121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014

Paper ID #9801

An energy assessment of a large grain storage and transfer facility in Michigan: An industry, university and public utility company collaborative effort resulting in energy savings outcomes

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ABSTRACT: In the spring of 2012 Lawrence Technological University was approached by DTE Energy (the local utility company) with funding to have students and faculty work on an applied research project with the Michigan Agricultural Commodities, Inc. (MAC) to undertake an energy assessment of the MAC Marlette, MI facilities. The MAC is a private company in the business of buying, selling, storage and distribution of agricultural commodities such as corn, wheat and other grains, dry beans and edible soya beans. Rising utility costs and fixed commodities prices necessitated the need for a concerted effort by the MAC to reduce their energy costs. DTE Energy was also interested in balancing the electric power utility distribution load in the predominantly rural area the MAC facility is located. For this project students served as part-time paid employees of the university working directly under the supervision of university faculty.

There were two major phases for this project. Phase 1 concentrated on establishing a reliable and useful power and energy usage data acquisition capability, and testing grain hopper aeration and drying fan systems both with and without the use of variable frequency drive power regulators. Phase 2 involved a full energy assessment of the MAC, Marlette facility including grain receiving, grain drying (which uses electric and natural gas), outdoor temporary grain storage piles, outdoor safety and security lighting, and office areas.

This paper reviews how Lawrence Technological University engineering faculty brought students into the project, and then how the student and faculty team directed, managed, and carried out all of the major tasks associated with the two major phases of this project. The nature of this project made it an excellent educational opportunity for students by providing them a real customer, real needs, specific timelines, and required deliverables. Also reviewed are how students had multiple opportunities to set up experiments, collect and interpret testing data, and then report the final results of those energy usage data, management and savings. Because of the various parties involved, there were several opportunities for students to interact with other business personnel, and technical specialists. Lastly, a summary is provided for how future similar projects might be created, structured and managed to assure successful projects with a broader use and application of the knowledge they generate.

1) Introduction and background:

According to the latest available statistics the food and agriculture industry in Michigan contributed $91.4 billion to the state's economy in 2010. Michigan's Food and Agriculture system is a large portion of the state's workforce, totaling (including direct, indirect, and induced) 923,000. The total employment impact accounts for about 22 percent of the state's employment. The farm sector employs nearly 73,000 and production and processing employs nearly 14,000.[1] State of Michigan GDP for the same year was estimated to be $384.2 billion.[2] Therefore, agribusiness contributed to 23.8% of the economy in Michigan in the year 2010. Agribusiness is big business in the State of Michigan.

There are several sectors to the agricultural economy. These include dairy, cattle, growers and producers, farm equipment services and sales, seed and post-harvest processing, and the many produce and commodity receiving, storage and distributors serving the industry. All of these sectors need and use energy when participating in agribusiness activities in Michigan. Primary energy usage includes electricity, natural gas, gasoline, and diesel for the field preparation, production, processing and handling of agricultural products. These is also a secondary energy usage component which includes fertilizers, which accounted for slightly more than half of the indirect energy use on U.S. farms in 2011, pesticides, which accounted for slightly less than half of indirect energy used on U.S. farms in 2010, and herbicides.[3]

This paper focuses on an applied research project carried out by Lawrence Technological University related to a major agribusiness in Michigan, specifically a facility involved in the receiving, storage and distribution of commodity grains. This paper discussed the process involved in establishing the project, the scope and breath of the project, the efforts to carry out the project, and the educational benefits for engineering students involved in the project. This paper does not review the data collected in this project, nor does it do into detailed recommendations provided by Lawrence Tech to the agribusiness involved.

In the fall of 2011, prior to involvement of Lawrence Technological University in the project, representatives from the Michigan Agricultural Commodities, Inc. met with representatives of DTE Energy (the primary utility company serving southeast Michigan) to request a review of the rate policies and equipment grants related to the use of energy reducing activities and the installation of energy and power management systems (such as variable frequency drives) in the agricultural industry. One of the representatives from DTE Energy to participate in that meeting was Gerald Polk, who at the time was involved in the Energy Optimization Pilot Programs group. Gerald Polk initiated this project effort within DTE Energy to investigate the situation and provide energy usage data to facilitate the possible implementation of new incentives for the agricultural community in Michigan.

Michigan Agricultural Commodities (or MAC) is a privately held, for-profit corporation that purchases, sells and stores agricultural commodity grains (primarily corn, soybeans, and wheat) throughout the United States and Canada. MAC is Michigan's largest grain handler with 8 locations in Michigan at Blissfield, Breckenridge, Brown City, Jasper, Lansing, Marlette, Middleton, and Newaygo. Michigan Agricultural Commodities does not produce flour or undertake any other grain milling or grain processing.

In early March 2012, Gerald Polk, of DTE Energy, contacted the Mechanical Engineering Department at Lawrence Technological University about possibly supporting this project. Shortly thereafter, meetings where held with Lawrence Tech, DTE Energy and Fanklin Energy Services representatives initiate the project.

After trips to the MAC facilities in Brown City and Marlette, Michigan, it was agreed that Lawrence Tech would indeed be interested in participating and supporting this project. By June 2012 the first scope of work was developed and the funding from DTE Energy was approved to begin work on this project. The focus of the operation was to be the Marlette, MI facility, which is located approximately 75 miles directly north of the Lawrence Tech campus. Formal work by Lawrence Tech began in the mid-summer of 2012 and concluded in December of 2013.

