Increasing Paper Machine Control and Reliability with PIV Replacement

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INTRODUCTION

Paper Machines throughout the world have utilized line shafts as a primary source for power. These can be either steam driven or electric. A single line shaft provided a very cost effective way to manufacture a paper machine. Over the years, several different approaches were developed to connect and vary the speed of the sections connected to the line shaft. One such method is the use of differential gear boxes and a small mechanical device called a Positive Infinitely Variable (PIV). PIV's, working with the differential gearbox, provide a means to adjust the speed of a particular section on the line shaft. PIV's can be costly to maintain and pose a threat to paper machine performance. Avtron has developed its *Electrogear*™ product as a cost effective solution to increase paper machine productivity and reliability.

BACKGROUND

A differential gearbox is used along with the PIV unit to control the speed of a particular section on the paper machine. A differential gearbox will typically be mounted in-line with the line shaft of the machine. The line shaft sets the main speed of the machine and the differential is used to vary the output speed that is supplied to the roll for a section. Figure 1 shows a typical differential gearbox and its associated PIV.

Figure 1 – PIV and Differential Gearbox

Differential gearboxes take the line shaft in and provide a means of varying the output speed through internal gearing. A typical mechanical schematic is shown in figure 2.

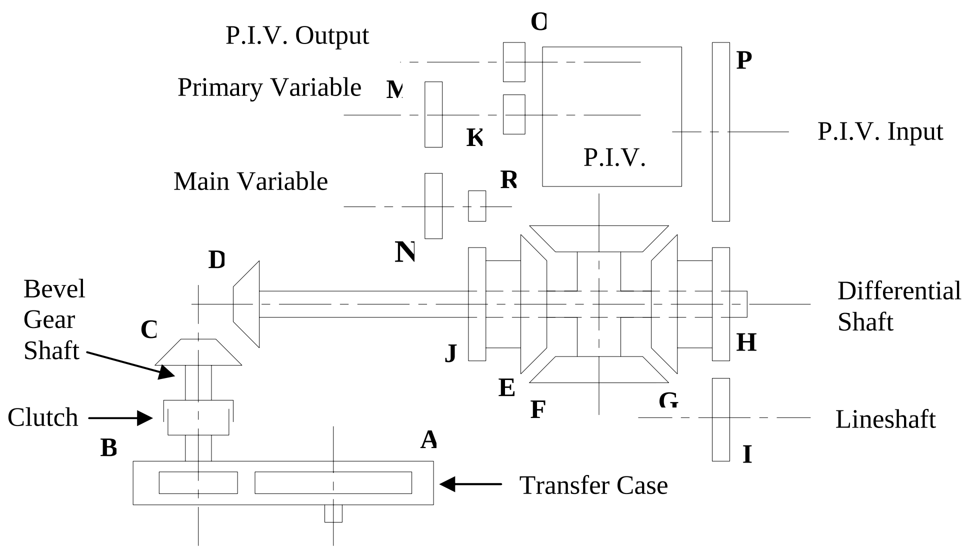

Figure 2 – Differential Mechanical Schematic

Sectional definitions include:

Line shaft - Input shaft to the differential that is connected to the machine's main line shaft.

Differential Shaft - Provides the lineshaft side of the differential gear. This is also known as the fixed speed side of the differential gear. Speed is related to the line shaft speed and the ratio between H and I.

P.I.V. Input - An output shaft from the differential unit that is connected to the input of the P.I.V. unit. This provides the input speed for the P.I.V. and is related to the lineshaft speed by the ratio "P" – "H". Typically the P.I.V. input speed is approximately ½ of the line shaft speed.

P.I.V. Output – Output shaft of the P.I.V. unit. This is a variable speed that is related to the P.I.V. input speed by the P.I.V. ratio. Typically in the range of 4:1 which provides an output RPM range of 250 – 1000 RPM (On a 1000 RPM lines haft).

Primary Variable – Input shaft to the differential that connects to the PIV output shaft.

Main Variable – Intermediate shaft on the differential. Typically used for internal gear reduction.

Differential Shaft, Variable Side – The variable speed side of the differential gear is established by taking the P.I.V. output RPM and the ratio between "J" and "O". This gives the Variable speed range that is used for the output speed adjustment.

Bevel Gear - Right angle gear that connects the differential output shaft to the clutch and transfer case. Set by the ratio of "C" to "D", typically in the 1;1 range.

