RESULTS OF DIGITARC REGULATOR AND SMARTARC POWER INPUT OPTIMIZATION AT A DC FURNACE IN NORTH STAR STEEL ST. PAUL

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Abstract

With the Smart Arc EAF arc regulation software, AMI-GE has already applied this fuzzy logic to numerous AC EAF installations with great success. The natural extension of this technology is the development of this system for the DC EAF. North Star Steel (NSS), with its policy in continuous enhancements programs for reducing conversion costs, was approached by AMI-GE with an optimization project for the EAF, using systems and expertise obtained from their installations on several AC EAF'ss, to be used for the first time on a DC electric arc furnace. A system was jointly developed at North Star Steel's Minnesota division to regulate the DC electric arc in a way, which yielded significant savings in electrical energy and graphite electrode consumption. Additional improvements have been realized in the area of DC bottom electrode life, cold startup practices, and peak EAF power demand.

Introduction

AMI-GE supplies automation software to numerous metals industries worldwide, with special emphasis on electric furnace steelmaking. They hold majority market-share in AC EAF arc regulators in North America, and hence their knowledge base in this area is very strong. A recent innovation has been the development of "Smart Arc" addition to their regulator that utilizes fuzzy logic to optimize the arc to user-defined parameters. The system is flexible to receive input (and work in combination) from multiple inputs – i.e. off gas, scrap, chemical energy systems, etc.

North Star Steel's Minnesota division is a diverse producer of long bar products. They produce a wide variety of steel grades comprising about rebar, structural, high C grinding media, and special bar quality. The melt shop is equipped with a 95 short ton VAI/Fuchs DC EAF, a ladle furnace, and a 4-strand continuous billet caster. Typical melt shop production is 500,000 short billet tons per year.

NSS St. Paul Melt Shop Data:

Furnace:

- VAI/Fuchs DC EAF Commissioned May 1994.
- 19’ Diameter EBT Shell
- 28” Diameter Electrode
- Tamini 80 MVA total (2 x 40MVA) Transformer
- GE rectifiers rated at 120 KA Max
- In line Reactor Coils 25 micro Henries
- Slag Door Oxy Lance with oxy-fuel burner/carbon lance (no other burners)
- Bottom Electrode (Anode) design uses a “fin” type design where an array of thin sheets of steel are embedded in a monolithic magnesia refractory ramming mass.

Ladle Furnace:

- Commissioned 1992 by VAI (from decommissioned EAF)
- 33 MVA transformer
- Porous plug stirring
- Bulk alloy, carbon injection, and wire feed capability

Caster:

- Four Strand with various equipment manufacturers
- 26’ radius
- JME Dual Coil Mold EMS
- Concast short lever arm oscillators
- Stel Tek Dual point unbending withdrawals
- 14-ton tundish with alumina lining and metered nozzle practice
- Bellows gas shrouding for tundish to mold stream protection
- All grades cast with Oil Lubrication practice in the mold
- 6 section sizes:
  - 120mm square
  - 5 ½ inch square
  - 6 ½ inch square
  - 6 x 7 inch
  - 6 x 8 inch
  - 6 x 9 ¾ inch

Project Motivation

Before the AMI-GE partnership, the Minnesota Melt Shop team had already put significant effort into tuning their existing power profiles. They tried to adjust the power profiles to the way they layered scrap in the bucket. These efforts yielded significant improvement and helped them understand their process and its limitations, but it helped them realize that their power profiles were a "one size fits most" profile which was unable to account for changing EAF conditions. This was most noted with changes in scrap density, which varied significantly with the higher quantities of obsolete scrap in the blend. Even when they adopted a strict "scrap layering" practice, the variation in the composition of the obsolete scrap was too great for a "one size fits most" power profile.

They also realized that the arc needed to have reaction characteristics (gains) tailored not only to the power program, but to the phase of the melt- namely bore in, melt in, and refine.

Scrap melting by definition has significant variability in its physical composition and a more flexible tool was needed to react to the constantly changing conditions in the EAF. NSS St. Paul realized that an improved tool was needed to further enhance their EAF improvements. Specifically, they needed a power program with more than simple discrete set points for current and voltage as a function of KWH. NSS needed a power program that would modulate set points within a defined range based on conditions in the EAF . AMI-GE wanted to develop such a tool for the DC furnace based on their similar expertise on AC furnaces. The partnership was a good match from the start, as both parties had common goals and a common vision of how it would be achieved.

