An Innovative Approach to Controlling Plastic Grinders in Injection-Molding Plants

Kevin Carpenter, Clark Energy Group
John Getlein, Plastic Molding Technology, Inc.

ABSTRACT

The standard plastic-injection molding process utilizes grinders that grind plastic scrap for re-use in the process. Most commercially-available plastic grinders are turned on and off via a simple button or switch. Due to the many responsibilities of a machine operator, a grinder is typically turned on at the beginning of a production shift and then "left alone" to run continuously. Grinding takes place for usually less than 5% of all production hours, leaving motors to idle for the remaining 95%+ of time.

To reduce wasted idling energy, grinder-control systems that incorporate proximity sensors and vibration detectors have been commercially developed. However, due to slow motor start-up time when a sensor is triggered, plastic scrap often jams the grinder blade before the motor can reach full speed. To avoid subsequent downtime and maintenance, machine operators often override or disable this type of control system.

A novel control system has been developed and installed at a plastic injection-molding plant to substantially reduce grinder idling time without compromising functionality. This control system allows a user to manually switch on a grinder, and signals through a display light when the motor has reached full speed and is safe for plastic to be loaded. The system shuts off the grinder motor after a set period of idle-amperage detection. This control system saved over 95% of grinder energy-use at the injection molding plant, with no machine-jams or maintenance needed. This paper presents the measured energy-saving results.

Introduction

Plastic grinders (or granulators) are widely-used equipment in the plastics-processing industry. Grinders are often characterized by their continuous operation throughout production hours, despite grinding requirements of as little as 5% or less of the total hours. These operating characteristics make grinders a major contributor to energy used in the plastics industry.

The U.S. plastics industry annually consumes approximately 1,070 trillion Btu of energy, which equates to about 6% of overall U.S. industrial energy use (US DOE 2005, 3). Plastics manufacturing plants have become prime targets for industrial energy reduction due to high energy intensity and savings opportunities in their thermal processes and motor systems. Leading industrial-energy sources, including the U.S. Department of Energy (2005), Southern California Edison (2012), Pacific Gas and Electric (2006), Natural Resources Canada (2007), and the European Commission (2006), have published numerous energy-savings strategies for the plastics industry. These strategies primarily include improved injection-molding press power-drive equipment, variable-volume/variable-speed hydraulic pumping control, extruder-barrel insulation, material-dryer energy improvements, and best practices in lighting, compressed-air, process cooling, and HVAC.

Additionally, these industry sources identify plastic grinders to be a significant energy-user in the plastics industry. For example, DOE describes a plastics-manufacturing facility whose grinders account for approximately 13% of total plant electricity use (US DOE 2005, 28). Grinders accounted for approximately 16% of the electricity used by the case-study facility presented later in this paper, prior to retrofit. However, published sources seldom identify effective methods to substantially reduce grinder energy usage. US DOE (2005) suggests turning off grinders and other process equipment when not in use, and using premium-efficient motors. Natural Resources Canada (2007) suggests using special rotors and cutters that require less input energy for cutting, as well as high-efficiency motors. However, the lack of control that causes as much as 95% of a total grinder's energy to be wasted often goes unaddressed.

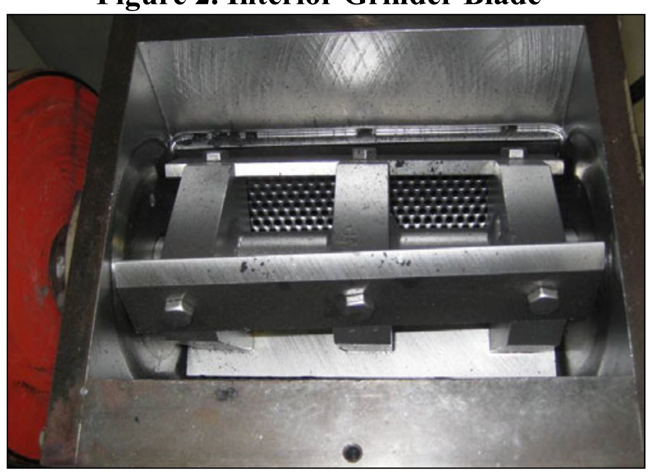
This paper presents controls solutions to substantially save plastic-grinder electricity usage and the measured results of a recently-developed control system.