Scope and objectives of project

There were three phases to this project. Phase 1 was initiated in June of 2012. Once the work in that phase was successfully underway, Phase 2 was initiated in September 2012. The reporting final documentation of the project was defined as Phase 3 and took place in the late fall of 2013.

The objectives of Phase 1 consisted of the following two initial areas of interest, with the bulk of the work primarily undertaken at the Lawrence Tech facilities. These two primary areas were:
1. To select appropriate metering and data logging equipment capable of complete electrical power monitoring of motors that represents systems used at the MAC and similar facilities.
2. The use of VFD's on fans used on temporary outdoor grain storage piles to provide aeration and also negative pressure to hold down the tarps. The thought here was to understand how this could reduce the fan negative pressure in times of low wind conditions and increase them as the speed of the wind increases.

The objectives of Phase 2 consisted of the following along with the corresponding analysis:
1. Conduct an on-site comprehensive energy assessment at the MAC facilities in Marlette, MI, to investigate the benefits of possible installation of motor drive controllers, generically referred to as Variable Frequency Drives (VFD) on electric motors used for grain movement to and from silos and grain temporary storage piles, as well as large aeration fans.
2. Analyze electrical usage as a component of total facility energy usage with the goal of providing a market assessment of the potential for energy savings at grain storage facilities in the State of Michigan.

The objectives of Phase 3 involved documenting and final reporting the efforts of Phase 1 and Phase 2 with the intent to broadly disseminate the results of this work.

This paper briefly reviews the efforts undertaken by the faculty and students from Lawrence Tech in carrying out and completing this project. This paper does not review specific data collected nor the detailed recommendations to the MAC facility gleaned from the data.

2. The Michigan Agricultural Commodities facilities in Marlette, MI:

The Michigan Agricultural Commodities facilities in Marlette, MI are located to the immediate south of the central town area of Marlette, Michigan. The original facility dates to 1865 with some of the original structures on the premises still used for unique and small quantity grain storage. The primary-use storage facilities are much newer and are located towards the rear of the property. The MAC facilities has a rail spur that allows transfer of stored grain directly into rail cars that can then be transported by rail train for distribution around the United States, or even abroad.

The MAC Marlette facility has sixteen permanent storage bins in their primary-use storage area for a total storage capacity of 3.754 million bushels of grain (4.693 million ft^3). The facility can also accommodate an added 1.055 million bushels (1.319 million ft^3) of temporary pile storage, as needed. See Figure 1 below showing an aerial view of the facility looking east. Grain is primarily received from local farmers at the Marlette facility in trailers pulled by trucks or tractors. There are two receiving stations. The first is the front receiving station that allows grain dumps to the "front receiving pit" that transfers grain to the front receiving leg for routing to any of the permanent grain storage bins on the site. The second is the back receiving station (located towards the rear of the facility) where grain can also be dumped into its own receiving pit that also allows grain to be distributed to all storage bins on site. Note that these receiving stations do not distribute grain to the original 1865 facilities.

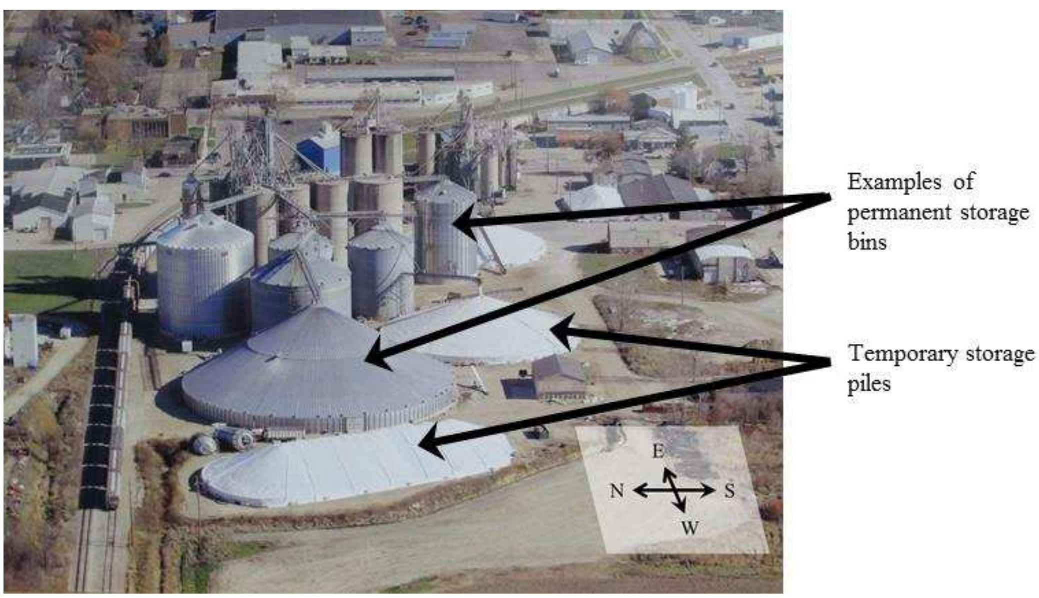


Figure 1: An aerial view looking east of the Michigan Agricultural Commodities facilities in Marlette, MI prior to addition of bins 28, 29, 30. Permanent storage bins and temporary storage files are indicated. The rail spur with train cars on it is located on the north side of the facilities (left side of the photo).

Figure 2 below, taken from Google Earth, shows a second aerial view of the Marlette facility. The various storage bins are indicated by number or name. The "Chief", as labeled in the photo, is a cone-shaped grain storage bin with a capacity of 950,000 bushels. The “Temporary Pile” in the lower center of the figure is used for the transient temporary storage of grain for a few weeks or longer, until it can either be sold or transferred into a permanent on-site grain bin. In the summer of 2013 the MAC erected two new permanent grain storage bins and are indicated as #29 and #30 in Figure 2 below with capacities of 225,000 and 310,000 bushels respectively.