Project Approach

When NSS was approached by AMI-GE, it was agreed that the project would be implemented in two phases. The first phase involved a replacement in kind of the existing DC analog voltage regulator with a digital version developed by AMI-GE called Digitarc Regulator. The Digitarc Regulator would utilize the existing power profiles and add the flexibility to adjust gain settings according to different phases of the melt.

After the regulator installation, process and data analysis would define the needs for the "Smart Arc" component of the regulator. The "Smart Arc" regulator would then be commissioned, and when selected it would provide all the voltage and current set points for the EAF according to the rules set up in the system.

Expected Results

The main goals and performance guarantees were the following:

- Reduction of 1% in energy consumption
- Reduction of 2% in power on time
- Reduction of 3% in electrode consumption

Other important results expected were: reduced bottom wear, improved automation of melting practices and better overall melting efficiencies.

Development and Commissioning

The project was developed in stages, or sub-projects, each providing the necessary foundations for each of the following stages.

1. Data acquisition
2. Regulator upgrade: the Digitarc Regulator (phase 1)
3. Process analysis
4. Process optimization: the SmartArc for DC EAF (phase 2).

The data acquisition stage required the installation of the "Logger System" into report formats that helped gather, analyze and visualize the vast amounts of information generated at the EAF. All variables logged were readily available at the existing PLC network, so no additional expenses on sensors or specialized equipment were necessary.

The PLC-based regulator substituted the original analog voltage regulator supplied with the rectifier system, allowing a flexible and more adequate control and regulation strategy. Performance analysis, experimentation and results during and after the regulator commissioning stage, allowed the basis for of the later "SmartArc" optimization stage.

Once the regulator benefits were clearly established, the "SmartArc" startup was executed.

EAF Practice Enhancement

During the development and commissioning stages, several practice changes proved beneficial for the Meltshop and success of the project.

1. Scrap mix layering and management concept was changed by providing a fast feedback to the scrap supervisor/crane operator at the end of a heat, allowing a review of the impact on furnace performance according to the scrap mix used.
2. Foamy slag injection practice was modified to upgrade from a pulsing flow regime to a continuous flow model.
3. Improvements were made to the bore in model to minimize scrap "undercutting" that can lead to late scrap caves.
4. Training workshops were held with all EAF operators to explain the smart arc regulation practices and what they would mean.
5. Foamy slag practice improved because the operators had an arc stability reading that allowed them to learn how to make better foam by their direct actions, such as the lance operation.

Results

The guarantees were met successfully and exceeded, and by a continuous exploration of new opportunity areas that appeared with the system installation and within stage development, the actual figure benefit obtained was the following:

Quantified Benefits

	Reduction Goal	Digitarc Reduction	Smart Arc Reduction	Total Savings
KWh/Billet ton	1%	4%	9%	13%
Electrode Consumption	2%	0%	14%	14%
Power On Time	3%	0%	5% (increase)	5% (increase)

Data showing the improvements in energy consumption are shown in Figure 1. Data on electrode consumption are shown in Figure 2.

The above savings are estimated to be $1.25MM/year

It should be noted that during the initial startup of Smart Arc, the power on time was reduced by 10% (vs. a goal of 3%), but there was little benefit in electrode consumption or energy consumption. Since the caster already limits the St. Paul plant, a regime was chosen that optimized the reduction of energy and electrodes. The team feels that they will be able to further adjust the arc to achieve optimized results in all three areas.

Other Benefits:

An innovation was realized several months into the commissioning that it was possible to run significantly reduced current (15-20KA) without any sacrifice in real power input. Conventional wisdom on DC furnaces dictates that arc set points above 7mΩ typically lead to an unstable arc. The Smart Arc logic allowed set points up to 9mΩ with no sacrifice in arc stability. The arc was stable at this higher set point when the conditions in the EAF would support it and then shift to a more stable setting during more difficult conditions (i.e. dense scrap). This reduction in current is the major contributor to the reduced electrode consumption.

With reduced current came significantly reduced bottom temperatures on the anode. Bottom electrode temperatures immediately dropped over 10% (50° F). This has translated into improvement of bottom life from 1300 heats average to 1500 heats.

