

# Smarter Shovels Dig and Load More Efficiently

*Digital drive upgrades allow older shovels to power through the bank smoothly while improving safety and reliability*

By Steve Fiscor, Editor-in-Chief



A crane lowers a new digital control system into an electric shovel.

Whether a mine is looking to optimize truck-shovel production or move as much rock as possible, electrical upgrades make sense for many older mining shovels. Faster cycle times and improved reliability are key components in boosting productivity. In the search for ways to improve shovel performance, however, many mines have discovered that digital drive upgrades offer a smooth, more efficient operating cycle that usually out-performs wholesale increases in horsepower.

Since it completed its first upgrade at a Wyoming coal mining operation in 1993, Flanders Electric has been on a mission to improve shovel productivity and the mine's ability to maintain its equipment. "We have been very successful at increasing production on DC machines," said Mike Casson, director, international operations, Flanders Electric. "The drives that are available today are much faster and they have a lot more capabilities to control the machine."

Flanders Electric upgrades are specifically targeted to improve the safety, reliability and productivity of electric shovels. These upgrades can include replacement of existing motion motors, replacement of the static drives or motors-generator (MG) sets, replacement of the complete control system or any combination. Many options are possible depending on the type and age of the shovel being considered. The most common candidates for upgrades are older shovels with analog control systems and some later model machines that require specific enhancements.

The Flanders Mine Technology Group has pioneered an effort to offer open architecture for shovel electrics. After numerous upgrades worldwide, the group has expanded to include professionals located in the United States—Wyoming, Utah, Nevada and Arizona, and Australia and Chile. They are currently working on the third of five shovel upgrades at the Asarco Ray Complex in Arizona.

"The first two upgrades took six days and the third one is scheduled for five days," said Nathan Wright, electrical manager, Asarco Ray Complex. "When the upgrades are completed, the shovels operate visibly faster than before." Wright is responsible for Asarco's Ray-Hayden Complex—the mine and the ore processing facilities.

Asarco is a leading U.S. copper miner. The upgrades to the company's electric mining shovels amount to a complete, open control system that consists of Flanders Electric manufactured motors, Allen-Bradley (A-B) PLCs, and the Power Performance Digital Drive upgrade. With an open system, or open architecture, mine operators can service and maintain machines where a closed system would limit the electricians to work with the OEMs exclusively.

To take full advantage of open architecture, the mine's electricians need to understand what has been installed on the shovels. That's why the Flanders Mine Technology Group prefers to work with the mine's electricians during the upgrade. They get to learn firsthand how the system works. The company also offers a formal training class that maintenance personnel can attend prior to or after the shovel starts up.

"One of the most appealing aspects of this system is that it's user-friendly," Wright said. "We have a crew that is divided evenly. Half of the guys have 25 years or more experience and the other half have only been on the job for two years or less. As soon as we installed these drives, the gap between the experience levels disappeared because these drives help the technicians. The diagnostic systems are so much more accurate, that it might make the new crew as effective as the experienced crew."

## Upgrading the Technology

Electrical upgrades differ from shovel-to-shovel and mine-to-mine. "Typically, we are replacing the old analog or an older dig-

ital drive with a new Power Performance Digital Drive upgrade,” Casson said. “If we’re replacing an MG set, the shovel must have a new power stack. On a lot of existing static machines, the power stack might still be good and we just install a new front end.” A new front end, Casson explained, is a new drive controller using existing silicon control rectifiers (SCRs). SCRs convert the AC power to DC power.

The electrical upgrade typically takes seven days. “We have completed them as quickly as four days,” said Manuel Trevino, manager, Mine Technology Group, Flanders Electric. “Typically, it takes five to seven days working 10-hour shifts to do the entire changeover. We can do it turnkey, but we prefer to work with the mine’s electricians on the installation using a couple of our technicians to oversee and commission. It’s a real training benefit and it also saves the mine a little money.” Trevino has been instrumental in developing shovel-specific technology. In addition to upgrades, the group is working on haul truck spotting with GPS, where trucks can automatically back into the loading area.

“The Asarco machines have technology from the late 1970s, or early 1980s,” Trevino said. “The system is reliable. This type of control has been on the market for 30 years, but it’s time to change, and they have decided to go to digital drives.