Grain delivery by local famers is typically by truck or tractor towing trailers with their hoppers filled with grain. Before the grain is actually received for storage the delivery vehicle and trailer is weighed. At weighing a sample of grain is evaluated for moisture content, grain size, quality, and the level of foreign materials present in the grain load. If the grain is dry (at or below 16% moisture by weight) the grain can then be received directly.

To receive the grain the truck or tractor pulls the trailer to the receiving pit where the grain is dumped directly from the trailer into the receiving pit. The grain in the receiving pit is transferred from the receiving pit by the receiving pit drag to the receiving leg. The receiving leg lifts the grain to a high central shoot (a few hundred feet about the ground). The shoot can then direct and route the grain via a directional nozzle to specific gravity pipes that empty out to one, or more in-series overhead drags located down-stream from the gravity pipe, this allows transport of the grain to the desired storage bin or temporary storage pile.

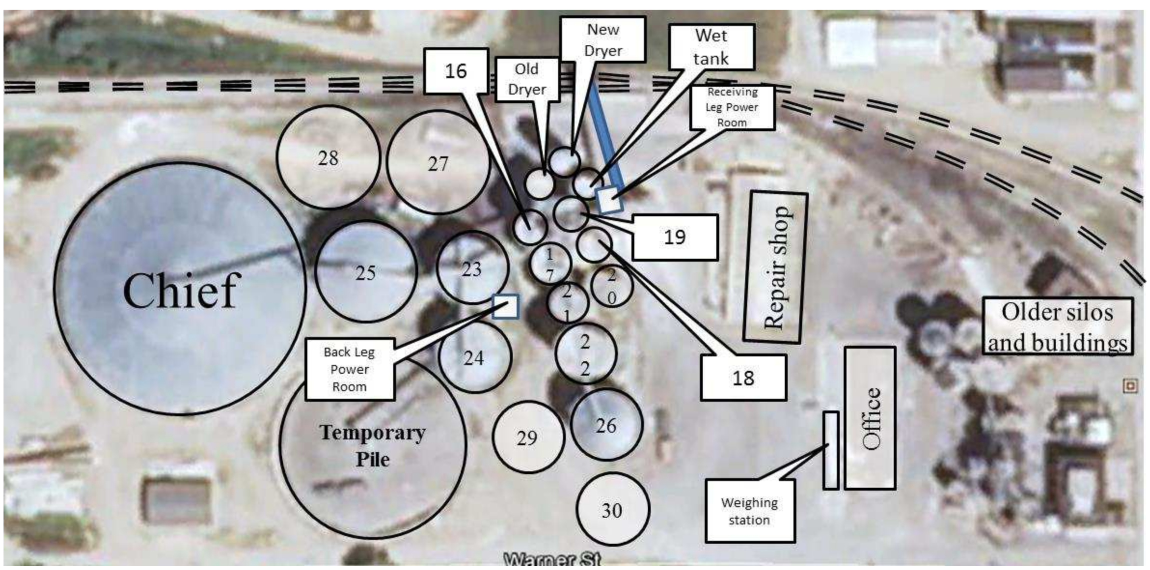


Figure 2: A second aerial view, coped from Google Earth, of the Michigan Agricultural Commodities facilities in Marlette, MI. The top of the photo is north. Each permanent bin or facility system is identified by number or name. The dashed line drawn shown in the upper portion the photo shows the position of the rail spur with a split for train car short term holding. The weighing station, facility offices, and older grain storage facility are to the lower right in this image. Bins 29 and 30 are drawn into this photo and postdate the Google Earth image used here.

If the grain evaluation indicates that the grain is not dry (above 16% to 16.5% moisture by weight) the grain can be routed to a bin for later drying, or it can be sent directly to the grain dryer. The grain drier (a Brock® dryer, installed in 2008, and heats at 45 million BTU’s per hour) is a tall cylindrical structure that intakes outside air at the bottom of the unit, and heats that outside air using a natural gas burner and blows the heated air into the dryer so as to help dry the grain. The grain enters the top of the dryer and flows downward while being exposed to the heated dry air to help dry the grain. Once dried, the grain can then be routed to longer term storage bins, or temporary bins, as needed. Note that for shipping the target moisture must be between 15% and 15.5%. The 0.5% to 1.0% moisture difference from dryer-processed grain to the targeted shipping moisture percentage can usually be removed later during storage by aeration of the grain in the bins. Once the grain has been off-loaded to the receiving station from the trailer, the delivery truck then pulls the trailer back to the weigh-station to determine the empty trailer weight. The difference in initial weight to final empty weigh is used to then calculate the weight of grain received by the facility. Figure 3 below shows a diagrammatic illustration of the major grain handling operations and storage systems at the Marlette facility. A list of key terms and their definitions are given in the Appendix of this paper.