Another innovation realized was the total automation of the cold startup practices after the down day. DC Furnaces must be started on a low power setting and ramped up slowly when melting on a cold heel. In the past this was performed manually with the operator stepping through the set points manually. Smart Arc provided a more even ramp up that reduced the power on time on the first heat by almost 20 minutes, reduced the

KWH on the first heat by almost 30% and minimized bottom arcing and arc flare in the furnace. In addition, this improved our ability to train new EAF operators in the practices involved in down day startup.

In general it was noted that overall melting characteristics were more even and consistent and led to reduction in late scrap caves.

Because we were able to run with a more stable arc, plant demand was reduced by 5 MW, which provided almost $75K/year savings.

Future Opportunities

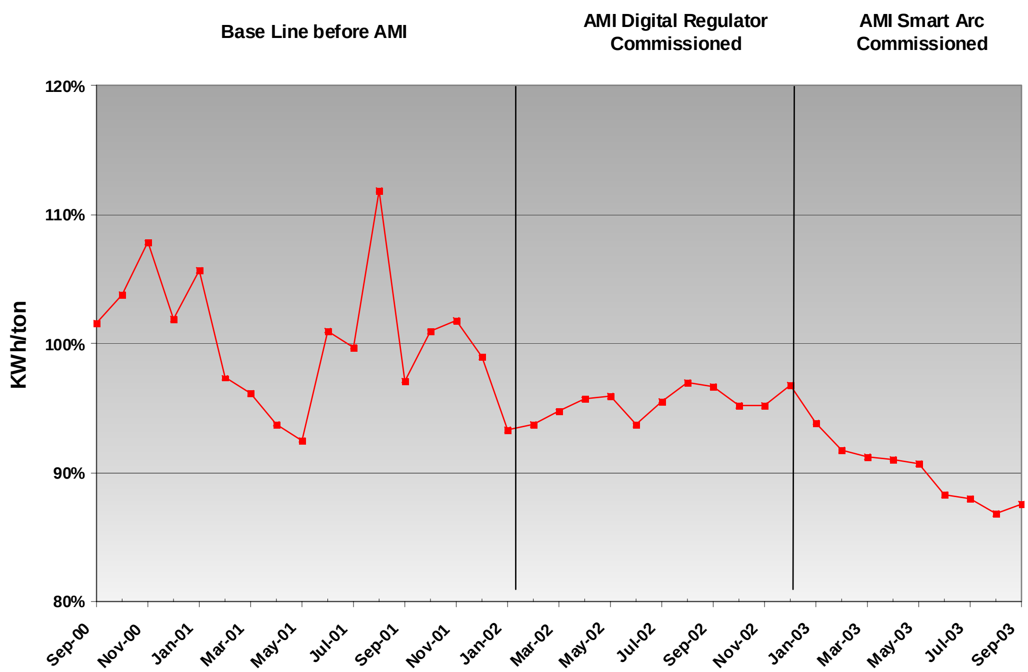
The flexibility to run longer more stable arcs in the St. Paul EAF has opened the possibility for future enhancements. Notably:

1. Foamy slag is currently only injected through the slag door, causing an uneven distribution of foamy slag, and arc voltages are limited due to refractory erosion in the back of the EAF. The addition of carbon injection in the EBT area will be implemented soon and we expect to be able to run higher stable voltages during the refine period.
2. Foaming on the first charge would provide more opportunity for arc stabilization at higher currents early in the melt. This will require the lime system to be modified to charge all the lime in the first bucket.
3. The addition of a chemical energy package (ie sidewall injectors) would provide more even distribution of energy in the furnace and further improve foaming slags, especially early in the heat. This would allow further optimization of the high voltage, low current arc throughout the entire heat.

Conclusion/Opportunities

The performance of the Smart Arc DC Regulator exceeded the expectations of both the AMI-GE and North Star Steel. Considering that the St. Paul EAF has no sidewall injectors or burners, only the door lance, the energy and electrode consumption figures that are achieved approach those typically seen using more significant amounts of chemical energy. The flexibility of the system to tailor the needs of the arc regulator to the changing needs of the process as well as link them to automated processes such as off gas control and chemical injection systems leave significant additional opportunities for improvements in steelmaking efficiencies in the EAF.

KWh/Billet Short Ton



Electrodes
(lbs/billet short ton)