Steel Dynamics Inc.'s Bold Upgrade of Galvanizing Line No. 1

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INTRODUCTION

Steel Dynamics Butler, Indiana plant knew they had to do something with Galvanizing Line #1 to ensure continued reliable operation. Computers, PLCs and I/O were 20 years old and obviously needed replacement. Not so obvious was what to do with the DC motors that still had useful life remaining. The solution was a Dual Purpose drive suitable for controlling both AC and DC motors while providing an upgrade path to all AC. AC-DC converters operating at unity PF relieved the plant of significant kVA loading with lower cost operation. This paper will review the successful upgrading of Galvanizing Line #1.

BACKGROUND

SDI Galvanizing Line #1

Steel Dynamics (SDI) Butler Flat Rolled Division includes operations in Butler IN, Jeffersonville IN, and Pittsburgh PA. The Butler IN campus includes EAF's, Hot Mill, two stand reversing cold mill, temper mill, two pickling lines, two galvanizing lines, a paint line, and batch annealing furnaces. Galvanizing Line #1 was built in 1999. The line includes dual entry pass lines, welder, entry accumulator, furnace section, galvanneal, temper mill, tension leveler, chromate coater, acrylic coater, oven, exit accumulator, oiler, exit shear, and tension reel.

Figure 1 – SDI Butler Campus is located in Northern Indiana, near Butler IN.

DISCUSSION

Reasons for Modernization

SDI wanted to increase the productivity of Galvanizing Line #1 but was limited by the capability of the furnace. Thicker strips required the line to run slower to heat the strip uniformly. The top end speed of the line was fine, but many products could not run that fast because of the furnace limitations. Increasing the furnace capability would also allow for increased flexibility of the line as it would enable it to run cold rolled product as well. The line lacked a cleaning section, so it was used only for pickled hot band products.

Planned Line Additions Required a Major Outage

SDI made plans to add a cleaning section to expand the line's capability to include Cold Rolled products. To address the furnace limitation, a plan was developed to extend the furnace. Addition of this equipment would require a major outage.

If you are planning to take a rare major outage, you might as well make the best use of it. SDI carefully considered other potential improvements that could also make use of the outage time. Addressing electrical obsolescence and replacement of high maintenance components emerged as prime candidates.

Electrical Obsolescence and Maintenance Issues

The major outage offered an opportunity to address electrical obsolescence issues. The following automation and drive components were obsolete:

- DC2000 DC drives were obsolete and no longer supported
- The line control PLCs were 90/70 with Innovation Series Controllers as communication bridges to DLAN+
- The I/O was mainly Genius I/O which was obsolete
- OC2000 Operator Control Panels were obsolete
- The Operating Systems and Computer Hardware were obsolete
- HMI hardware was obsolete and the software was an early version of Cimplicity

Maintenance issues that SDI wished to address:

- The whole mill was DC, and an all AC mill would offer reduced maintenance and increased reliability..
- The DC furnace motors were a frequent maintenance issue
- Subsystems on the line were implemented in their separate PLCs (90/30, 90/70, PLC5) with only an interface to the main control system, some nothing more than hardware I/O which made maintenance and troubleshooting challenging.

Options considered for DC Drive Replacement

SDI considered every possible option for replacement of their obsolete DC drives:

- For the furnace, replace all small motors and drives with AC drives to reduce maintenance.
- Replace all non-furnace DC drives with new DC drives.
- As a cost advantage, employ new Digital Front Ends (DFEs) for the larger DC drives allowing the power bridges to be retained.
    - For the smaller DC drives, they would be replaced with new DC drives.
- Replace all motors and drives with AC.
    - This option was quickly discarded due to prohibitive cost and extending of the line outage.
- One electrical vendor offered a newly developed alternative; a dual purpose AC drive that could also control DC motors.

Dual Purpose Drive Concept

Upgrading an existing and productive DC line to AC is an expensive proposition. The DC drives become obsolete, but the DC motors, especially the larger ones, still have a lot of useful life. If you replace the existing DC drives with new DC drives, you will likely never get to AC and never enjoy the lower maintenance, increased reliability and power system benefits. The concept of the dual purpose drive is to offer an intermediate step to replace the drives yet retain the DC motors.