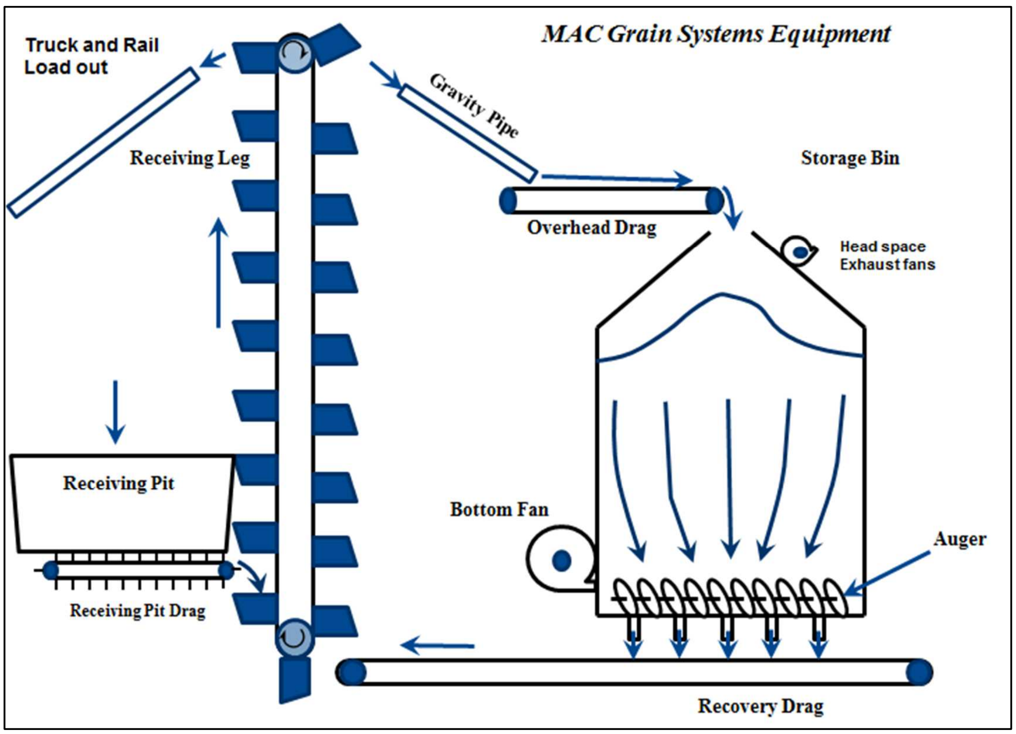


Figure 3: This diagram shows the major equipment components used at the MAC Marlette facility.

It is important to note that all grain received at the Marlette facility is handled at least twice, once at receiving for storage, and once again for sale and shipment. In some additional instances grain can be mixed with similar grain in other on-site bins. This involves yet another handling of the grain. Repeated or excessive handling and movement of the grain is undesirable because this can cause damage to the individual kernels of grain, which lowers the dollar-value of the grain.

All legs and drags are electric motor powered using 480 VAC delta connections. No motors in Marlette use a 240VAC wye-start that switches to a 480 VAC delta-run mode. The two 125 horsepower fans on the Marlette Brock® dryer each have a soft-start feature that ramps the power up to full-power to the motors for these fans. The soft-start feature limits the electric current per phase for each drier fan motor to not exceed 400 amperes. Moist grain (above 16% when initially received) can be stored for a short time and then would be routed to the dryer for drying, as required.

Once the grain has been routed to its initial storage destination within the MAC Marlette facility it can be routed to three other on-site destinations. These are 1) to the dryer if it is initially received with moisture above 16%; 2) to a longer-term storage bin, if dry; 3) if additional foreign materials are present then it can be blended with other similar grain with lower foreign material levels to meet sale specifications. The final destination for all grains at the MAC Marlette facility is, of course, to be sold to external customers. This is done by extracting the grain from the storage bin with grain movement facilitated by an auger located at the base inside of the bin, were the grain drops down though shoots to a lower recovery drag that then routs the grain to a leg that lifts the grain to an elevated position. The elevator dumps the grain to a shoot with a directing nozzle, which then dumps the grain onto an overhead drag to rout to either a truck-loading hopper, or to a train loading hopper that routs the grain to a rail drag to dump the grain to a train car.

Minimal handling and movement of grain at the facility is always desired. Grain transport has two financial impacts. First each grain movement activity can cause damage to the grain. Such damage is undesirable because it negatively impacts the quality of the grain and, thusly, lowers the value of the grain. Second, additional grain movement requires electric power use to energize motors for drags and legs.

3. Project organization:

From the outset of the project it was understood that Lawrence Tech students would be directly involved in the project, from the testing, collection of data, the analysis and documentation of data, and the final reporting of the results. Adequate funding was made available from the outset of the project to pay for up to five students for one year. A major challenge of this project to secure student workers. This was because funding from DTE Energy was formally approved in June 2012. This was over six weeks after the end of the spring academic semester and the vast majority of students were no longer taking classes nor on campus. Two possible engineering students had been contacted by the author about participating in the project in the mid spring, but due to the mid-summer approval they had already committed to other summer work and were not available at the time of project approval.

Recruitment of student workers:
Because of the summer start date, the author, and principle investigator on the project contacted known students working on campus and also students who were “friends of friends” of known students. In some cases “friends of friends of friends” were contacted. The Lawrence Tech Office of Career Services, who keeps a recent pool of student resumes on file for possible on-campus employment as well as local industry co-op or internship opportunities was also contacted for possible project employment candidates. Eventually seven undergraduate students were hired to support project work; three mechanical engineering students and four electrical engineering students.

Administrative structure:
The structure of the project was intentionally kept as simple as possible. The day-to-day activities were typically completed by Lawrence Technological University students working with, and under the direction of the author, a faculty member on the Mechanical Engineering department at Lawrence Tech. The author directed the activities by coordinating site visits to Marlette with personnel from the Marlette facilities.

