Low-Cost Solution to a Complex DC Drive Obsolescence Problem at ArcelorMittal Coatesville 140-Inch Plate

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INTRODUCTION

The ArcelorMittal Coatesville drive for the 140" Plate Mill experienced obsolescence problems that caused an increase on the downtime, reduced productivity, slow troubleshooting, reduced reliability and lack of spare parts. The Plate Mill runs with an unusual drive configuration in which the top roll motor, bottom roll motor and edger motor are parallel connected to one of a kind 6 phase/12 pulse drive system with 4 converters in parallel. Revamping to a complete up to date DC drive configuration was extremely costly due to the costs associated with installing news drives, transformers, reactors, reconstructing the DC copper bus to separate the motors in addition to a long downtime for installation and commissioning. Another option was upgrading the existing system by replacing only the control section and reuse the power section of the drive, but in such a rare configuration, taking this decision was very risky.

After a thoughtful risk assessment and based on both technical and economic reasons, the plant decided to retrofit the drive system. AMI Automation proposed a Firing Circuit Replacement (FCR). The FCR is a surgical replacement of the controls of the drive system consisting on a tailor design to fully satisfy the needs of the application. The FCR was implemented in May 2014. The results of this solution increased the reliability, reduced the downtime as well as the troubleshooting time by using enhanced digital tools.

DISCUSSION

Problem description

The obsolescence of the mill was causing increasing downtimes of longer durations while being able to troubleshoot the existing system became very difficult due to the lack of monitoring tools. In addition to this, having the appropriate personnel with the know-how needed to understand and fix problems to such an old system was a major issue as all the new engineers are more oriented to new digital technology rather than old outdated analog technology.

Since the original design, the drive system of the Plate Mill had a unique configuration of a double 12 pulse 6 phase, double wye, half wave rectifier with interphase reactors, energizing the two main mill stand motors and the edger at the same time. The drive system uses four parallel SCR bridges to power the motors.

The double wye configuration was a common solution when the semiconductor industry had not yet developed high current products, and nowadays is very difficult to find. The last revamp to the drive system of this Plate Mill was in 1978 using the same configuration to avoid major civil and electric power equipment modification, as well as to reuse some of the existent equipment such as interphase reactors, transformers and others.

ANALYSIS

Problem definition

The main goal of this project was to increase the reliability of the mill, decrease downtime, and upgrade the main mill drives to the latest technology available by spending a competitive budget.

Four main problems were defined:

- Unique System Configuration.
- Obsolescence
- Budget Constraints
- Control Philosophy.

Unique System Configuration Analysis.

The plate mill drive system has a unique configuration that is rare to see on these days. The configuration is double 12 pulse, double wye, 6 phase half wave rectifier with interphase reactors, feeding the two main mill stand motors and the edger at the same time. Figure (1) shows a diagram of the configuration.

