graphs of a variable versus time were needed, the paper tape output would have to be understood and analyzed and the data organized. Then, the graphs could be plotted by hand or by using a graphing program, such as Excel. Although the Dranetz 808 that belongs to The Engineering Technology department is functional, it is seldom used anymore. The reason is that a more modern power analyzers were developed and the university acquired several of them.

One of the newer power analyzers is a Dranetz 4300. It consists of a power platform, a program card and a memory card. The power platform can have up to 4 current inputs and 4 voltage inputs. The university acquired one of these as part of my start up money. The total cost of a Dranetz-BMI 4300, set up for a student lab is about $8,000. The Dranetz-BMI 4300 power platform is a much more flexible instrument than the 808, with some real advantages for laboratory applications. The first thing is the ease of connection. As with the 808, no leads have to be broken to insert current meters. All current measurements are taken with clamp on current probes. For a three phase circuit this involves two, three, or four probes. It is almost impossible to connect the probes in such a fashion that the current probe will be destroyed. Then there are two, three, or four voltage leads and a ground wire to connect. Since voltage probes are always connected in parallel, they can be connected into the circuit without removing any wires or breaking any previously built circuits. Since they are high impedance devices, even connecting them wrong will usually not destroy the equipment. With all its ease of use, it will do most, if not all, of the things that the older 808 will do, plus a lot more. There are a number of current probes available including 10 and 30 amp ratings. This makes it very adaptable to our lab and, I believe, most university power labs. There are also available some DC current probes for DC measurements. For laboratory measurements, it is possible to scroll through a series of measurements that appear on one of the data screens. This enables the student to see at a glance what all the voltage, current, power and other measurements are at any particular instant. If it is desired to record data, it can be recorded by hand, or the 4300 has a memory card, with up to 256 mega-bytes that can be used to interface with a computer. This also enables it to be used as a monitoring device over a period of time. This is the same thing that the old 808 did with the paper tape. Then, using the available software, any of the recorded functions can be printed or graphed. This is a real advantage over the 808. Most lab applications don't need this ability. However, this is a very good meter for use on senior projects. It has already been used this way with very satisfactory results. Dranetz-BMI Corporation has donated a second 4300 meter to The University of Memphis as part of their educational assistance program.

Another advance that the industry has done is to make a meter that is directly interfaced to a lap top computer. Fluke Corporation donated one of these to the university, a Reliable Model 1650 Power Meter. This meter is used for senior projects and is available to the university physical plant. This does everything that the Dranetz 4300 will do with the ability to connect directly to a computer in the field, either a laptop or desk mounted machine. With a laptop computer in the field, power measurements and trends can be looked at right in the field. The software of both machines enables the operators to make graphs of all the measured variables versus time. Both of these newer generation meters have extra capabilities. One of these capabilities is the ability to capture events. This is not very useful in the classroom, but might be useful on senior projects. It is definitely a useful function for real life problems encountered in the field. Another thing that the newer generation meters do is to measure harmonics. This is beyond what Engineering Technology students do at the present time, but it is very useful as a demonstration to show the students what happens to power sources when AC or DC drives are in operation. With all of the harmonic generating, solid state power equipment in operation today, being able to measure harmonics in the power supplies is becoming more and more important.

Now, to bring the Power Lab further into the 21st century, 4 state of the art computers were obtained. These came from the college of engineering stock. So now there were four Dell computers that were installed on the four tables in the back of the lab. These were set up with some standard software and some specialty software and made available to the students. Two of the software packages that were installed were the Dranetz 4300 software and the Fluke Reliable 1650 software. The addition of the computers completely changed the character of the power lab. There were now workstations where students could work together, and learn to co-operate in a comfortable environment. Not only was everyone happier, the room took on a new aliveness.

Moving further into the 21st century, Rockwell Automation donated four model 22A-B8P0N104 AC drives and four series 1200 programmable logic controllers (PLC's) with analog input output modules. These were mounted in some old meter panels that were obsoleted. This made nice functional packages that were placed near the computers on the newly liberated tables. With this setup, labs could be devised where the PLC could take an analog input signal, convert it to an analog output signal, and speed control the drive which could be running an induction motor. The Hampden Engineering Company equipment also had DC tachometers that could be used as feedback to either the PLC's or the new inverters. This is a perfect example of how different pieces of equipment could be interfaced. With equipment like this the students are able to see how engineers in the industrial world make things work. This has been very useful in The Engineering Technology Department because one of chief functions of technology programs is to get students ready to work in the industrial world.

All in all this has been a remarkable experience. The Engineering Technology Department at The University of Memphis has grown into a more viable department. A new class is being offered in Advanced Electrical Power topics. Attention is being given to the importance of teaching electrical power ideas to the present generation of engineering students.

This project was started at a time when electrical power programs are in a serious decline all across the United States. As a matter of fact there are only approximately 20 large power programs operating in colleges and universities in North America[1]. At the present time there are only about 500 graduating electrical engineers with a power concentration per year[1]. About 50 % of the students taking power classes are international students[2]. The whole problem of declining enrollment in electrical power studies is exasperated by a decline in the number of electrical power educators, whose average age is increasing[3]. Since many electrical power professionals and educators are approaching retirement age, there is an impending crisis in the supply of engineers and educators who understand electrical power and the electrical power industry[4].