Clutch - Separates the differential assembly from the paper machine section. Allows the section to be taken off-line from the line shaft. Typically air driven and is adjusted to provide a ramping feature when the section is clutched in.

Transfer Case - Is the transfer point from the differential to the driven section. This ratio is set-up by "A"- "B" and is in the range of 2:1.

The differential gearbox is connected to the line shaft and drives a set of gears directly from it. A second set of gears connects the PIV input to the line shaft input providing the line shaft speed mechanically to the PIV unit. The PIV output shaft comes out of the differential and connects to the PIV unit. A second shaft coming out of the PIV unit is then connected back into the differential providing a variable speed input.

Output shaft speed of a differential is calculated by taking the input speeds on each side of the planetary gear, adding them together, and dividing by two. On one side, the shaft speed matches line shaft speed. The second side is adjusted by changing the gear ratio of the PIV unit. As the ratio is changed, the output speed of the PIV changes causing the second shaft on the differential to change speed. This speed is then mechanically calculated to form the differential output speed. Typical speed ranges are generally limited to +/-3% of the line shaft speed.

PIV REPLACEMENT

Paper makers are demanding better speed and draw control to improve reliability of machine operation and better quality products for their customers. Line shaft machines with PIV's and differential gearboxes can be upgraded to provide the required performance. By replacing the PIV with an AC motor and controlling it with an AC drive, sectional speed control can be improved. Progressive draw control can also be achieved if multiple sections are converted.

One concern with upgrading a differential gearbox is that if the differential shaft spins in the opposite direction, a mechanical runaway condition occurs. This runaway condition causes the differential unit to continually speed up until a mechanical failure occurs. This failure can cause severe damage to both equipment and personnel. Several years ago, a device was designed to provide anti-backlash in the differential. This mechanical upgrade package inhibits the differential shaft from rotating in the reverse direction protecting the differential from runaway conditions.

Replacing a PIV unit on a differential requires two items:1.) modification to the differential for the anti-backlash hardware, 2.) Installation of the AC motor and controls.

<u>Anti-backlash</u>
Each differential to be upgraded must be equipped with an anti-backlash assembly. Retrofitting the differential includes the installation of a new output shaft and a gear assembly. The retrofit kit acts like the gearing on a ten-speed bicycle. It engages in one direction but is allowed to free-wheel in the opposite direction. This ensures that the differential shaft can not spin in the opposite direction. Once installed, the PIV could be reattached allowing the upgrade to be done in two steps if desired.

<u>PIV Replacement</u>

Once the differential has been modified, the PIV can be replaced with an AC motor. Typical motors will run approximately 25% of the total differential horsepower rating. A size three differential and motor are shown in figure 3.

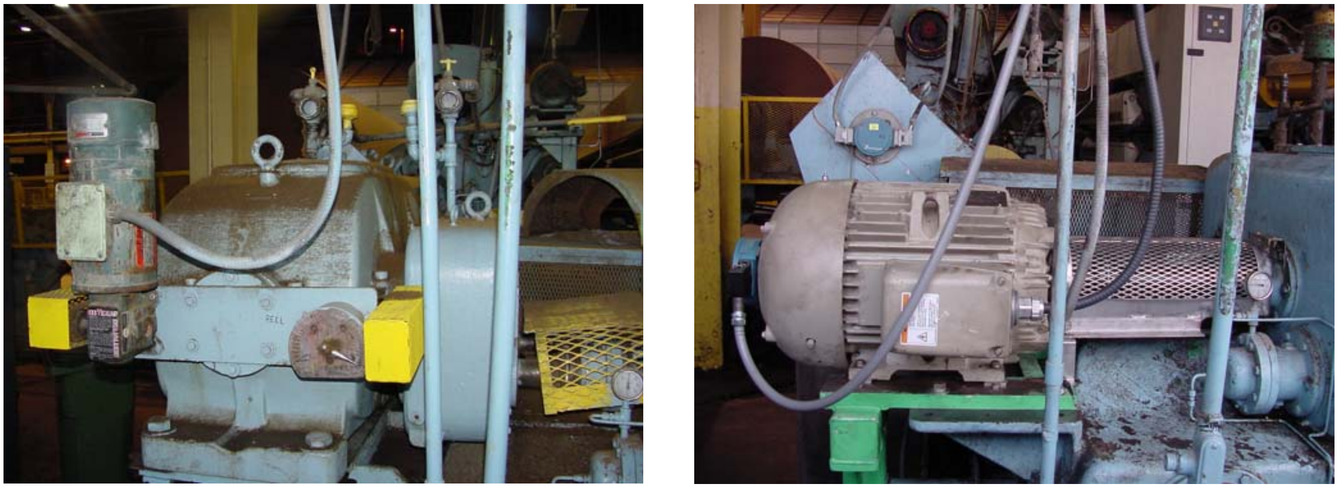

Figure 3 – Size 3 PIV Upgrade Before (left) and after (Right)