The dual purpose drive starts out as a standard AC drive. Four of the IGBT devices in the bridge are used for the DC armature (Refer to figures 2 and 3). One of the remaining two IGBT devices is used for control of the DC field (Refer to figure 4). Filtering to smooth the output and protect the existing motor from switching transients is added to both the armature and field circuits in an outboard auxiliary cabinet. All this extra hardware associated with the DC application is located in the AUX panel so that it can be discarded when the motor is changed to AC sometime in the future. Finally, new software is loaded into the drive to make this AC drive capable of controlling a DC motor.

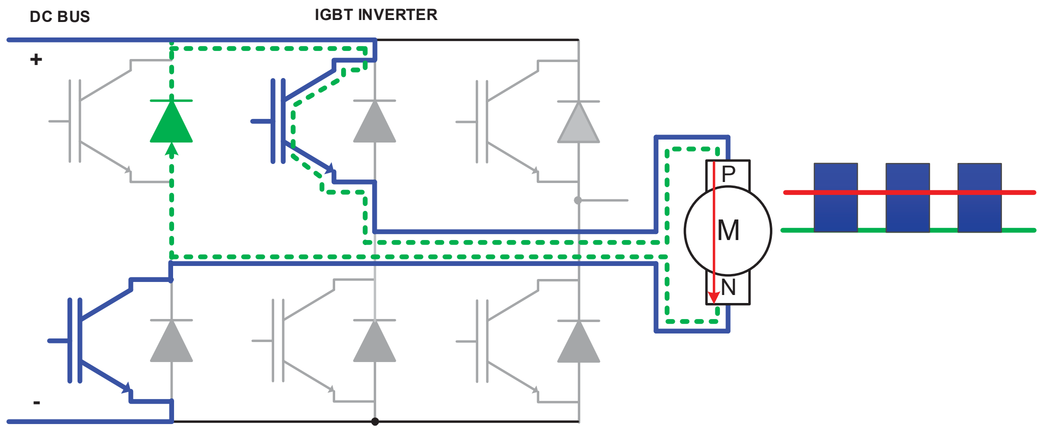

Figure 2, DC Motor Armature Positive Voltage case (Quadrant 1)[1]

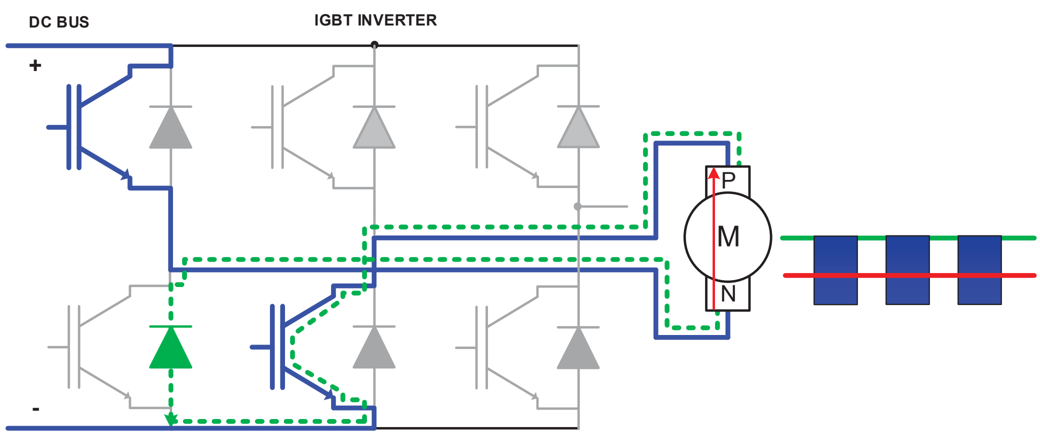

Figure 3, DC Motor Armature Negative Voltage case (Quadrant 3)[1]