“We have open architecture, no black boxes,” Trevino said. “The mine owns the system and they do not need to call us to fix the machines. If it gets to a point where they need our help, we will be there, but the Power Performance drives are reliable. They maintain a 20-year parts supply, which is the life of the shovel. We have installed off-the-shelf A-B Control Logix PLCs. They can buy it directly from A-B. We make no money on selling parts, we just want the customer to be happy and for them to have a reliable system.”

“The open system is really innovative in the industry,” Casson said. “A-B PLCs are the most common PLC. Most electricians know how to work with them and how to troubleshoot them. It’s much more user friendly and the mine’s maintenance personnel can work on the equipment. Black boxes frustrate electrical engineers.”

Open architecture was a large selling point for Asarco. “The only other digital drive out there is just the opposite, completely proprietary,” Wright said. “Our technicians are A-B qualified and they

have been trained on the Power Performance drives. So, we have access to every part on the machine.”

The system can be as advanced as a mine wants it to be. Some mines are now using remote diagnostics. If the mine has a wireless LAN, mine engineers could watch the shovel dig from their desk. They can not only troubleshoot the PLC system from anywhere with an Internet connection, but they could also pull the production reports. If the mine, for example, is using the Accu-Weigh system, it could pull all of that data up to a SQL server and generate production reports for each of the machines.

### Smoother Operating Cycles

The upgraded machines operate more efficiently and load more trucks in the same period of time. The Power Performance Digital Drive upgrade gives the operator the sensation that the shovel is not moving as quickly because there is no bouncing. “The operators initially complained that the shovel is not moving as quickly,” Wright said. “We rode it with them and asked, ‘What do you mean?’ They said it just moves through the bank. We explained that the continuous motion was a result of the improved control and

more effective as it increases productivity and decreases operator fatigue.”

The digital drive upgrade controls the motors to ensure peak power is provided during the digging process. Both the current and voltage are regulated to ensure the drive will provide the power the motor needs to pull through the bank, while controlling the motor to stay within the mechanical limits of the machine, Casson explained. Older systems are basically speed regulated. “Once the armature current approaches the stall current, the voltage is simply reduced to attempt to reduce the voltage to hopefully reduce current,” Casson said. “This makes the machine ‘jerky,’ which is more taxing on the mechanical components of the shovel.”

Because the older control system does not have that level of precision, a conservative approach to the stall limit is necessary. Flanders motors are more robust, Casson explained, which allows the digital drives to regulate the true power of the machine—voltage and amperage—and control the machine at peak power. “The acceleration and deceleration times are actually reduced with the Power Performance Digital Drive upgrade,” Casson said. “They are done with an ‘S’ curve



The Power Performance Digital Drive controls the motors to ensure peak power is provided during the digging process.



Flanders Electric manufactures motors, such as this hoist motor, specifically for mine-duty applications.

function to make speed changes smoother. Doing this in conjunction with controlling maximum power allows the dipper to dig through the bank more smoothly and continuously. This reduces the mechanical stress on the shovel and improves the cycle time. The smoother controls facilitate a more repeatable cycle time among various operators. It eliminates the need for the operator to have vast experience on the shovel in order to control it more smoothly. The approach also makes the machine cycle faster.”

Matching hoist, crowd, and swing is critical to having a smooth machine. “If you can hoist really fast, but swings take twice as long, there is no benefit,” Casson said. “All of the motions have to be balanced with what the shovel is digging and trucks being loaded.”

With the analog system, the crowd was real slow compared to the hoist speed, Wright explained. A lot of times the operator is waiting for the motion to catch up. “With the digital drive, all of the speeds are matched,” Wright said. “When the operator lowers and retracts to get back into the

tuck position to dig, he does not have to wait for it to tuck. It’s lowering and retracting at the same speed so the operator does not have to wait on one or the other. The drives are all matched. When he begins to dig, it’s a smooth motion.”

This is accomplished through what Wright calls continuous field regulation. “They can speed the motion when the dipper is empty by reducing the field strength,” Wright said. “With the analog system, there were only two choices: strong or weak fields. These drives match that for smoother operations.”