The Plastic Grinder

In virtually every plastics-manufacturing process, scrap is generated as a byproduct and/or in defective parts. To be recycled and reused in the process, plastic scrap must be re-ground into pellet form. Grinding is done via a plastic grinder that typically consists of a motor-driven rotating blade. This blade is enclosed by housing; the top part of the housing has a chute where plastic scrap is fed, and the bottom part of the housing has a hopper to where plastic pellets fall. The rotating blade cuts plastic by passing over a stationary blade or blades, with a clearance of a few thousandths of a centimeter (Lee 2006). A metal screen is located between the rotating blade and lower hopper to ensure pellets are ground to a certain size before passing through. Figure 1 is a photo of a plastic-grinder exterior with chute in front. Figure 2 shows the plastic-grinder interior rotary blade.

Figure 1. Plastic Grinder Exterior

Figure 2. Interior Grinder Blade



Grinder motors in most mid-to-large plastics facilities typically range from 1 hp to 25 hp, but can exceed 50 hp for larger applications. Standard commercially-available grinders are not built with sophisticated controls, but are simply equipped with a START button and STOP button. However, aftermarket controllers can be installed as a retrofit on a grinder.

Grinder Controllers

Due to the demand for energy reduction and longer equipment life, a market for plastic-grinder controls has recently emerged.

Commercially-Available Controllers

The typical commercially-available start/stop plastic-grinder controller consists of a central control box connected to a proximity sensor and vibration detector (IMS 2013). The proximity sensor is installed at the grinder chute to signal the motor to turn on when triggered by parts entering the chute. The vibration detector detects when grinding activity is complete and then signals the motor to shut off after a user-defined period of inactivity.

The grinder controller just described can effectively save energy if used properly and if plant staff is made aware of its operating characteristics. However, the major issue plastic manufacturers have experienced with this type of controller is that production-staff sometimes load large amounts of scrap-product into the grinder when the motor is off. Although the grinder is triggered to start when product is loaded through the chute, the motor does not have sufficient time to reach full speed before product comes in contact with the blade. This causes the blade to jam or become damaged. Such events have resulted in maintenance and downtime costs that exceed energy cost savings, and have caused multiple manufacturers to override or disable such control systems.

A possible solution would be to launch an educational campaign to properly instruct production-workers on how to use the grinder control system. However, employee turnover rates along with the general probability for human-error have made such educational campaigns not feasible for many plastics companies.

A Novel Controller Development

A new controller with unique start/stop triggers was recently designed, built, and installed on all grinders at a plastic-injection molding plant in El Paso, TX. This controller is designed to save grinder energy by controlling runtime while eliminating many of the issues associated with the common commercially-available controller.

The new controller is user-interactive, thus mitigating the possibility of rapidly loading product into a non-activated grinder out of unawareness or forgetfulness. An operator turns on the grinder motor via a simple START button located on the controller. Red and green display lights on the controller's panel indicate to the operator whether it is safe to load product through the chute. The red/green light status is controlled by a current transducer connected to the grinder motor, with a programmed amperage threshold that is slightly higher than the motor's steady-state amp-draw. The red light is on when the motor is off. Upon motor startup, amp-draw is elevated, causing the red light to stay on. When the motor approaches its rated speed after several seconds, its amp-draw gradually decreases to a steady level; thus activating the green light and indicating that it is safe for the operator to load product. If product is overloaded, the elevated motor amp-draw will re-trigger the red light indicating that the operator must delay loading more product until the grinder has processed enough to return to steady state. This unique feature that alerts the operator of motor overload can lead to maintenance and productivity savings by mitigating equipment failure. When the current transducer senses amp-draw to be at an "idling" level for two straight minutes, the controller is programmed to automatically shut off the motor.

The new controller was designed to mitigate grinder jams and increase user safety, and has been successful thus far. Machine operators have given positive feedback, and no safety-related or process-related issues have been reported. Operators have generally found the controller to be user-friendly, with little difficulty in grasping how to use it.