Removal of the PIV unit leaves a base mount where the motor mount can be installed. A shaft and coupling are used to mechanically couple the motor with the differential. A safety guard is then installed to protect personnel when they are working in the area.

CONTROL SYSTEM

AC drive control on a PIV is achieved using an AC Flux Vector drive. Figure 4 shows the basic control system used.

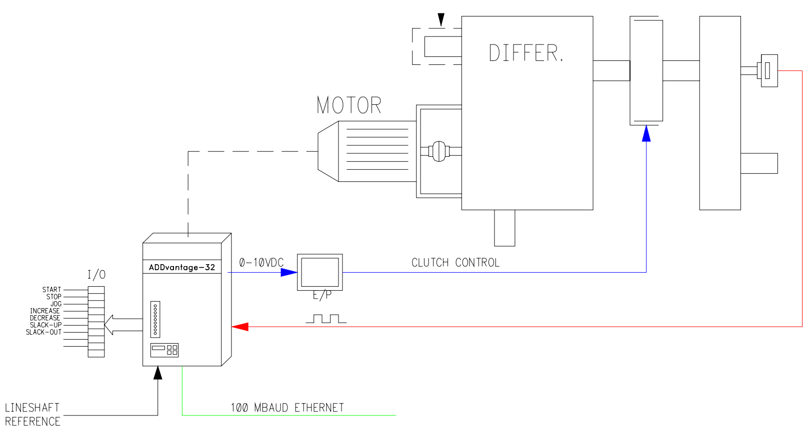

Figure 4 – PIV Control One-line.

A line-shaft reference is required by each section. This can be a pulse generator signal or an analog reference of the actual line-shaft speed. Actual motor speed is detected by the AC drive directly (via an encoder). Output speed of the differential is controlled by monitoring the line shaft speed and adjusting the AC motor speed for the desired output of the differential. For optimum performance, the differential gear ratios should be known.

Avtron's drive-centric PIV control is unique with respect to the control hardware required. Most PIV upgrade systems being offered require not only the AC drive but also a Programmable Logic Controller (PLC) as well. The PLC is used to calculate the required output speed and to handle control loops for the speed control. Avtron's Electrogear™ system does not require a PLC to achieve the upgrade of the PIV. With smart drive technology, all control parameters required for the upgrade reside in the AC drive allowing for a more cost effective upgrade on the machine. Features like progressive draw, tension control and other paper machine functions are also built directly into the drive.

Tension control can also be achieved using Electrogear™. Upgrading the PIV unit on the reel of a paper machine allows for better control of tension on the sheet. Torque is monitored through the motor current and can be adjusted by the control system based on operator desired setpoints. More motor torque produces additional pull on the reel producing more in-wound tension.

SYSTEM BENEFITS

Upgrading the PIV sections of a paper machine offers several benefits to the user. One such benefit is the potential of increasing the speed of the machine. In many cases, the speed of the machine is limited by the amount of draw that can be produced at the wet end. PIV's can generally only produce about a 3% swing range per section. A typical speed profile chart is shown in figure 5.