A lot of these improvements can be attributed to a Fly-by-Wire approach to electrical engineering. Fly-by-Wire is a term that refers to the joystick control system that allows fighter jets to interpret what the pilots want to do. “On a shovel, when the operator hoists and crowds, he might have it full on, but the digital drives know what kind of current it takes to go through the bank,” Wright said. “It automatically regulates. So, even when the operator is telling it to apply more power, it knows what it takes to continuously move

the dipper through the bank. Without the stall, the mine saves money on motor life.”

Flanders has automated some of the dig functions. “When the operator hoists the dipper through the bank, the shovel will crowd itself to keep a full load in the bucket,” Casson said.

“It’s an intuitive control,” Wright said. “The drives understand by the way the operator pulls on the stick that he wants to fill the dipper and it fills the dipper based on the summation of the operator’s input and the drives programming. It understands that, yes, the operator might be telling me to continue to crowd, but it knows it will stall soon. So it lets off, to keep the dipper moving through the bank. It’s not completely autonomous. If the operator lets go of the stick, the shovel would stop.”

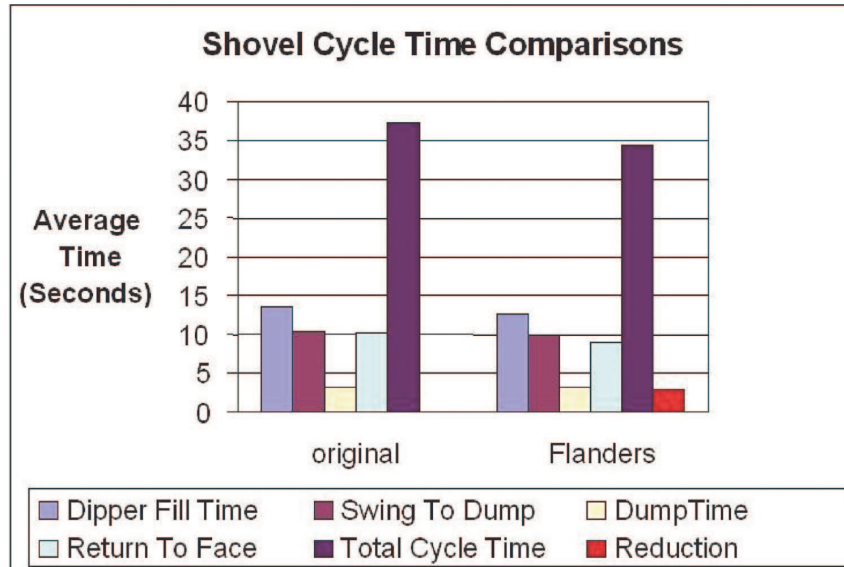
### Fault Recognition

The new system also uses Smart Fault Recognition to power down in a controlled fashion. “The one area where we have really improved is faulting and how to power the machine down rather than just doing an emergency E stop on the main contactors,” Casson said. “The way some systems are set up, with any fault, they automatically shut the entire machine off at the main contactors. With all of that energy moving, oftentimes what was a small problem results in a different failure, not what actually tripped the machine.”

The Smart Fault Recognition system shuts down the motion that has the fault while the other motions remain active. If the swing motors trip, Casson explained, when the shovel is still hoisting, the system automatically controls the hoist to a stop. “The machine stops, but it does not just slam to a stop,” Casson said. “It’s an emergency power down, not an open-the-main-contactor fault.”

In the case of a catastrophic fault, it will shut down the machine. “If the shovel has an over-current on hoist and the operator starts to swing, the OEM system would shut down all of the motions even when the swing has no fault,” Trevino said. “That energy on the motors will have to go somewhere and it usually comes as a flash.”

“With the analog machines, we had the choice of an instantaneous or a 30-second shut down,” Wright said. “The upgraded machine identifies specific areas and starts shutting the machine down in a controlled, systematic fashion. Instead of a shutdown that was like hitting the emergency kill switch, it’s more like pressing a



Data from an Australian coal operation showed a 3.5-second reduction per cycle.

stop button. It phase retards the converters and everything is shut down sequentially.”