Figure 3 is a photo of a grinder equipped with a new controller. Please note the START button, EMERGENCY STOP button, and red and green display lights on the controller.

Figure 3. Grinder Equipped with New Controller

Novel Grinder Controller Application

This new grinder controller was designed, built, and one was installed on each of the 40 grinders at the Plastic Molding Technology (PMT) plant in El Paso, TX.

Plant Description

PMT is a plastic-injection molding company, located in El Paso, TX, that produces components for the automotive, electronics, and medical-products industries. The PMT plant has a continuous 24 x 7 operation that operates year-round. Forty grinders are present at PMT, with individual capacities ranging from 1 hp to 20 hp and with a total aggregate horsepower of 247 hp. None of the grinders were equipped with controls prior to the recent controller retrofit.

Logging Plan

To quantify grinder energy use before and after the controls retrofit, a sample of six (6) grinders were each power-logged for a two-week period when not equipped with controllers and for a two-week period when equipped with controllers. Of these six grinders, three are rated at 5 hp, two are 15 hp, and one is 20 hp. Because the plant is a 24 x 7 operation with consistent machine runtimes throughout the year, it is assumed that 1) the six logged machines are a representative sample of the remainder of the grinders, and 2) energy usage and savings can be extrapolated on an annual basis for all grinders in the plant. Power-logging took place in 30-second intervals, and the periods when all grinders were collectively drawing the highest amounts of energy (similar to an electric-utility coincident-peak period) were noted.

Measured Energy Use and Savings

The following figures are the time-series pre-retrofit and post-retrofit power readings of three of the six logged grinders. The remaining three grinders have similar profiles to the ones shown below.

Figures 4 and 5 show a two-week power profile of Grinder #30 (15 hp) both prior to and following the controller installation. The figures indicate that the grinder draws approximately 6 kW when idle, and generally between 7 and 12 kW when grinding parts. The power readings indicate that the grinder ground parts for 2.8% of pre-retrofit logged hours and 4.9% of post-retrofit logged hours. The grinder was on during the entire pre-retrofit logging period.

Figure 4. Grinder #30 (15 hp) Two-Week Power Profile Prior to Controller Installation