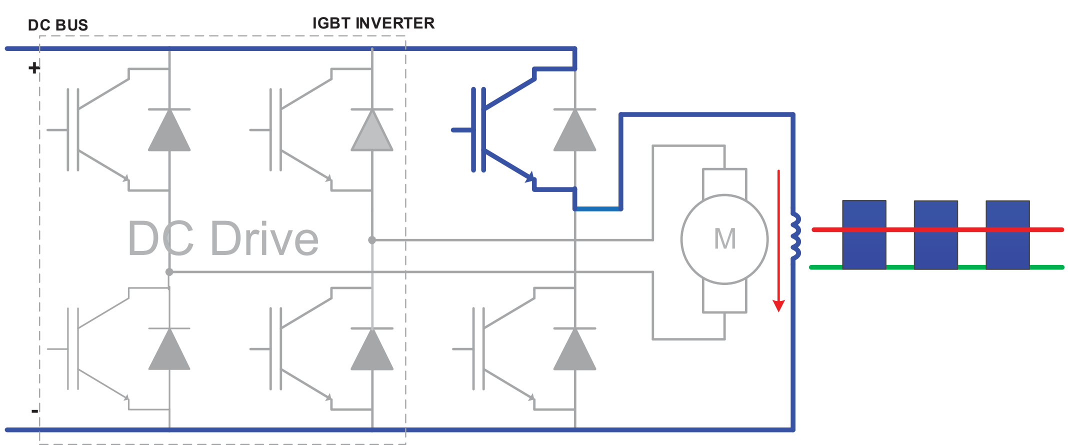

Figure 4, Inverter Bridge provides excitation for DC Motor Field[1]

Why was the Dual Purpose Concept attractive to SDI?

- It provides a path to an all AC line without having to replace the larger DC motors immediately.
- The new AC dual purpose drive immediately provides benefits for the power system:
    - Near unity power factor, even when controlling DC drives (solid state DC drives have notoriously poor power factor, especially at light loads)
    - Low harmonics
    - Improved efficiency
- The concept could be proven without burning any bridges, because the existing DC drives could be left untouched.
- This concept could be proven on Galvanizing Line #1 and later applied to the Continuous Pickle Line where converting to AC provides maintenance advantages in the corrosive pickling atmosphere.

Project Scope

After several years of careful consideration and evaluation of alternatives, SDI decided on the following mechanical approach:

- Extend the steel superstructure supporting the furnace westward towards the Entry section.
- Split the existing furnace and move the pre-heat portion of the existing furnace westward onto the new steel structure.
- Insert a new Radiant Tube provided by CMI between the two existing furnace sections.
- Prepare and install a new cleaning section provided by DFHI underneath the new steel structure.
- Install a new hot bridle provided by CMI on the new steel structure.
- Move Bridle Roll 2 to its new westward location.

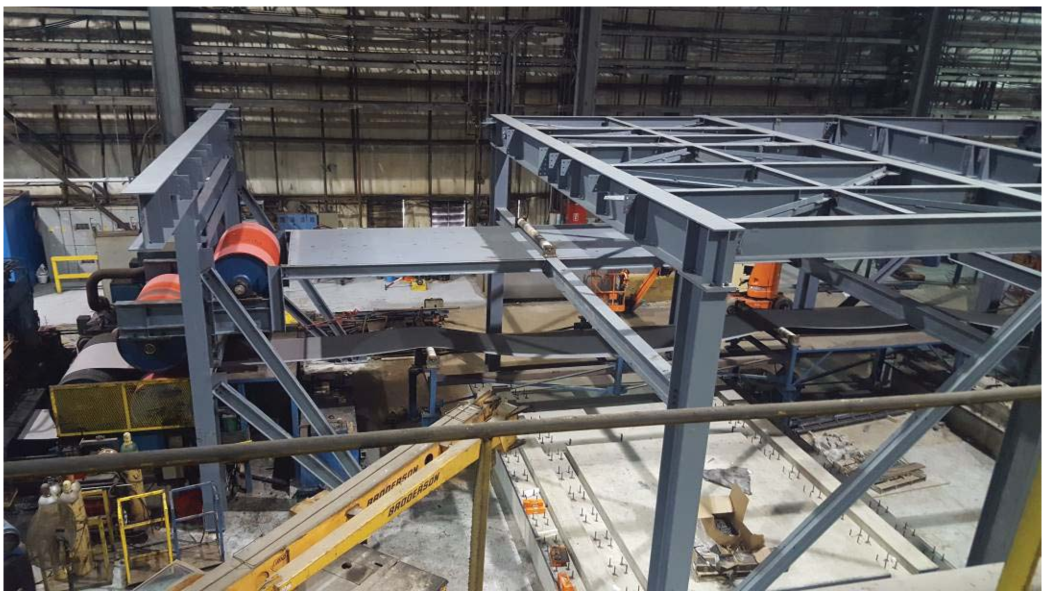

Figure 5, New Steel Super Structure to support Furnace Extension

As part of the same project, SDI decided on the following electrical approach:

- Replace all of the DC furnace motors and drives with new AC motors and drives.
- Replace all of the small DC motors and drives in the line with new AC motors and drives.
- Retain all of the larger DC motors and power them with new AC Dual Purpose Drives.
- Begin the conversion to the Dual Purpose drives with the Entry Bridle in order to prove the concept.
- Gradually switch to the Dual Purpose drives for the remainder of the line on a planned basis during subsequent maintenance outages.
- Locate the new drives in three new E-houses so that the existing drives can be maintained in their existing PCRs throughout the transition period.
- Replace the existing line control 90/70 PLCs & UC2000's with new nV Controllers.
- Replace the existing Genius I/O with new nV I/O.