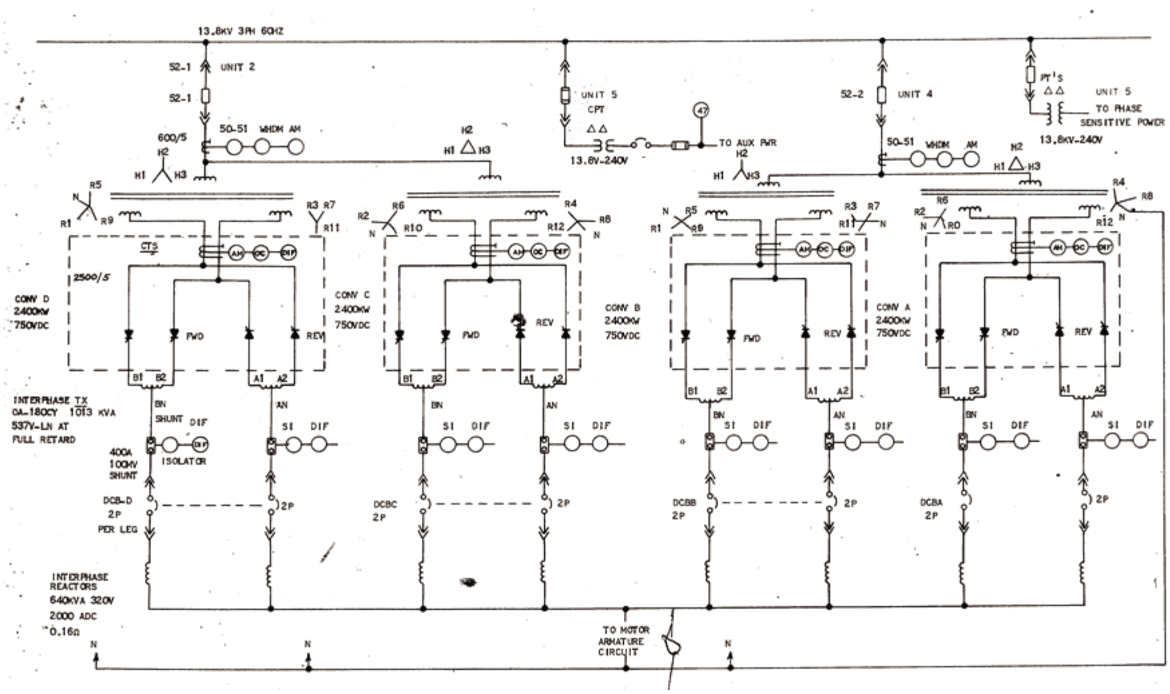

Figure 1.

The drive system control consists on:

- (4) Armatures 12 pulse regenerative bridges that work as voltage regulators.
- (3) Field power supplies (one for each motor)
- Main control system cabinets.

The main control system cabinets receive the speed reference, and calculates the voltage for the armature bridge and the field flux reference for every field power supplies. More details are described on the Control Philosophy section.

The two main mill motors and the edger motors are fed from the same drive system. The rolling speed achieved by the main mill motors and edger at base speed is not the same. The reason of this behavior is not only a result of different motor characteristics or working rolls diameters but the gearbox ratio design. This issue complicates a lot the control techniques.

Obsolescence

Even though the original design worked flawlessly for many years, the fatigue and deterioration of some of the control boards and components, the loose connections due to the years of operation, the electronic components that long passed their lifetime span, and the lack of spare parts, compromised the reliability of the system. Moreover, the outdated analog technology along with the lack of diagnostic tools for troubleshooting complicated the search of the right people who can properly maintain the system which later on translated on a negative impact on production objectives.

Budget Constraints

Upgrading the complete system by replacing the drives was an expensive option, due to the fact that the 6 pulse half wave rectifiers are not so common any more, and going to a 3 phase full wave rectifier would force the user not only to replace the drives, but the transformers, reactors, and the bus bar too. Following this path would represent additional cost for civil installation, maintenance personnel training and a longer outage.

Even though retrofitting the equipment was a much more economical option, the decision was not easy at all because of the associated challenges foreseen in such a complex drive system.

Control Philosophy

The plate mill drive system operated on an open loop. In other words, it receives the speed reference but never take into account the speed feedback to compensate. The main control boards, receive the speed reference, and calculate a voltage reference and field current reference based on the speed reference itself, current limit, load balance between main motors and voltage of the complete system.

Since the power SCR bridges are regulating voltage, this control philosophy do not guarantee that the 4 bridges will operate with the same load each one.

The original control philosophy is shown on the next diagram:

Figure 2.

SOLUTIONS PROPOSED

The technical and economical analysis of the actual situation helped to determine an engineering solution that satisfied completely the needs of the plant. Driven by the need to increase the availability of the mill while maintaining the cost low, the following functional requirements were determined.

1. Upgrade the Plate Mill drive system by retrofitting the actual control using an ultimate technology drive system control. This decision was taken due to budgetary reasons.
2. Upgrade the control philosophy, from voltage regulation to speed regulation, looking to reach to amore standard solution that is use on the present days.
3. Digital Control and Enhanced diagnostics that help to troubleshoot the drive system in order to minimize downtime in case of failure.

The Design

The design process started in order to fulfill the technical requirements. The design was divided in four different areas in order to define the ideas that consolidate the final solution.

1. Armature Bridges
2. Field Bridges
3. Main Drive System Control.
4. Protection equipment (circuit breakers).

Even though that each area can be treated separately, each area are also related to one another. The diagram on figure 21) shows the description of the qualities of each area and how they are related with each other.