All equipment purchases were made at the request of the author through the Lawrence Tech purchasing department. Purchases were billed to the project account at Lawrence Tech, which then sent monthly invoices to DTE Energy for reimbursement. Outside contractor services, such as electricians, etc., were processed similarly to equipment purchases and handled through the Lawrence Tech accounts payable department. Student and faculty labor charges where processed by the Lawrence Tech payroll office and paid to the individuals working on the project either every two weeks or twice a month. All charges and expenses to the project were kept on-file with the Lawrence Tech business services office and are readily available for inspection or audit purposes for seven years.

Contracted electrical support was provided by Maurer Electric, of Bad Axe, MI. Maurer Electric was used because they are the electricians of choice for the MAC Marlette facilities manager and are very familiar with the MAC Marlette facilities.

4. Data collection system:

For this project it was felt that data collection needed to be accomplished with a portable, robust and reliable electric power and energy data acquisition (DAC) system. Initially it was thought that a small portable DAC system using a laptop and custom assembled current transducers and voltage sensors could be developed at Lawrence Tech. But after seeing the facilities and need for out-door data collection, it readily became apparent that such an approach was not at all practical. Two students on the project were assigned the task of determining which portable power and energy data acquisition system was best suited for this project. It was decided that the Fluke 435 II three-phase power quality and energy analyzer portable power meters were best suited for the project. See Figure 4 showing the showing a Fluke 435 II unit and also in use at the MAC Marlette facility. Five of these units were purchased TEquipment.NET, of Long Branch, NJ.

5. Aeration fan and temporary pile fan focus:

Grain storage facilities, such as the MAC facility in Marlette, MI, use a significant number of fans. All fans used at the Marlette facility are three-phase 480 VAC power fans that typically are controlled in a simple on/off (no-power or full-power) mode. Except for two 125 horsepower fans in the Brock® grain-dryer that have soft-start controllers, the rest of the MAC Marlette facility has on/off fans ranging from 7.5 horsepower up to 60 horsepower. These fans are used in four applications. These include a) the aeration of grain in storage bins, b) the creation of a low-pressure (suction) condition under temporary grain pile tarpaulins to hold the covering tarpaulins in place under windy conditions, c) the venting of air from the top of grain storage bins, and d) preventing the accumulation of grain dust from areas such as a receiving pit. The Marlette facility has approximately 60 operating fans in their major permanent storage bins, with each bin typically having four aeration fans around the base perimeter of the bin.

Temporary storage piles typically require six to eight suction fans to adequately secure the tarpaulin in place over the grain pile. These temporary storage pile fans are rated between 7.5 to 10 horsepower and pull air out of the bottom of the pile to create a low-pressure condition under the grain-covering tarpaulin. As a result there can be an additional 30 or more of these suction fans deployed around the facility during high-volume grain storage periods that require the temporary grain piles.

Depending upon weather conditions it may be that only some of a bin’s or a temporary pile’s aeration fans are needed. In other cases all aeration fans may be needed. During high-winds, all temporary pile suction fans will be in operation. When significant weather temperature fluctuations occur, all aeration fans may also be needed. No permanent storage bins or temporary piles have speed-varying motor controls, so these fans induce high current spikes when their motors are turned on. Per information from Marlette facilities personnel under some cases each permanent bin fan can turn on between thirty to forty times in a month and remain on for several hours to days. As a result, these fans can use significant electrical energy depending upon the grain storage inventory throughout the year.

(A) (B)

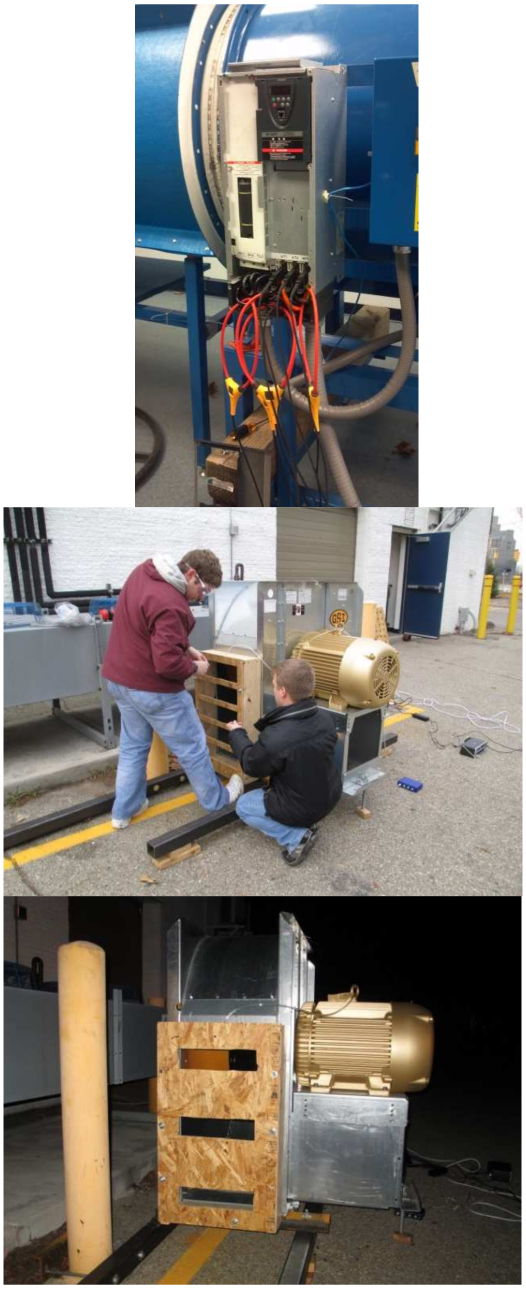
Figure 4: (A) shows a close-up picture of the Fluke 435 II Power Quality and Energy Analyzer meter display and control buttons; (B) shows one of the Fluke 435 II power monitoring meters in use in one of the electrical power rooms at the MAC Marlette facility. These meters monitored both current and voltage and record each value four times per second. Data storage was a function the size of the SD card contained in each meter.