- Replace the existing HMI and OC2000 Operator control panels with the latest Cimplicity HMI and Touchscreen clients.
- Replace the existing Level 2 with new Level 2 including web based production and quality reports.
- Replace the existing computers and operating systems with the latest Windows based Servers and Clients.
- Move functionality from the existing Furnace Controllers to the new nV controllers.
- Move functionality from the existing Galvanneal Controller to the new nV controllers.
- Move functionality from the existing Air Knife Controller to the new nV Controller.

Figure 6, Existing DC2000 DC Drives

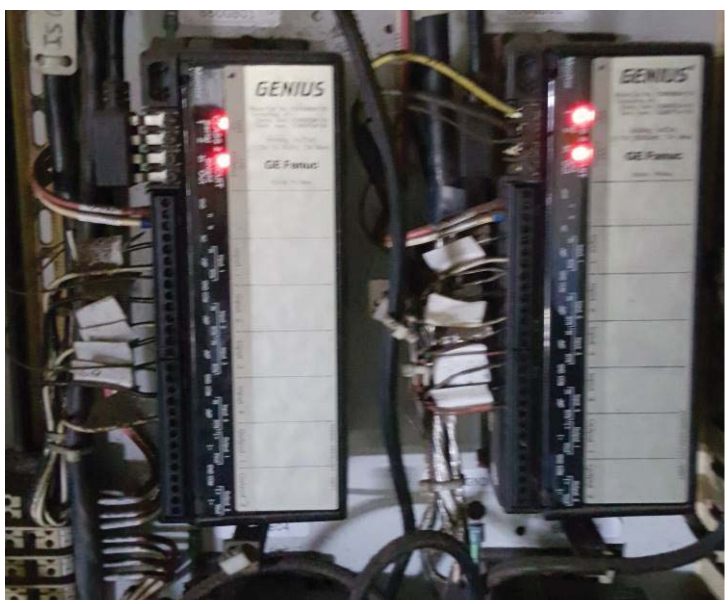

Figure 7, Existing Genius I/O

Figure 8, Existing OC2000 Operator Panels

Engineering Phase
Software and hardware engineering for the new automation system, project management, and dual purpose drive development were all performed in Roanoke, Virginia by TMEIC Corporation. TMEIC worked closely with SDI to identify the physical and electrical requirements for the new equipment. SDI provided the three new E-houses for the new drive and automation equipment.

Figure 9 One of three new E-houses for new Drives and Automation Equipment

The existing drive and automation equipment were arranged in PCRs located near the Entry, Process, and Exit sections of the line. To minimize disruption with existing equipment and to allow the maximum amount of work to be done while the line continued to run, it was decided that the new equipment would be located in new E-houses near the Entry, Process, and Exit sections of the mill. The E-houses were located just outside the north wall of the building in separate structures (see Figure 9).

SDI insisted that the control of subsystems, particularly the furnace control, be integrated together as part of the main automation system using the same hardware platform and software tools. Normally, these are just interfaces between separate and typically different hardware and software systems and not integrated together. This required a lot of coordination between SDI, TMEIC, and PyroAir, the furnace experts. The upgrade incorporated the subsystems into the new I/O, control platforms, software tools, HMI, and alarm system.