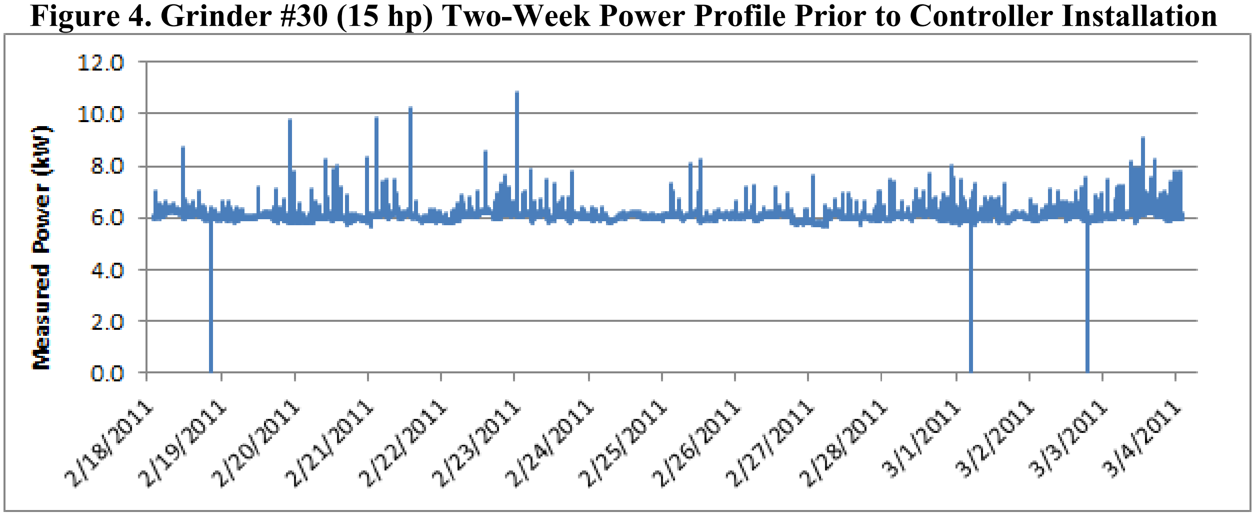
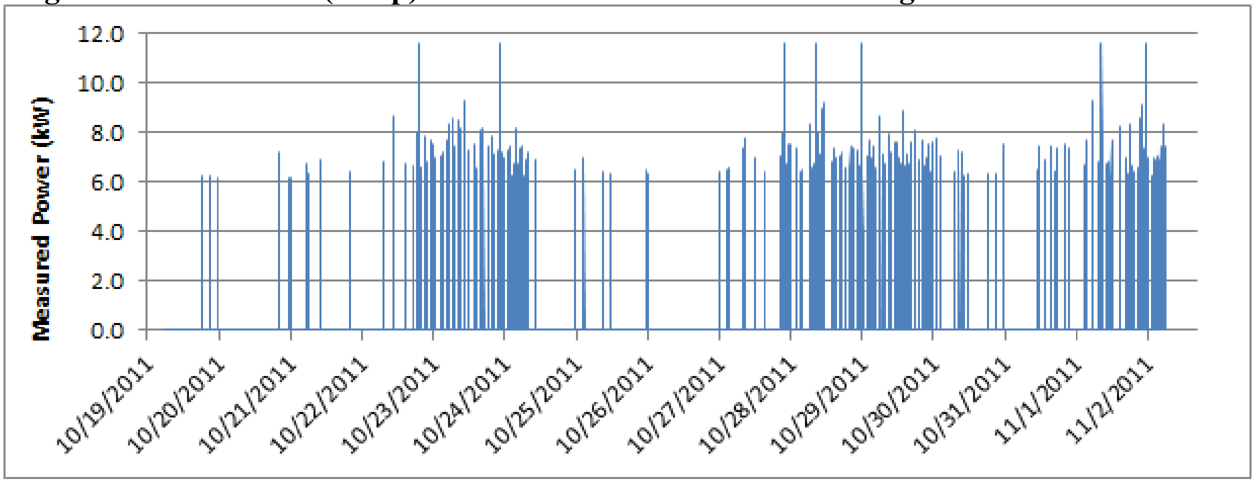


Figure 5. Grinder #30 (15 hp) Two-Week Power Profile Following Controller Installation



For higher resolution, and to demonstrate the loading cycle, Figures 6 and 7 show a 1-day power profile of Grinder #30 both prior to and following the controller installation.

Figure 6. Grinder #30 (15 hp) Power Profile on 2/23/11, Prior to Controller Installation