An instantaneous shut down would always result in damaged components. That was a huge problem for Asarco’s shovels previously. “When we shut down a motion under full load, we would lose SCRs, fuses, or a variety of our electrical and mechanical components,” Wright said. “SCRs cost about \$800 to \$1,000 each. It depends on what the operator was doing when the machine received the fault.

“If we were lucky enough to blow only components we had in the warehouse, it would cost us four to six hours of unscheduled downtime to isolate and repair,” Wright said. “Otherwise, the mine is waiting at least a day on parts from Milwaukee.”

## Smarter Shovels

The shovel now knows the machine’s geometry, where the dipper is located, and its position relative to the machine. If the mine is trying to maintain a level grade, they can incorporate GPS and bucket position technology to keep the shovel from operating too high or too low. This technology is also very useful for boom and track protection.

A BoomPro limit system keeps the torsion box from hitting the boom during the operation of the machine. “If the torsion box comes too close to the boom, the system will remove reference from the operator on whichever motion he is using and give a negative reference to move out the torsion box,” Trevino said.

The boom profile system on the original analog machine, Wright explained, is a

stepped protection. “The way it’s set up, you could protect the boom or you could dig,” Wright said. “There was not a lot of leeway. If you set it to protect the machine, you could not fill the dipper.”

With this boom profile, the drives know the geometry of the boom. “We can get in close to the boom and the drive will protect it,” Wright said. “When the operator is calling for it to retract toward the shovel and it gets close, the drives oppose that effort because they know the boom geometry. They start to push out rather than allowing the torsion box to clabber into the machine.”

A boom replacement will cost \$1 million. Wright knows. Asarco just replaced one on one of these shovels because of that exact reason. “The torsion box kept hitting the boom,” Wright said.

## Cycle Time Improvements

Flanders acquired data from an upgraded machine working in Australia that showed that they are saving 3.5 seconds per cycle. “If the mine has the trucks, this becomes a massive number at the end of the year,” Casson said.

In addition to a smoother operation, the upgrade shovels can transfer from dig to propel much more quickly. Switching to propel is close to instantaneous, according to Wright. “The operators are in and out of propel much quicker, which cuts down the time they are waiting to move and non productive time.”

“We are able to lower the machine’s time to transfer from propel to dig to two

seconds each way,” said Trevino. “In Wyoming coal, where they load from one side of the shovel, they have to propel every three loaded trucks and they paid for the system through time savings alone.”

With the way some of the older control systems were set up, the shovel would take as long as 10 or 11 seconds to transfer from dig to propel. “That doesn’t sound like a lot,” Casson said. “If a mine propels every five trucks and it is loading 250 trucks per shift, those numbers start to add up.

“This is a site specific benefit,” Casson said. “If the mine is truck-limited, where the shovel is always waiting on trucks, it’s not a big deal. But, if there’s enough trucks to keep the shovel efficiency up, that becomes a major concern, when a mine is shovel limited.”

Casson readily admits that no one upgrade is ideal for every shovel at every mine. The mine needs to determine their needs as far as production goals. “If they are truck-limited, there are still ways to improve the reliability of the shovel to reduce the maintenance costs,” Casson said. “For even further reduction on maintenance costs, our latest development is a complete AC replacement for the older DC systems on both shovels and draglines.”

Wright is very happy with the mine’s decision to work with Flanders Electric. Asarco was in an alliance where the company would only purchase OEM motors and parts. Wright and the other Asarco managers did their homework and Asarco decided to not renew the alliance. “We have saved the company more than \$1 million in motor rebuild costs alone during the last seven months,” Wright said. “Flanders manufactured motors come with a 12,000-hour warranty. That is four times what the OEMs offer.”

According to Wright, Flanders stocks motors onsite and the OEMs won’t do that. “Flanders is investing their capital in keeping our operation running. That also saves six or eight hours, provided it is not after-hours, weekend, or holiday, in unscheduled downtime waiting for a motor to arrive.” Flanders Electric, Wright said, offers twice the motor life at half the price.

The first upgraded Asarco shovel went online in November, and the shovel has not experienced a drive fault. “They are living up to everything they said they would do the first day we called them in,” Wright said. “We needed a partner and Flanders was the right guy. They have increased shovel availability two-fold.”