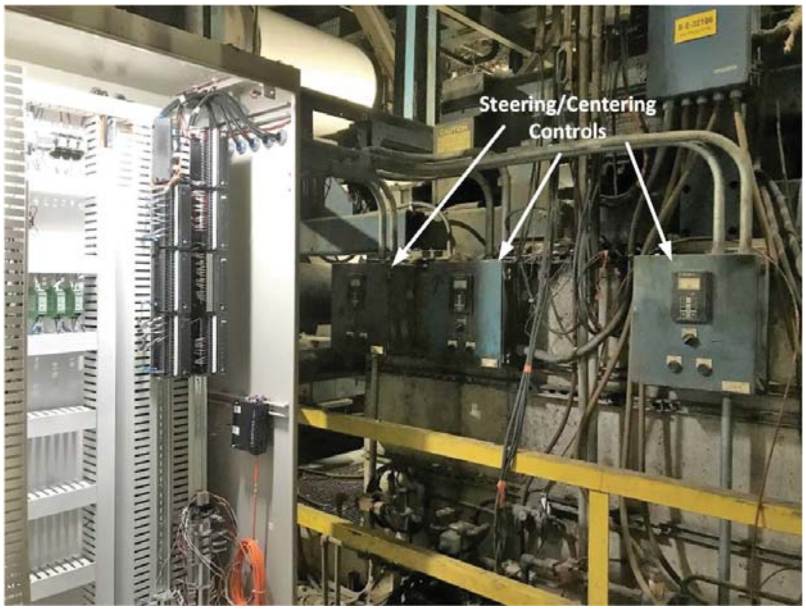

Figure 10, Steering/Centering Controllers (indicated by arrows) were replaced with new remote I/O (left) and nV Controllers

Procedures were adopted to minimize the outage time and facilitate pre-outage work prior to the shutdown. Existing wiring that was to be re-used was double tagged with both the existing wire number and the new wire number to speed and improve accuracy of wiring changes.

Software System Integration Test in Roanoke, VA

The Galvanizing Line #1 software was tested and confirmed during System Integration Test performed in the TMEIC software test lab in Roanoke, VA. A System Engineer was assigned to define and orchestrate the System Integration Test. Testing activities, defined by a formal System Test Plan, include a checklist to sign off on each test. Level 2, Level 1, and HMI are all included. Simulation software takes the place of the missing items such as the motors, drives, Line, I/O, and operator stations. Each operator station is exactly simulated so that every signal is appropriately exercised and confirmed. Actual PDI from the mill is utilized for testing purposes. Coils are accepted into the tracking system on the entry conveyor. References are generated and distributed at the correct time. Coils are rolled in simulation and functionality is checked – the HMI screens appear just as they would when running a coil with the real system. This provided a comprehensive test of the software and a realistic view for the operators to get familiar with the new system.

Erection and Pre-Outage

The plan was to do as much work as possible while the mill was still running to minimize the outage period. The new steel superstructure to allow extension of the furnace was all completed while the line was running. Similarly, the foundation for the new Cleaning Section was poured while the line was running.

The new E-houses were located and the new drives and automation equipment were located inside. Following software system test, the electrical equipment was transported to site and set in place as planned. The new computers and communication networks were powered up and communications were confirmed. Checkout of the new I/O with the new system was performed. As much of the new wiring was done in advance as possible.

Outage and Commissioning Phase

The outage began on May 1, 2017. The new Cleaning Section was moved to its recently prepared foundation under the new super structure. The pre-heat portion of the furnace was prepared and then moved westward onto the new steel super structure towards the entry end. The new Radiant Tube was arranged between the furnace sections.

Figure 11, New Cleaning Section in place

Figure 12, New Hot Bridle installed

Figure 13, New Radiant Tube inserted between two existing Furnace Sections

Commissioning of the new Furnace Motors and Drives

The existing furnace motors were replaced with new motors. The new furnace motors (see figure 15) were commissioned together with the new furnace AC drives (see figure 14).

Figure 14, New Furnace Drives

Figure 15, New Furnace Motors

Commissioning of the first Dual Purpose Drive

The Entry Bridle was the targeted as the first of the Dual Purpose drives to be commissioned in order to prove the concept. The drive had been developed and tested in a lab setting, but it had never run a line in a production setting.

Figure 16, Entry Bridle was the first Dual Purpose drive

Figure 17, Entry Bridle Dual Purpose Drive

Figure 18, Aux DC panel for Dual Purpose Drive

Commissioning of the Automation System

Once the outage began, the remainder of the wiring changes were made to connect to the new n/V I/O. The new I/O was confirmed with the nV software. Software functionality that could be commissioned without the line running was performed. The new functionality that had been moved from the subsystem controllers and its associated HMI screens were commissioned.