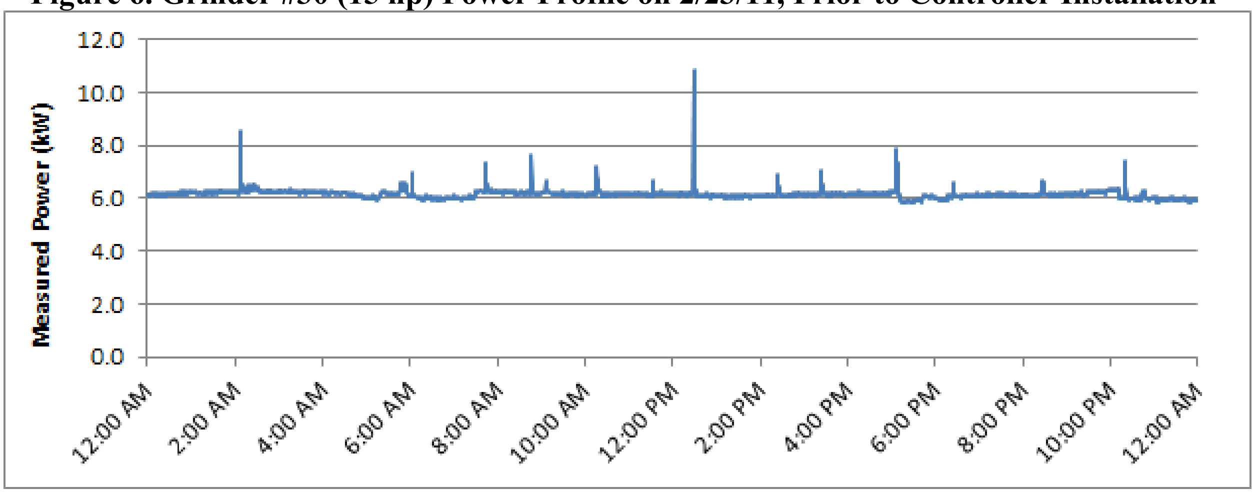
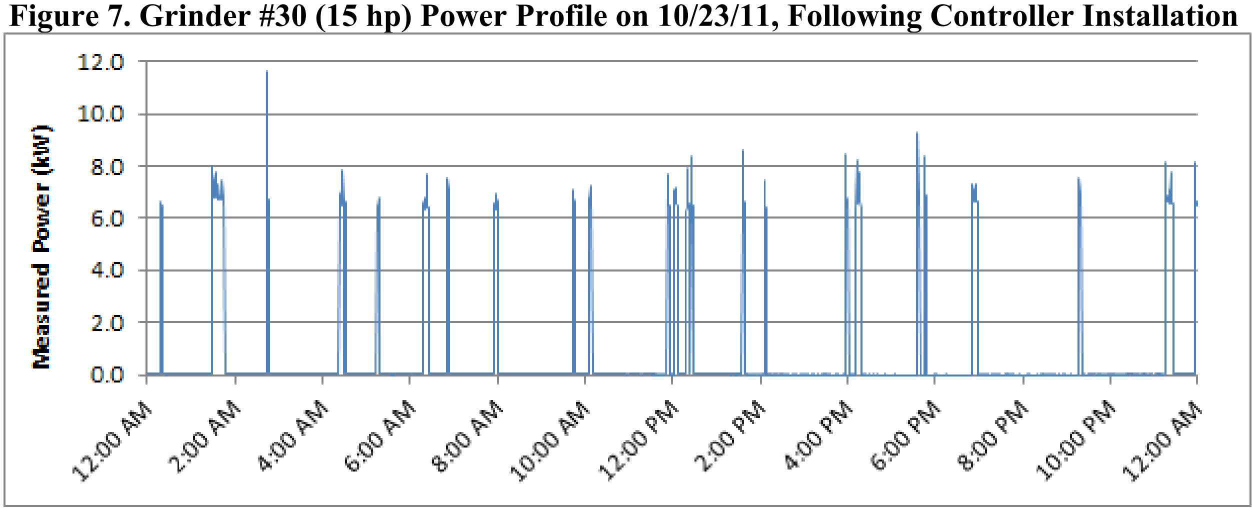


Figure 7. Grinder #30 (15 hp) Power Profile on 10/23/11, Following Controller Installation



Figures 8 and 9 show a two-week power profile of Grinder #31 (5 hp) both prior to and following the controller installation. The figures indicate that the grinder draws approximately 1.4 kW when idle, and generally between 1.7 and 4 kW when grinding parts. The power readings indicate that the grinder ground parts for 3.4% of pre-retrofit logged hours and 0.2% of post-retrofit logged hours. The grinder was off for 23% of pre-retrofit logged hours.

Figure 8. Grinder #31 (5 hp) Two-Week Power Profile Prior to Controller Installation