Once the Fluke 435 II meters were acquired initial fan testing was done at Lawrence Tech by student project members. The author was on hand to assure that data collection methods were properly defined. MAC Marlette personnel loaned Lawrence Tech a ten-horsepower Spreads-All SA-241003-210# aeration fan for testing purposes at Lawrence Tech. The Spreads-All fan was configured at Lawrence Tech to be able to run in the typical on/off mode, as is standard operation in Marlette. An ABB 10 horsepower programmable variable frequency drive (model number ACS550-U1-023A-4) was installed to also control the Spreads-All fan under various loading conditions to assess their basic operation. Since the Spreads-All fan is used in suction mode, loading of the fan was accomplished by placing various wooden covers with various sized openings crating obstructions over the fan inlet. See Figure 5 showing photos of the Spreads-All fan testing set-up employed at Lawrence Tech. Because fans are not subject to abrupt torque variations, such as might be encountered with a conveyor system, variable frequency drives (VFDs) are acceptable devices to control the start and stop of fans. All data using the Fluke 435 II were collected upstream from the ABB VFD. This was to assure that a clean 60 Hz power signal was measured for all testing without interference from the various output signals possible from the VFD.

A second series of tests were undertaken at Lawrence Tech using a 50 horsepower aeration fan (GSI Model CHS-50-36 Centrifugal Fan 3450 RPM 50HP 3PH 460V) purchased specifically for evaluation for this project. This fan is a common aeration fan used in large storage bins at the MAC Marlette facility. Due to its size and volume of air flow the fan was installed outside in the Applied Research Center building (ARC) parking lot at Lawrence Tech. This location was optimal because a research wind tunnel with a 50 HP fan that is controlled by a Toshiba VF-AS1 variable frequency drive (VFD) is also located in the ARC building. The GSI aeration fan was tested both without and with the Toshiba VFD. A wooden outlet shroud was attached to the fan housing outlet allowing for various wooden boards to cover the fan system outlet with differing degrees of openness (openness refers to the amount and size of holes in the board that would let air travel through and exit the blower fan). These produced different loading on the fan motor. Figure 6 illustrates the testing setup for the 50 HP GSI aeration fan.

(A) (B) (C)

Figure 5: (A) The 480 volt electrical power feed directly to the Spreads-All fan or to route the power through the ABB 10 HP VFD and then to the fan, along with data collection using the Fluke 435 II meter. (B) The air-flow outlet of the Spreads-All fan test setup. (C) The Spreads-All fan inlet with a partial inlet obstruction to assess basic fan performance. Several obstructions ranging from complete obstruction to no obstruction were placed across the fan inlet for this study.



(A)

(B)

(C)

Figure 6: Photos showing the testing configuration used for the GSI 50 HP aeration fan. (A) The Toshiba VFD (normally used to control the Lawrence Tech research wind tunnel 50 HP fan) with the Fluke 435 II current transducers and voltage leads connected for data collection was used for GSI fan was testing. (B) The GSI 50 HP fan outside of the Lawrence Tech ARC building with students attaching the wooden outlet cover to introduce an outlet load on the fan motor. (C) The same GSI fan outlet with a different outlet cover to introduce added outlet resistance for different loading on the fan motor.

Also evaluated during these initial fan tests at Lawrence Tech was the monitoring of the fan outlet pressure. This was done using a Pasco pressure transducer and data logger controlled by a laptop computer. The pressure transducer was attached to the outlet section of the fan to monitor the positive air pressure immediately exiting the fan. The pressure device was then attached to the laptop computer where a program would record the pressure information. Unfortunately, this system proved to not be a particularly useful method as the buffeting of the air immediately exiting from the fan crated such a signal noise in the pressure sensor that little useful data were obtained.

6. Assessing the MAC Marlette facility's energy use:

Starting in the fall of 2012 the author and Lawrence Tech student team members began regularly traveling to the MAC Marlette facility to begin electrical energy usage data collection from various motor systems used in processes there. All major grain transfer systems used at the Marlette facility are powered by electric motors, which are supported by some gravity feed systems. Because of these motor systems it was vital to collect data on-site at the Marlette facility using the Fluke 435 II Energy and Power Monitoring meters.

The first area of attention was the front receiving station comprised of the receiving pit, the receiving pit drag, the receiving leg and receiving fan. The reason for starting data collection there was because the majority of grain received at the Marlette facility passes through this station. A second area of focus was the various aeration fans located on site at the base of some of the large storage bins. Later various overhead and recovery drags were evaluated. All initial work was done to characterize the as-is performance of the motors and how they been run for the past several years. No VFDs or VTDs were yet installed and data were collected under typical operating conditions.

In conjunction with on-site data collection a detailed review of energy usage history was also done through the review of historical utility billings for the Marlette site. On-site power meters were documented and multipliers were cross-checked with utility billing invoices.

To support the assessment and value of VFDs and VTDs at the Marlette facility project funds were used to purchase appropriately sized VFD and VTD systems for use at the MAC Marlette facility. Altivar units (Schneider Electric) were selected because the electricians from Maurer Electric, who are the preferred electrical contractors at the MAC Marlette facility, were most familiar with these units, and had previously installed and programmed these systems.