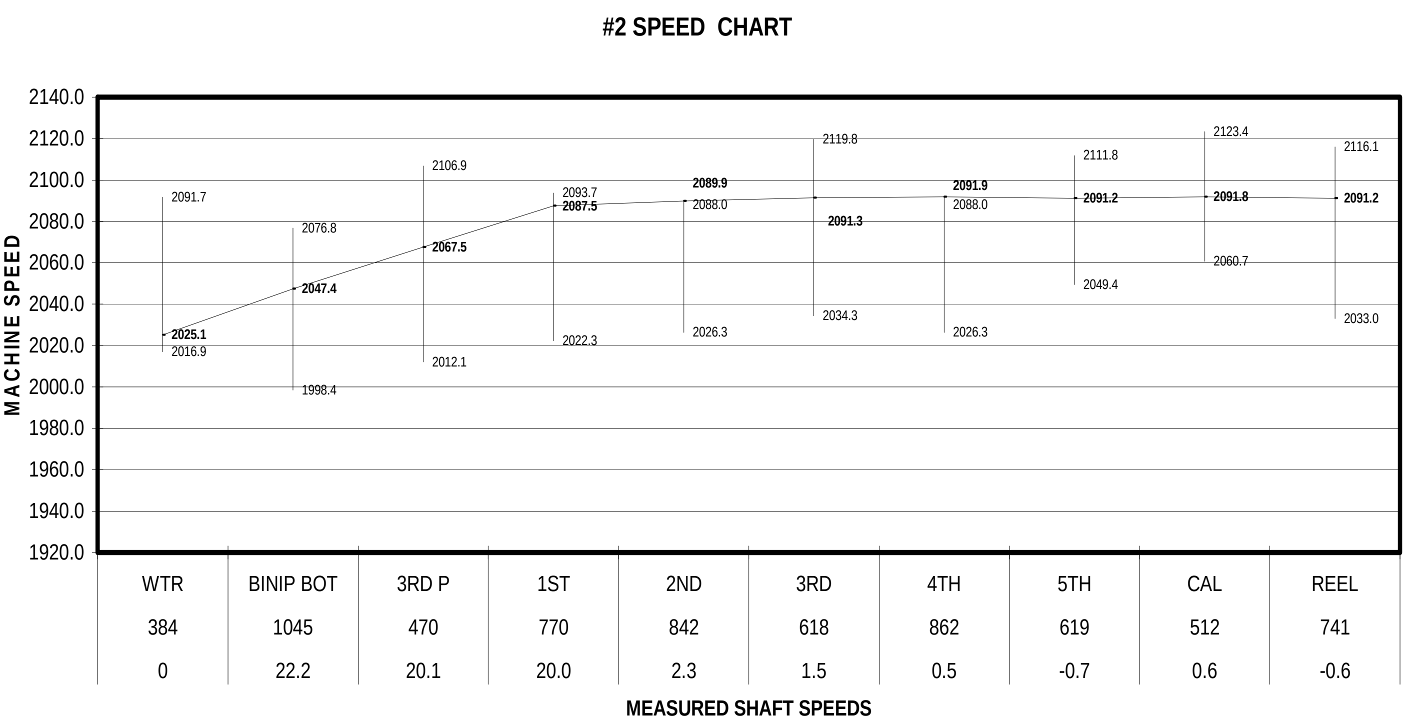

Figure 5 – Machine Speed Profiles

The chart in figure 5 shows the speed capabilities for each section of the machine. Desired sectional speeds are listed along with the potential speed range that each section can provide. Analyzing the graph shows that the 1st, 2nd and 4th dryer sections are all at the limits of their adjustments. Because no other draw adjustment is capable, the machine is at the highest speed it can produce. Increasing the speed would cause the sections to hit their limits and not be able to produce the draw required to produce the paper properly.

Looking at upgrading these three sections with Electrogear™ PIV replacements, the speed chart in Figure 6 can be generated.