The question that needs to be asked is 'What Can We Do?'. The first and most obvious thing is to let the world know what has happened in the last 50 years. The problem has just quietly appeared because of several factors. When the deregulation of the power industry happened, many electrical power engineers were let go to pursue other careers. In the 1980's there was also a lessening of the rate of increase of demand for electrical power[5]. Furthermore, the average pay of power professionals was considerably lower than other engineers. As an example, in the year 2000, Solid State Circuits engineers had a median salary of $93,500, while Energy and Power engineers had a median salary of $73,625[5]. The computer revolution also had an effect as power engineering came to be looked on as an undesirable career to pursue. And then there was the general decline in the number of engineering students from a peak of 460,000 in 1983[1]. In recent years, about 65,000 new engineers graduate in the United States per year.

In light of the above, it is obvious that there will soon be a shortage of qualified power engineers to help run our increasingly power dependent society. Even though the median pay that power engineers receive is less than solid state electronics engineers receive, the law of supply and demand will inevitably take effect and raise power engineer's salaries. This is true, not only because of the demands of the power generation and distribution industry, but also because of the need for engineers who understand electrical power at the user end. All large electrical power users, and many medium and small power users, need someone on staff who understands power. As long as we, as a society, demand inexpensive, reliable electrical power, there will be a need for engineers to keep the system running.

REFERENCES

[1] Heydt, Gerald T. and Vittal, Vijay, "Feeding Our Profession" IEEE Power and Energy Magazine, January/February 2005

[2] Wagner, Charles L. "The Changing Electric Power Equipment Industry and the Future of the Power Engineering Society" IEEE Power Engineering Review, January 1990

[3] Joos, Geza, "Training Future Power Engineers" IEEE Power and Energy Magazine, January/February 2005

[4] Sauer, Peter W. Crow, Mariesa and Venkata, Mani, "Manpower Development, Industry and Educators Need to Work Together" IEEE Power and Energy Magazine, January/February 2005

[5] Chowdhury, Badrul H. "Power Education at the Crossroads" IEEE Spectrum, October 2000.

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Inventory for Room 202, Engineering Technology Building, Electrical Power Lab

#	Description
4	Universal Laboratory Machines, Hampden Model # H-REM-120C-MP
4	Three Phase 9 kva Transformers, Hampden Model # HTT3-M
2	Hampden LC Panels 2 kva
2	Hampden C Panels 2 kva
2	Hampden L Panel 2 kva
4	Hampden R Panel 2 kva
4	Three Phase Variable Frequency AC Motor Controllers. Hampden Model # H-VFD 300A
4	Fractional HP Motor/Generator Test Benches, Hampden 100 series. Each bench includes the following: 1 – Mounting Panel 1 – 1/3 HP DC Machine 1 – 1/8 KW DC Generator 1 -- AC 3 Phase Induction Motor 1 – AC 3 Phase Synchronous Alternator 1 – AC 1 Phase Synchronous Alternator 1 – Pony Brake 1 – RLC Load 1 – R Load 1 – Zero-Max Model # B2420 Tachometer 3 – 20 ohm, 5 amp slide wire rheostats 3 – 5 ohm, 10 amp slide wire rheostats 1 – 3 ohm, 100 watt resistor
1	Hampden Appliance Tester, Model # H-APP-1
1	Hampden 2 HP Synchronous Rotary Converter
1	Hampden Power Panel Model # HMB-100_PP with the following equipment: 3 – Mounting Panels 1 – 1/3 HP DC Motor 1 – 1/8 KW DC Generator 1 – Single Phase Split Phase Motor 1 – Single Phase Capacitor Start Motor 1 – Three Phase Synchronous Machine 1 – Pony Brake 1 – Dynamometer 1 – RLC Load 1 – R Load
1	Dranetz Model 4300 Power Analyzer with 500 Amp Current Probes and Software
1	Dranetz Model 4300 Power Analyzer with 30 Amp Current Probes and Software

1 Fluke Reliable Model 1650 Power Analyzer with 100 Amp Current Probes and Software
4 Allen Bradley – Rockwell Model # 22A-B8P0N104 AC Motor Controllers
4 Allen Bradley – Rockwell Model # 1762-L24AWA Programmable Logic Controllers with Analog I/O Card
4 Tektronix Type 564B Storage Oscilloscope
1 Hampden Model 3 HMR-AR12520, DC Power Supply, 0-125 VDC, 20 Amp.
4 Dell Dimension XSP Pro 200N Computers
6 Simpson Model 260 VOM's
8 Simpson Model 880 Watt Meters 1000 Watt
14 Simpson Model 880 Watt Meters 2000 Watts
2 Lutron Model DW-6060 Watt Meters 6000Watts
4 General Radio Type 1531 Strobotac's
4 EICO Model 1171 Resistance Decade Boxes, 0 to 99999 ohms
7 CDE Capacitor Decade Boxes, Model # CDB, .01 to 1.1 uf
22 DC Ammeters (obsolete)
12 Simpson Model 375 DC Ammeters (obsolete)
1 Weston AC Voltmeter (obsolete)
1 Weston AC Wattmeter (obsolete)
1 Bell and Howell Model # 3870-A Still Picture Projector
4 Variacs 120 VAC, 1.4 kva
1 Variac 120 VAC, 2.8 kva

There are also some obsolete analog voltage and current meters and various resistors that are available for use.

There are also some obsolete FET Electronic VOM's that are available for use.

There are also some obsolete AC Clamp-on current meters that are available for use