An additional area of review for energy usage at the MAC Marlette facility was their natural gas usage. The Borck® grain drier uses natural gas to heat ambient air that is forced through the unit to dry overly moist grain. Grain dryers are critical to prevent commodity spoilage and to meet customer moisture limits upon sale. The Brock® drier does have controls and monitoring systems, but for efficient operation proper maintenance and cleaning of vents and inlets are required. These require operator training to assure best operation of the unit. One area of possible prediction of natural gas usage for the grain dryer at the MAC Marlette facility was to track the local area's relative humidity just before and through the harvest season. Data were found for previous years that grain moisture from area relative humidity correlated very well with natural gas usage. Tracking this over time during the harvest season by MAC Marlette personnel could be a useful predictor for the demand on the dryer, to anticipate personnel support and system maintenance, as well as the obvious natural gas demand.

7. Variable torque drive installation and evaluation on MAC Marlette processes:

The large number of motors (ranging from 7.5 horsepower to 60 horsepower) used at the MAC Marlette facility and the limited number of VFD/VTD units available made it necessary to choreograph the selection of study equipment, the installation of the VFD/VTDs, the installation of the Fluke meters and the data collection for meaningful process energy usage information. This all needed to be done without interruption of the receiving, movement and transfer of grain at the Marlette facility, nor could it prevent any operation at Marlette. This was not always easy to do. All VFD and VTD installation was done by the MAC's preferred electricians from Maurer Electric. During this process occasionally equipment would breakdown. Sometimes systems would not be available due to unscheduled service, or significant grain deliveries or train-load grain sales would come up – sometimes the night before previously scheduled activities. These events often resulted in the delay or deferment of equipment installation and testing activities. Energy evaluations were done around keeping a large grain receiving, storage and distribution facility fully functional and fully operational.

None-the-less these actions were accomplished and significant amount of information, data and knowledge were gained. Figure 7 below shows two photos of installed Altivar VFD/VTD systems used for study at the MAC Marlette facility.

(A) (B)

Figure 7: Four Altivar variable speed/torque motor drives installed for used in the front receiving station power room to control various fans and drags are shown here. (A) Shows one of the Lawrence Tech students working in the power room getting ready for data collection using the Fluke 435 II meters. (B) Shows a close-up view of an Altivar 61 ten-horsepower unit at right center and an Altivar 71 forty horsepower unit fully installed for evaluation at the MAC Marlette facility. In (B) at the upper far left an Altivar twenty-five horsepower unit is partially visible.

The front receiving leg uses a 60 horsepower motor and its energy consumption was evaluated both without and with an Altivar 71 seventy-five horsepower VTD. This unit is shown if Figure 8 below. All grain storage and handling facilities are dusty venues. Grain dust and farmland dust are common and can accumulate over short periods of time. Figure 16 shows dust accumulation on the 75 horsepower VTD after only a few weeks in the electrical power room. This could be a VFD/VTD cooling-fan maintenance and service issue over time with these units if not frequently checked and assessed.

Once testing of one system was completed, the VFD/VTD units were moved to other locations at the Marlette facility. This eventually was reasonably well coordinated when no other un-related equipment system failures occurred, and things usually went smoothly. Data collection was interrupted on more than one occasion due to heavy and windy rains, and occasional lightning strikes did prevent some testing during the summer months.

Figure 8: The energy consumption of the receiving leg at the MAC Marlette facility was evaluated both without and with an Altivar VTD unit, as pictured here. Note the dusty conditions of the power room.

An important aspect of using variable torque drives learned in this study was that VTDs should be well matched to the motor they are controlling. During initial conversations with Schneider Electric (the manufacturer of the Altivar units) at the time of specifying and purchasing the Altivar units the Schneider support engineer made two cautionary suggestions regarding this motor/controller matching. The first was that due to the fluctuation current demands common with variable torque drives that the next size VTD should be installed for a given horsepower motor. For example a 20 horsepower motor should be controlled by a 25 horsepower VTD. This accommodates the often fluctuating current during abrupt torque changes when operating. The second caution was to not use too high of a horsepower rated VTD over and above a given motor horsepower rating. The Schneider support engineer’s recommendation was to not go over two VTD horsepower ratings above a given electric motor’s horsepower rating. There was some debate by the Maurer Electricians regarding this last point. However, any debate was settled on this when an Altivar 71 forty horsepower VTD was installed to control a 15 horsepower motor. The oversizing of the VTD did not allow for proper control of the motor and performance was severely compromised. The VTD was quickly removed and a more appropriately sized VTD was installed. Schneider Electric technical support recommended for VFD applications that the motor horsepower and VFD horsepower ratings be matched, or closely matched for best performance, i.e. use a 20 horsepower VFD with a 20 horsepower electric motor.

8. Data review:

The Fluke 435 II Power and Energy data logger interfaces with Fluke Power Log® software for data analysis and review. The Power Log® software is available free from Fluke and, therefore, can be uploaded on student laptops. (All Lawrence Tech students are issue a high performance laptop for course work.) This allowed various data sets and files to be issued to students on the team to evaluate the quality of data and for assessment and graphical presentation. Several hundred data sets were evaluated. As will all data on some occasions key questions were answered by the data, and on some occasions the data raised more questions than the answers it provided. These added questions required more thoughtful approaches to data collection and often required the project team (the author included) go back to question MAC Marlette personnel about greater details about their processes and systems. The learning benefits of this iterative knowledge acquisition process for students was invaluable. Students team members quickly learned to take notes and to keep track of the work they had done, the proper set up of the data acquisition systems and to make sure they asked the right questions during about the purpose of the data being collected.