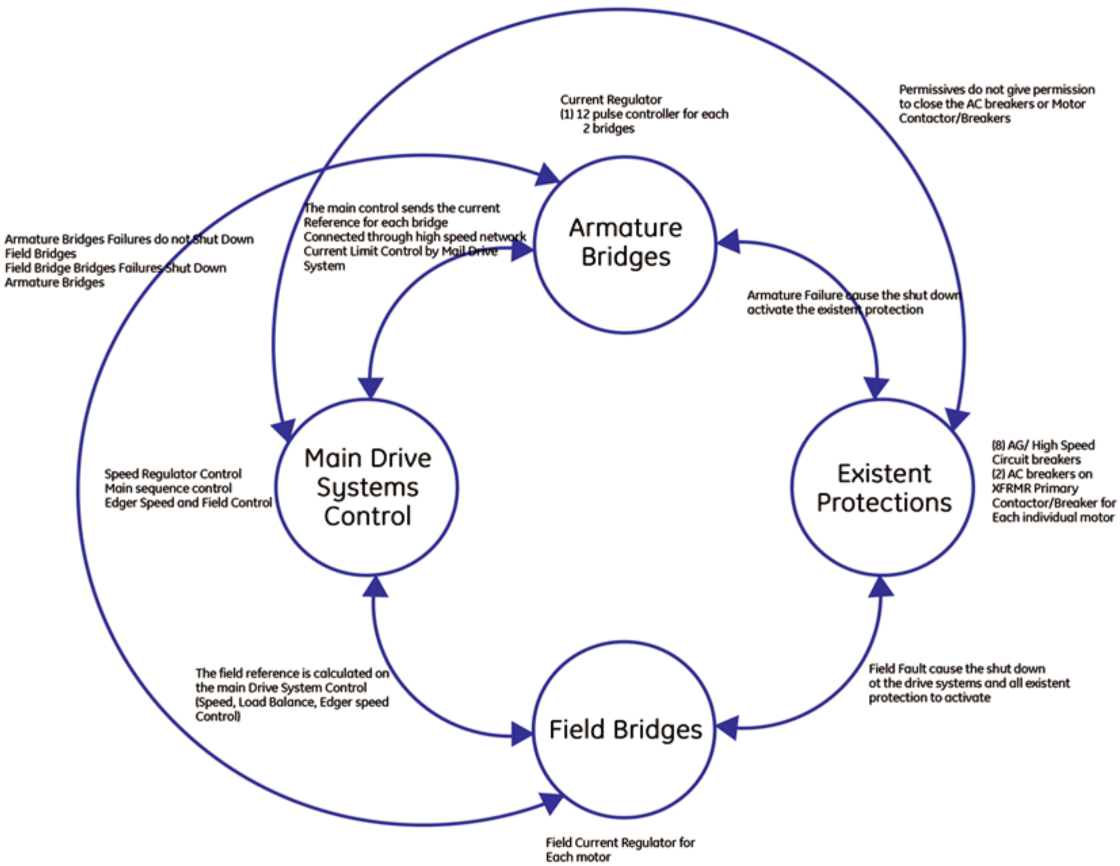

Figure 3.

Main Drive System Control

AMI Automation technical team decided to use a high speed programmable controller as the Main Drive System Control. This controller receives the operational commands and references such as creep speed, speed direction, speed reference, connect/disconnect edger, jog, roll diameter, etc. The controller, process this information, and use it to control the complete sequence of the mill (start, stop, quick stop, etc), speed regulator, field weakening control, current limit of each individual motor, load balance, nose up/down control, etc. The controller uses a fast I/O card and a remote I/O unit to receive all the feedbacks and commands from the field.

The speed regulator generates a torque reference which is converted on an armature current reference and a field current reference. The current references are sent to the armature bridges control and the field power supplies control.

The Main Drive System Control also counts with an HMI screen that is used for maintenance. The HMI shows a trend of the most important variables, fault history, active faults, and also receives the Work Roll diameters to calculate the Linear Speed of the system. The control also has the capability to record high speed trends of the last 7 faults, a valuable tool used to recognize the root cause of failures.

The new control philosophy for the system is shown on the next diagram:

Figure 4.

Armature Bridges

It was decided to control the four armature bridges using two drives control set, and use them just as current regulators. The armature bridges control receives the armature current reference and since every pair of bridges is controlled by the same CPU board, controlling the corresponding load balance between both bridges was simplified. The control sends the same firing angle to both SCRs bridges with the proper phase shifting, then the load balance regulator compensates by using trimming firing signal generated by a Push-Pull Control Technique to each bridge controller in order to accomplish the goal. The control of the bridges also has the ability to open at ultra high speed the AG7 (DC High Speed Circuit Breakers) in the case of several severe rectifiers faults like AC or DC Overcurrent, Diametrical Fault, etc.

Each armature bridge controller has the capability to record at ultra high speed the trends of the last seven faults that occurred and storage them on its non-volatile memory; this information is widely used for troubleshooting.

Field Power Supply Bridges
It was decided to control the top and bottom field power supply bridges using the same CPU, and another one to control the edger field current. Both of the field power supply control sets receive the field current reference from the main drive system control.

Just as with the armature bridges, each field power supply controller has the capability to record at ultra high speed the trends of the last seven faults that occurred and storage them on its non-volatile memory for troubleshooting.