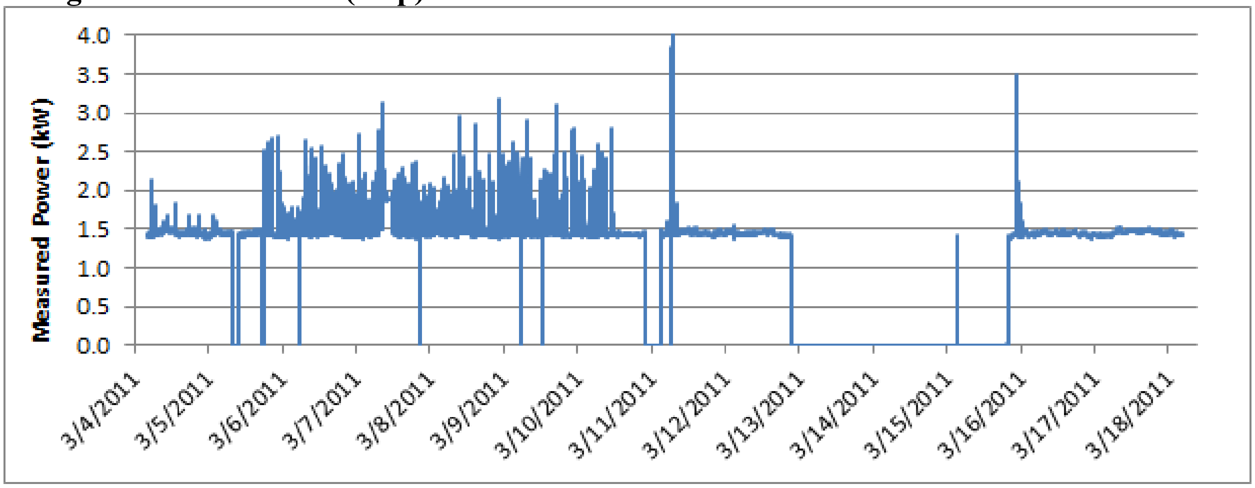
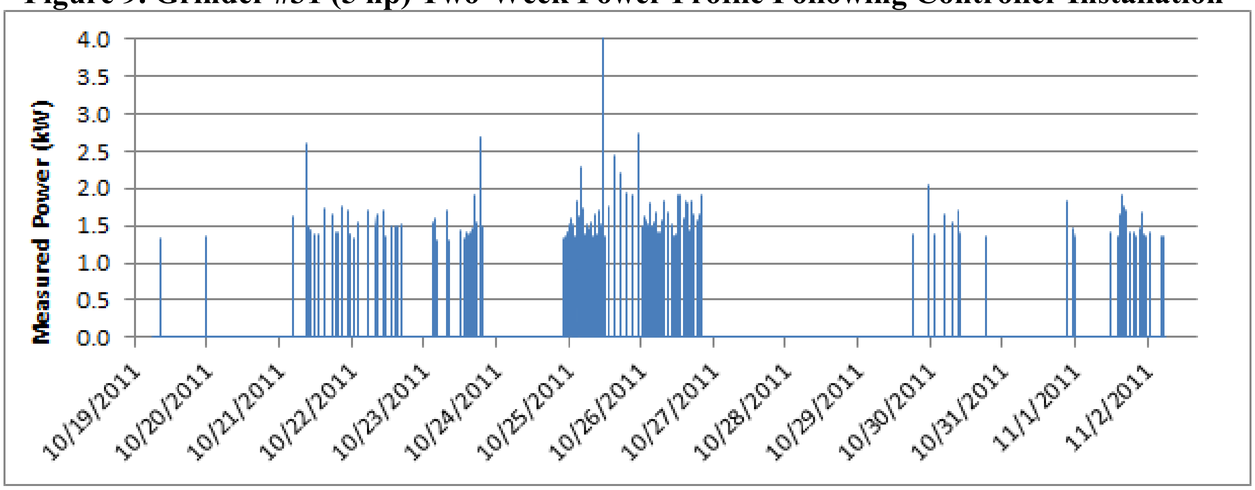


Figure 9. Grinder #31 (5 hp) Two-Week Power Profile Following Controller Installation



Figures 10 and 11 show a two-week power profile of Grinder #40 (5 hp) both prior to and following the controller installation. The figures indicate that the grinder draws approximately 2 kW when idle, and generally between 2.5 and 5.5 kW when grinding parts. The power readings indicate that the grinder ground parts for 1.3% of pre-retrofit logged hours and 2.6% of post-retrofit logged hours. The grinder was off for 12% of pre-retrofit logged hours.