Four formal data review presentations were made by student team members to DTE Energy engineering and management representatives for technical updates regarding the data collected and to field questions from DTE Energy personnel regarding the status of the project. This required appropriate selection of representative data, presentation preparation and rehearsal, and detailed planning to assure a professional effort. This was extremely helpful (though sometimes nerve-wracking) for students, some of which had not had to interface with professionals in industry.

Over the course of the project on numerous occasions both formal and informal data sets were presented and reviewed with MAC Marlette personnel and management. Since these data were being presented to the people who knew their operation best, it gave students a good opportunity to better understand the nature of the data they had collected, the processes being evaluated and to put a clear context upon the work they were doing.

9. Summary of the educational gains made by student project team members:

This project focused on understanding energy usage at the Michigan Agricultural Commodities, Inc. facility located in Marlette, Michigan. Seven Lawrence Technological University undergraduate engineering students served as team members supporting the project. Funding was provided by DTE Energy with students serving as paid Lawrence Tech research employees on the project. This author, a Lawrence Tech faculty member in the A. Leon Linton Department of Mechanical Engineering, served as the principle investigator and primary coordinator of the work. The project ran from June 2012 to December 2013. Numerous educational benefits for students were provided during this project. Some of these simply cannot be taught in the classroom and help prepare the student for eventual work in industry. The more prominent benefits gained by students on this project are listed below:

- Dealing with various levels of working professionals in an industrial agribusiness setting such as the Marlette facility

- Learning from others who may not have the same education level but have more extensive industry experience
- Dealing with contractors and the labor force
- Giving professional presentation preparation and delivery skills
- Having to collect data at times that were best for the process and not the most convenient for the students…especially 6:00 AM start times (after a 90 minute drive)
- Data collection and the selection of appropriate data collection systems, methods and approaches
- Complex data review, analysis and interpretation skills
- Experimental setup and the resulting sometimes failure and success
- A fundamental learning and applied knowledge of power electronics
- Scheduling of work over a long travel distance

REFERENCES

1. Michigan Department of Agriculture and Rural Development website; http://www.michigan.gov/mdard/0,4610,7-125-1572-7775--,00.html, last accessed 01/02/2014

2. Jonathan E. Avery, Todd P. Siebeneck, and Robert P. Tate, Gross Domestic Product by State Advance Statistics for 2010 and Revised Statistics for 2007–2009, Survey of Current Business, Vol. 91, No.7, 142-169, July 2011.

3. Jayson Beckman, Allison Borchers, Carol A. Jones; Agriculture's Supply and Demand for Energy and Energy Products; United States Department of Agriculture, Economic Research Service, Economic Information Bulletin Number 112, May 2013.

APPENDIX

Aeration fan – a fan that blows outside air into the bottom of a grain bin to aerate the stored grain (also known as a bottom fan)

Auger – a large screw device at the bottom of a storage bin that rotates to help move the grain from the bin

Bottom fan – a fan that can blow air into a bin to help aerate the grain to help keep the grain cool, or to help dry the grain (also known as an aeration fan)

Bushel of grain – a typical unit of grain used in the commodities markets for shelled corn - 56 pounds per bushel (for a density of 44.97 lbs per ft^3), soybeans – 60 pounds per bushel (for a density of 48.18 lbs per ft^3), wheat - 60 pounds per bushel (for a density of 48.18 lbs per ft^3)

Grain dryer – a large vertical system where wet grain is placed in the top and flows downward to the bottom of the dryer while being heated with warm air (heated with a natural gas combustion system) to dry the grain

Gravity pipe – a large diameter tube that that is tilted at a steep incline angle for grain to flow via gravity and directs the grain to a desired location, usually an overhead drag

Headspace exhaust fan – a venting fan located at the top of a grain storage bin to facilitate air circulation in the bin

Overhead drag – an overhead conveyor to transfer grain to bins

Pit fan – a ventilation fan located in the grain receiving pit that removes hazardous grain dust

Rail load out – a grain transfer conveyor that carries grain to a railcar loading station

Recovery drag – a drag conveyor that collects grain at the bottom of a bin to remove grain from the bin for transfer the grain to another location

Receiving leg – a vertical conveyor with buckets that lifts grain to a high elevation above most of the facilities bins so that it can be dumped to a gravity pipe and an overhead drag to storage bins near or away from the grain receiving station

Receiving pit – a grate-covered pit that has a pit drag that conveys grain to a receiving leg

Soft-start controller – an electrical device placed upstream from an electric motor that ramps up the power to the motor at a programmable ramp rate so as to eliminate any significant current draw upon start-up of the motor

Storage bin – a large cylindrical storage container made of concrete or metal that stores grain and usually outfitted with augers, aeration fans, and headspace fans. The various size bins at Marlette can store between 55,000 bushels to 950,000 bushels of grain

Temporary pile – a short-term (two or three months) grain storage pile where the grain is placed on the ground with a supporting frame around the perimeter of the pile and covered with heavy gage tarpaulins, where the tarpaulins are held in place via suction fans drawing air out of the pile to create a vacuum in the grain pile to hold the tarpaulins in place

Truck load out – a grain transfer conveyor that carries grain to a truck trailer station

Variable frequency drive – a motor controller that has various adjustments that controls a motor for maximum efficiency with changing width voltage pulses at fixed positive and negative voltages to simulate an alternating current sin wave, also known as a "VFD"

Variable torque drive – a motor controller similar to a variable frequency drive that has various adjustments that controls a motor for maximum motor torque efficiency with various voltage-width pulses at fixed positive and negative voltages to simulate an alternating current sin wave