Existent Protections
The system has different protective devices that actuate in case of failure.
1. (8) AG7 DC High Speed Circuit Breakers,
Two for each armature bridge, one for forward, one for reverse.
2. (2) AC circuit breakers on the primary of the transformers.
3. (3) individual breakers ONE for EACH motor.

The fastest protection in the system are the (8) AG7 breakers. In order to trigger the AG7, a high speed circuitry fires an SCR which in turn short circuits a charged capacitor. The current generated will activate the trip coil. The AC breakers are open every time the breaker goes to a permissive or a fault status.

The individual breakers for each motor work mainly as contactors, but also covers the individual motor overload protection.

Other Features
Another feature added to the design is the possibility to run using only three armature bridges at the time. This feature is only used under contingency conditions, for instance when the ingot is inside the mill and one armature bridge trips.

In case of any field power supply bridges fault, the control will suppress the firing of all the field bridges and the armature bridges, while triggering the DC High Speed Circuit Breakers.

IMPLEMENTATION AND OVERALL PERFORMANCE

The new system was implemented in two stages, pre-installation and main outage. The main outage was done on May 2014 and lasted for 14 days. During the pre-installation, the new Control subpanels for the armature bridges where installed on a spare cabinet of converter A and C, voltage feedback attenuator boards where installed on the line panel at the basement, internal network cabling was installed. The final configuration is shown on figure (5).

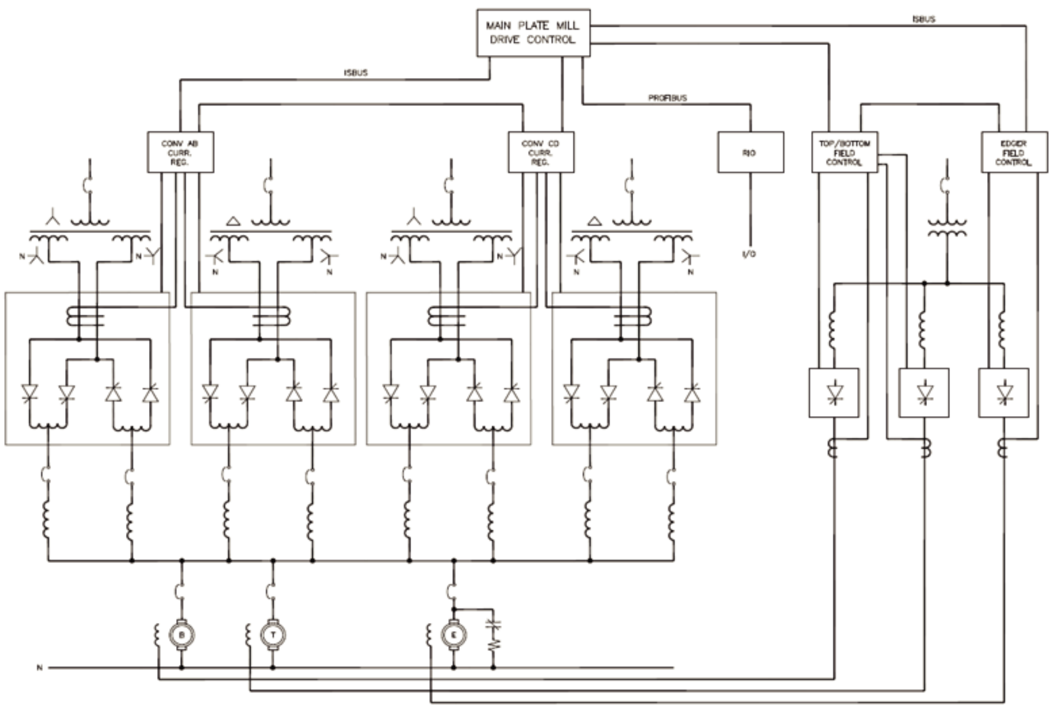

Figure 5.

During the final outage, the field power supplies of the three motors where installed, the main control cabinet was installed, and the equipment was commissioned. The commissioning was done on the following steps:

1. Complete Installation.
2. Digital Feedbacks and Commands checkup.
3. PLL
4. Bottom Motor Field Current Regulator
5. Top Motor Field Current Regulator
6. Edger Motor Field Current Regulator.
7. Lock Rotor Test and Armature Tune Up Using Armature Bridge A and B
8. Lock Rotor Test and Armature Tune Up Using Armature Bridge C and D
9. Jog Top and Bottom Motor.
10. Speed Regulator Tune Up
11. Jog using Top, Bottom and Edger Motor.
12. Adjust Speed Regulator while using the Edger Motor.
13. Final checkup of sequence and protections.
14. Start Hot Commissioning.