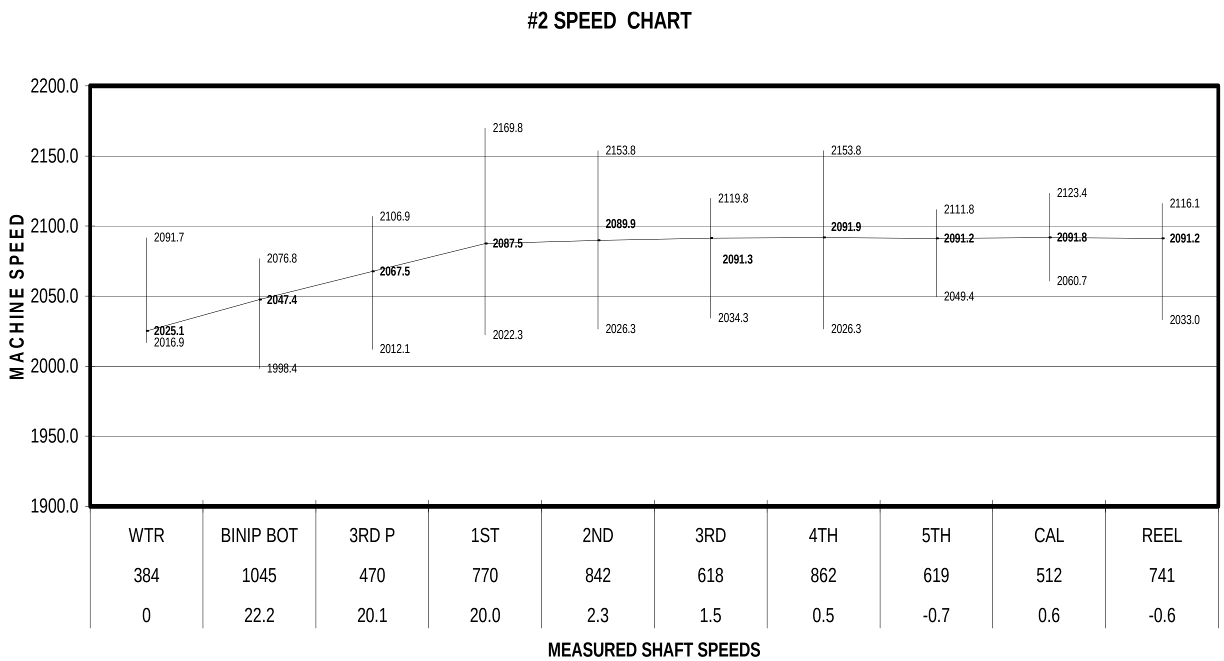

Figure 6 – Sectional Speeds after PIV replacement

By adding Electrogear to the three dryer sections, the ceiling has been raised on the draw capabilities of these sections. This allows the line-shaft speed to be increased and the paper makers to adjust the draws to the required values. Upgrading select sections can produce machine speed increases in the range of 5-10%. Several other factors contribute to this being achievable including dryer capacity, line-shaft speed capability, etc. These factors should be evaluated in conjunction to determine the amount of machine speed increase that is really available.

Other benefits realized when upgrading PIV’s to AC motors and drives include:

<u>Progressive Draw Control</u>

A major benefit to upgrading PIV sections on a paper machine is the ability to obtain progressive draw control. Line-shaft machines, by design, offer very little control capability. If draw changes are required, each section must be manually adjusted to achieve the appropriate ratios. Upgrading the PIV’s allows the machine operators to have a digital control system where progressive draw setpoints can be executed from a single location and also allows for adjustment on the fly. This can reduce set-up times and increase the quality of the product. Even if the line-shaft speed swings, Draw ratios can be kept constant reducing sheet breaks and other draw related issues.

Tension Control

Performing a PIV upgrade on a Reel section provides the capability of adding tension control to the paper machine. Adding the AC motor/drive provides the capability for torque control of the Reel section. Torque regulation allows for better tension control and can reduce wrinkling as the Jumbo is built and produce better in-wound tension.

Slack-up/out

Slack take-up and take-out are beneficial features of a PIV upgrade. It is very common for operators to manipulate the slack seen in the sheet. With a PIV in place, this must be done manually if the capability even exists. With an upgraded system, slack-up and out are simple pushbutton entries which provide a consistent amount of over or under speed to adjust the slack in a section. This reduces thread-up times on the machine.

Diagnostics

Troubleshooting paper machine problems on a line shaft machine can be daunting. There is typically little to no data available due to the mechanical structure of the machine. With PIV replacement sections in place and the proper diagnostic monitoring system like Avtron's PerformanceView™, machine data can be recorded and monitored so problems can be diagnosed and solved faster. Sectional data like speed, torque, draw, etc. can be monitored eliminating issues quicker and increasing production time. A typical section's data can be seen in Figure 7.