Figure 10. Grinder #40 (5 hp) Two-Week Power Profile Prior to Controller Installation

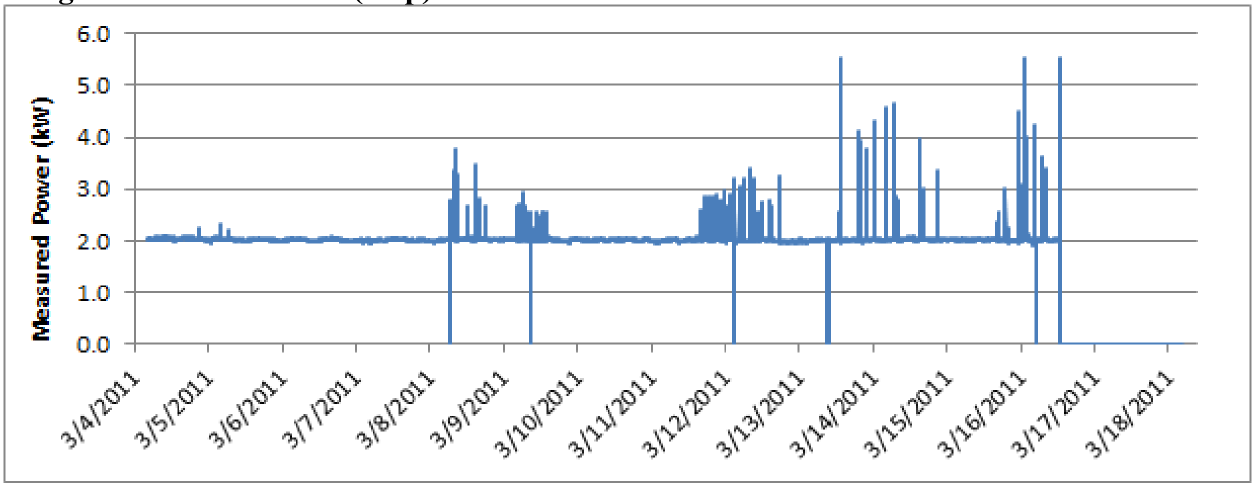
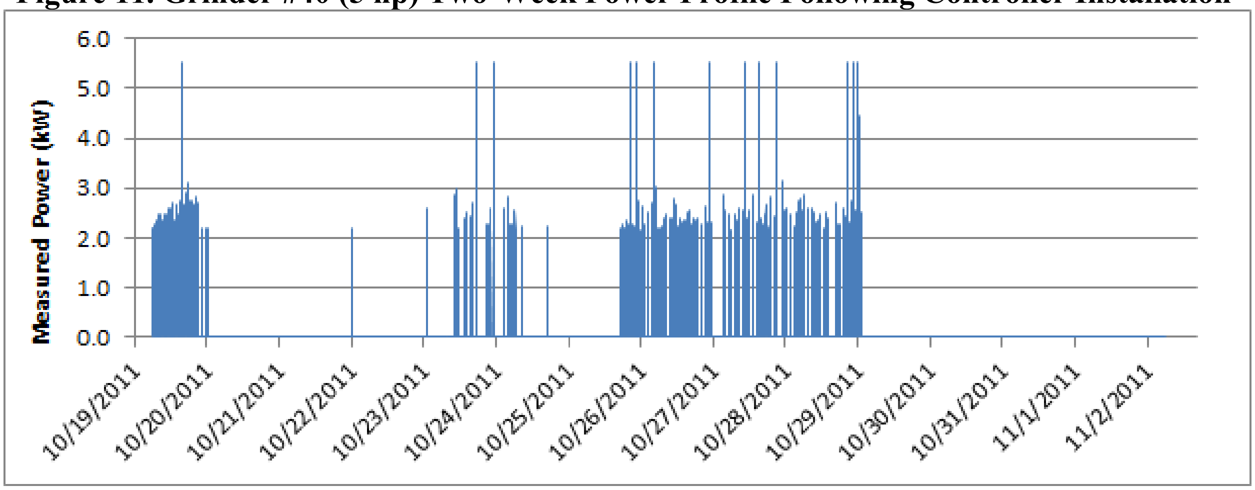


Figure 11. Grinder #40 (5 hp) Two-Week Power Profile Following Controller Installation



The logged data of all grinders analyzed indicate that grinder motors draw substantial power (25% - 50% of full-load power) when idling due to the friction on the motor shaft and the air-resistance on the spinning blade. Of the logged grinders, grinding only took place on average of 2% - 3% of the entire logging period, although the grinders were running for an average of 85% of all hours prior to retrofit. Some grinders were properly shut off during certain periods of non-use prior to retrofit, but all grinders experienced periods of running idle for several straight hours or days.