Completing the installation took 8 days. Figure (6-9) shows some pictures of the installation. The cold commissioning took 6 days. During this time, the field current regulators, armature current regulator, lock rotor test, and spinning the motor without load was done. The production started using only low speed for the first shift, while some adjustments where done. After 8 hours, the system was stabilized and the complete range of speed was liberated to run the complete system. Minor adjustments to the speed regulator and to the crossover logic were done during operation to avoid failures during regeneration periods.

Figure 6. Armature Bridge Current Control Cabinet

Figure 7. SCR Cabinet Installation

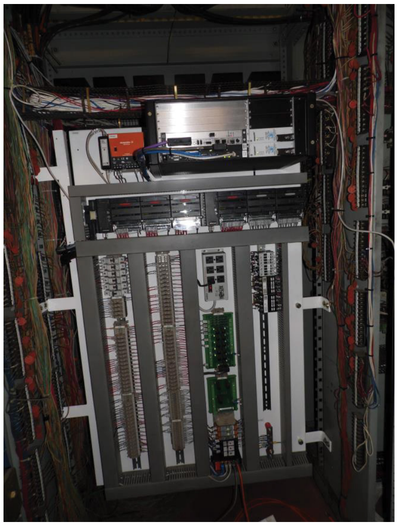

Figure 8. Main Control Cabinet

Figure 9. Field Power Supply Cabinet

The new system has been flawlessly running for the past three years, increasing the availability of the equipment and considerably reducing the troubleshooting time. The new system gave the maintenance personnel the capability of enhanced trending tools for fault finding.

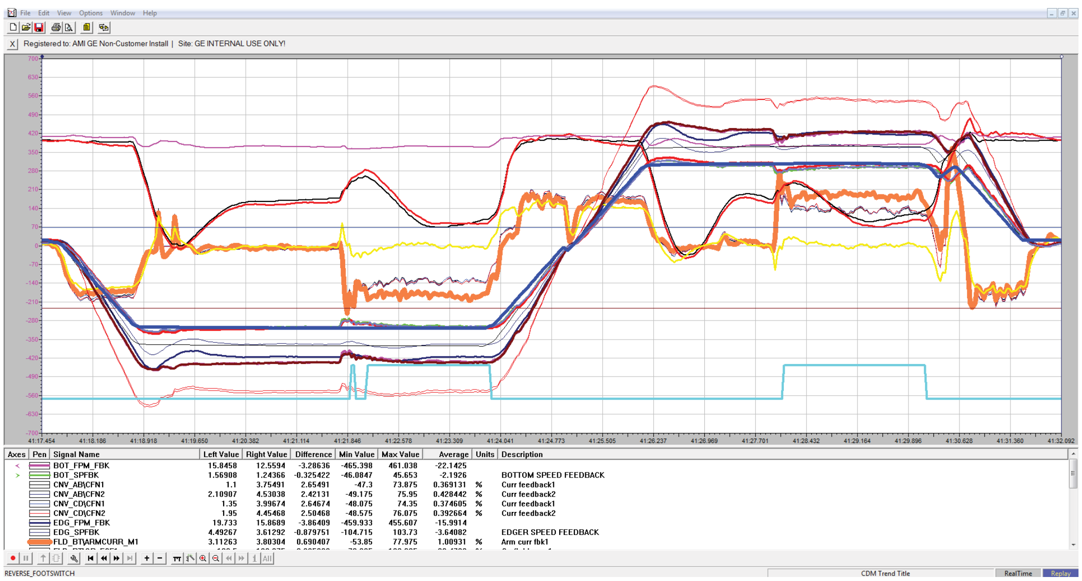

Figure 10.

CONCLUSIONS

After installation and commissioning of the FCR, the system came back very quickly to normal operation despite all the encountered challenges. The plant recovered from the potential risk of obsolesce and a weakly position to face system problems. The new system greatly increased the availability of the mill and helped to empower the plant personnel to learn the new troubleshooting tools.

The low impact on the plant budget also demonstrated the apparent risky decision was the correct one when choosing to follow an upgrade path. Since the installation time was considerably reduced vs the full upgrade option, and the commissioning time was done in a record time, the turnaround of the money invested was remarkably fast.

AMI Automation Technical Team faced several challenges during the implementation of this project as overhauling this peculiar system was a very meticulous and surgical job where new technology had to coexists with the old one. Such fusion among technologies is key for the Firing Circuit Replacement which gives the end user the possibility to evolve existing power converters into state of the art drive control system, increasing performance, protections, reliability and maintainability while keeping the costly components of the system.