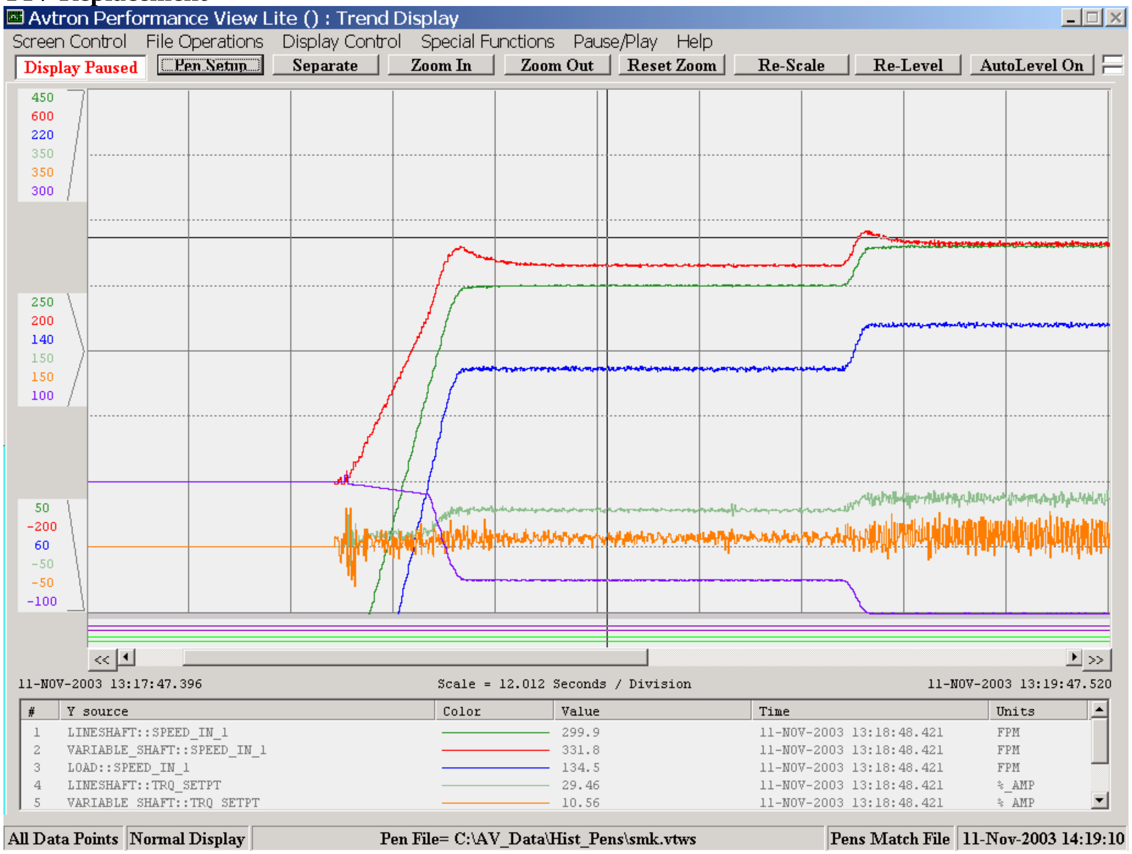

Figure 7 – Typical Diagnostics Available after upgrade

Less Maintenance

Mechanical PIV's are very complex machines and can be very costly to maintain and repair. Typical maintenance consists of a rebuild every 2-3 years. On larger sections, this can run into thousands of dollars. In addition, a mechanical failure of the PIV can cause several hours of down time as it is replaced or repaired. Eliminating the PIV also eliminates the most likely device to fail reducing the risk of costly down time.

Clutch Slippage Detection

A very costly repair on line-shaft machines with differentials is clutch repair. Air pressure drops, mechanical failures, and lack or preventive maintenance can all contribute to the failure of the clutch. By monitoring the transfer case speed of the section along with the differential speed, slippage of the clutch can be detected and the appropriate actions taken before a major failure occurs. Clutch failures can cost upwards of $40,000 to repair in addition to the significant amount of downtime seen by the machine. Detecting slippage when it occurs and warning people of its presence allows the operators to bring the machine down in a controlled manner and rectify the situation before a major failure occurs.

CONCLUSION

There is great pressure on the paper industry today to make machines run more reliably and provide better quality product. A significant percentage of machines in North America still utilize a line-shaft as their primary source of propulsion. These machines are typically very robust but have limited control and diagnostic capabilities. Set-up time and grade changes can be very time consuming and reduce machine efficiency. Typical upgrade paths used in the past were to break sections off of the line shaft and replace them completely with a new motor and AC or DC drive. This is very costly and requires longer outage times than a PIV upgrade to perform the work.

A more cost effective way to upgrade line shaft machines that use PIV’s and differentials is with an AC motor/drive replacement. These upgrades can be performed in a fraction of the time and cost as a wholesale drive replacement and can provide 95% of the benefits of a sectionalized machine. Progressive draw control, slack-up/out control, diagnostics, machine speed performance and sectional operator control are all available with an upgraded section. Projects can typically pay for themselves in a year or less.