To demonstrate the electricity savings achieved by grinder controllers, Table 1 presents the 2-week energy usage and coincident electrical demand numbers for all logged grinders prior to and following controller installation.

Table 1. Two-Week Energy and Demand Analysis of Grinders Prior to and Following Control Installation

Logged Grinder Designation	Motor Horsepower (hp)	2-Week Energy Usage				Coincident Electrical Demand*			
		Pre-Retrofit (kWh)	Post-Retrofit (kWh)	2-Week Savings (kWh)	% Savings	Pre-Retrofit (kW)	Post-Retrofit (kW)	Savings (kW)	% Savings
#6	5	271	36	235	87%	1.4	0.1	1.3	93%
#29	20	1,302	41	1,261	97%	4.1	0.1	4	98%
#30	15	2,035	115	1,920	94%	6.1	6.5	-0.4	-7%
#31	5	378	16	362	96%	2.7	0	2.7	100%
#33	15	2,345	19	2,326	99%	7.6	4.2	3.4	45%
#40	5	600	44	556	93%	2	0.3	1.7	85%
Totals	**65**	**6,931**	**271**	**6,660**	**96%**	**23.9**	**11.2**	**12.7**	**53%**

*Determined as the average power draw of each grinder during the 30-minute period of highest measured aggregate energy use of all logged grinders

The savings results in Table 1 were extrapolated to estimate the overall annual plant energy and demand savings based on a 40-grinder plant with an aggregate horsepower of 247 hp. The savings extrapolation assumes that 85% of the grinders typically operate in the plant (i.e. not down for maintenance or in standby-reserve) for an average of 51 plant operating weeks per year. Table 2 presents the extrapolated annual energy, demand, and cost savings estimated from installing a controller on all grinders at the PMT plant.

Table 2. Extrapolated Annual Energy, Demand, and Cost Savings Estimated from All Grinder-Controllers Installed

Extrapolated Plant Annual Energy Savings (kWh)	891,395
Extrapolated Plant Electrical Demand Savings (kW)	67
Estimated Annual Electrical Cost Savings*	$58,183

*Based on electric avoided costs of $0.0506 per kWh and $16.35 per kW

Based on Table 2, the average annual electricity cost savings for each of the 40 grinders is approximately $1,455 per grinder. Each controller was built and installed for less than $1,000 for this pilot project, resulting in a payback of less than nine months.

Summary and Conclusions

Grinders are a substantial energy user in the plastics industry, as indicated by industry-leading references and field studies. The majority of energy used by an uncontrolled grinder is wasted idling, and reducing this wasted energy has not been widely addressed. Commercially-available grinder start/stop controllers exist, but are prone to user-error and are oftentimes overridden or disabled due to the maintenance and productivity issues they cause.

A novel grinder controller was recently designed and built to be more user-friendly and less prone to error than the abovementioned commercially-available controllers. The newly designed controller was installed on each grinder at the PMT plant in El Paso, TX. A sample of grinders was power-logged before and after grinder installation, and the following observations were made:

- Grinder motors were drawing 25% - 50% of full-load power when idle due to friction on the motor and air resistance on the spinning blade.
- Grinding only took place during 2% - 3% of all logged production hours, on average.
- Electrical energy savings of 96% and electrical demand savings of over 50% were achieved.
- The project yielded a payback of less than nine months.

In addition to saving energy, this new controller's user-friendliness has gained favor among plant operators. The controller's mechanism to alert operators when it is ready to accept product has the potential to increase safety and reduce downtime and maintenance costs. All of these effects contribute to a more energy-efficient and economical future for the plastics-processing industry.

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