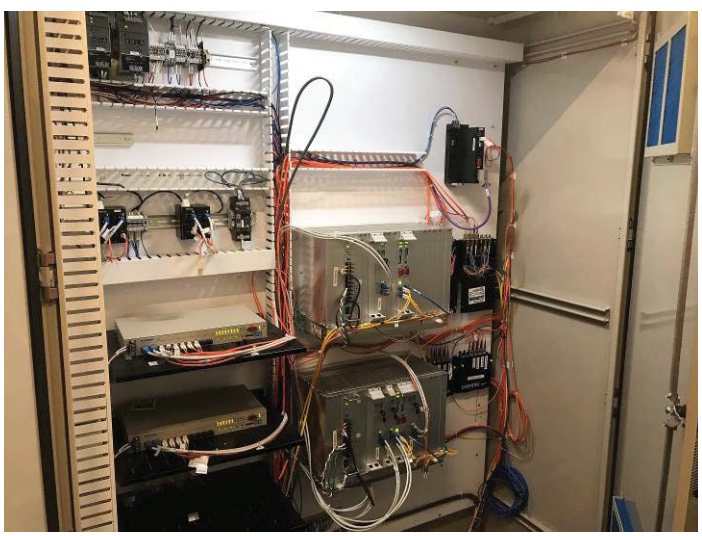

Figure 19, new nV Controllers

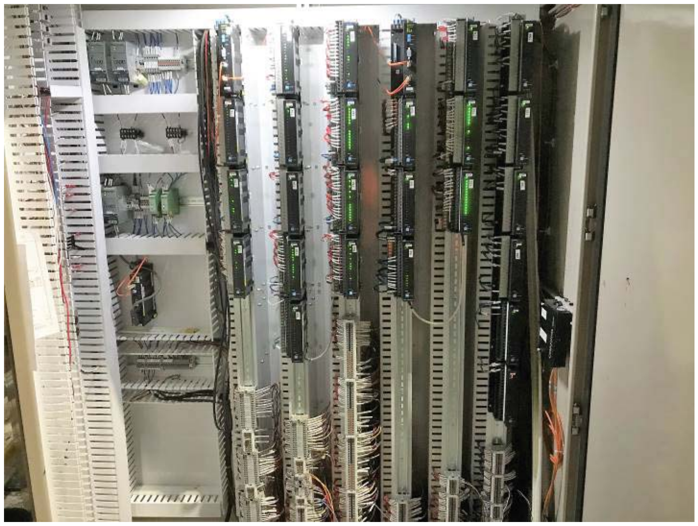

Figure 20, new nV Remote I/O

Figure 21, new HMI

Results
The SDI Galvanizing Line #1 has been back in production for seven months at the time of this writing. The project has been a big success. The following table summarizes the results.

Item	Result
Expand the number of products that the line can run to expand Cold Rolled product.	The addition of the new cleaning section has added Cold Rolled product to the Line's capability.
Increase line speed on thicker products by removing furnace limitations.	Average line speed is up 25 to 30%.
Address obsolescence of Drives, I/O, Controllers, Computers, Operating Systems, Operator Control Panels, and HMI.	All have been replaced with latest and greatest.
Switch all furnace motors and drives from DC to AC to increase reliability.	All furnace motors and drives are now AC.
Begin the transition from all DC to all AC motors and drives.	All small motors have been already switched.

Prove the Dual Purpose drive concept on the Entry Bridle as a low risk approach.	The new Dual Purpose drive has performed well in a production setting. Low risk was obtained by not burning any bridges with the old drives, but switching back was never considered.
Continue the transition from DC to AC on future maintenance outages.	March 2018 is targeted for the next conversion from DC to Dual Purpose drives.
Integrate external control systems together with the main automation system to improve maintenance and troubleshooting.	The following subsystems have been successfully integrated in to the new nV Controllers, I/O, Software, and HMI: • Furnace Control • Steering/Centering Guides Control • Cleaning Section • Air Knife/Galvanneal interface • Oiler control • Acrylic Coater control • Chromate Coater Control
Accomplish Outage tasks in 19 to 21 days	Line re-started on day 22.
Improve Quality and Production Reporting	Web based Quality and Production Reports provided by the new system are world class and provide near real-time information using only a web browser.
AC Power System Benefits	The new AC drives and dual purpose drives operate at near unity power factor and are more efficient. With the line operating at a much improved power factor, this frees up additional substation power capacity.

CONCLUSIONS

The modernization of the SDI Galvanizing Line #1 has been successfully completed. The ambitious and multiple project goals have been realized. Line limitations have been addressed. Obsolescence of the automation and drive system has been fully addressed. Improvements in Production, Operational flexibility and Efficiency have been realized. A new Dual Purpose drive concept has been proven and provides a path to an eventual all AC line. Integration of the subsystems into the main automation system and near real time web reporting provide tools to allow SDI Butler to continue to improve their results going forward.

REFERENCES

1. Ronald Tessendorf, Chip Sondek, Ben Rudolph, Chris Uliana, *Upgrade Legacy DC Drives to AC Now and Worry About the Motors Later,* AISTech2018, May, 2018.