

***McMaster Symposium
on Iron & Steelmills
Steelmaking Optimization in Mini-Mills***

Experiences of High Impedance AC EAF arc
regulation using the new AMI Automation's Power
Input Optimization

**Hamilton, Ontario
May 28th, 1997**

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Introduction

Years ago, Previous EAF operation technologies were focused into short arcs, high currents and a lower impedance system design to transfer more power into the furnace, with the consequent high electrode consumption.

It was not until the development of the foamy slag practice that people changed to a long arc operation, with a swing to lower operational currents and lower impedances, minimizing electrode consumption.

However, this new practice brought new challenges, mainly higher flicker, especially during the boredawn period, and an increased un-stability of the arc, with the corresponding higher harmonics, and higher stress on all mechanical components due to vibrations.

“High Arc Impedance”

Recently a new concept has been developed to minimize this drawbacks and achieve an even longer arc operation. This concept is frequently called “ High Impedance operation”

The goal with this new concept is to operate in a point very close to the maximum power point of a given tap, to lower the sensitivity of MW changes versus Current changes. This is achieved adding a reactor on the primary circuit, and raising the voltage taps on the secondary of the furnace transformer to compensate for the voltage drop the reactor creates.

Figure 1, shows how through a combination of different transformer taps and series reactors in the primary of the furnace, 4 points that will run at similar power levels at their maximum, can be achieved with very different secondary currents.

FIGURE 1.-

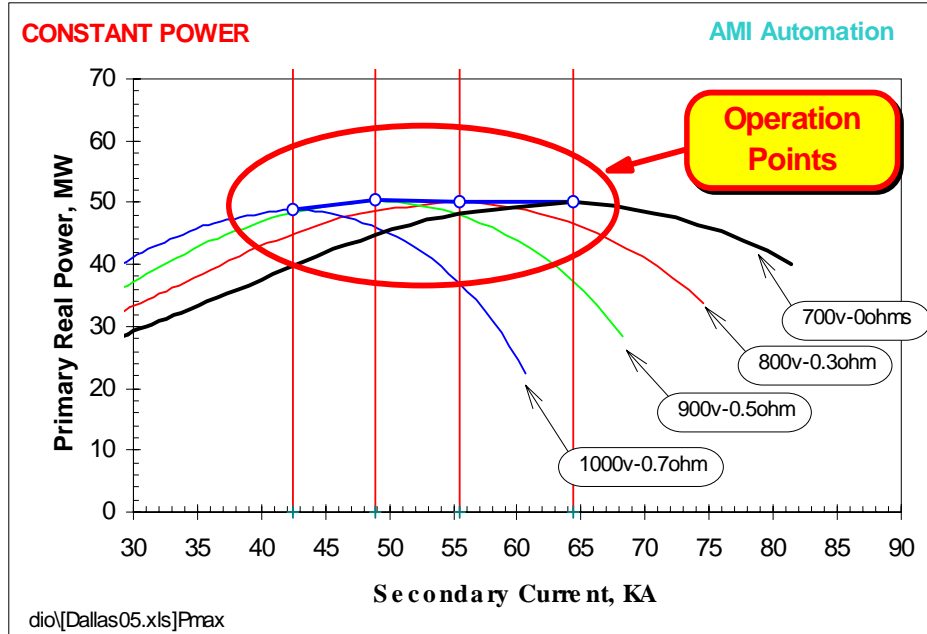


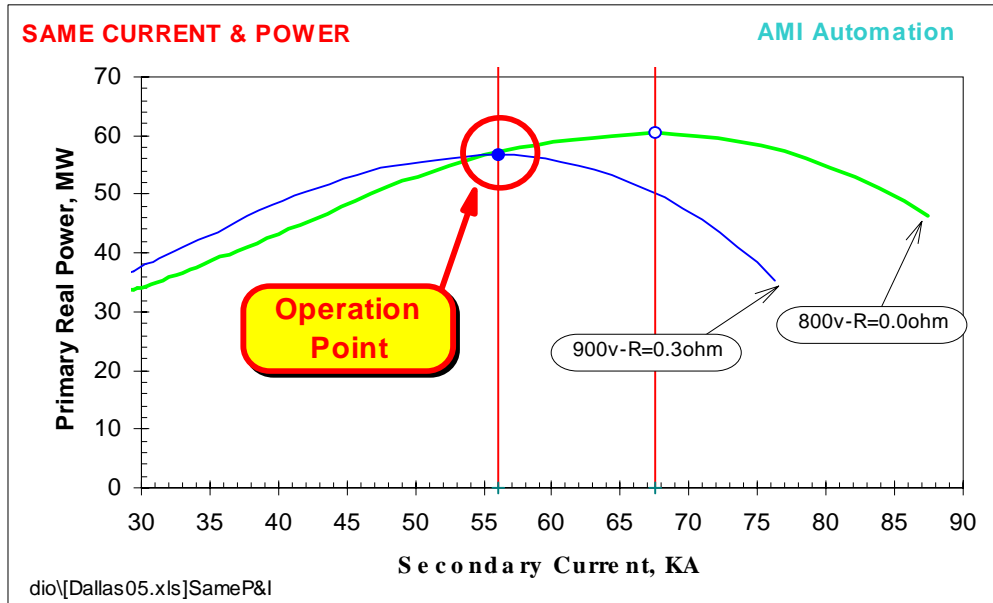
Table 1, shows this same four points in a tabular form, where it can be realized that the minimum current “maximum” requires an arc length almost double than the one with the maximum current. The low current operation (42,4 K.Amps versus 54.4K.Amps) has an electrode consumption of nearly a third, but a RWI (Refractory Wear Index) almost double.

TABLE 1.-

Concept	Units	CONSTANT POWER			
		700V	800V	900V	1000V
Scenario Description					
Series Reactor	mOhms	0.0	1.0	2.1	3.7
Secondary Current	KA	64.4	55.5	48.8	42.4
Primary Real Power	MW	50.0	50.1	50.3	48.8
Arc Length Indexes					
Length	in	6.3	7.9	9.5	11.0
Arc Length Index	mm/KA	2.5	3.6	4.9	6.6
Power/Current	MW/KA	0.8	0.9	1.0	1.2
Electrode Cons. Index	I2H	4,148	3,080	2,385	1,801
RWI	MW/cm	9,487	12,338	15,155	17,301

In fact, every operation Arc (Power, Current), can be achieved with different combinations of secondary voltage and reactor sizes. This is shown on figure 2. This figure shows the same point belonging to two different curves.

FIGURE 2.-



On one of the curves, this point is almost the maximum, leading to a very stable operation, while in the other one, the point is very far left of the maximum for that particular curve, resulting in a very un-stable arc.

This comparison is shown in a tabular basis on table 2

TABLE 2.-

Concept	Units	SAME POINT	
		800V	900V
<i>Scenario Description</i>			
Series Reactor	mOhms	0.0	1.3
Secondary Current	KA	56.1	56.1
Primary Real Power	MW	57.3	56.9
<i>Arc Stability</i>			
Arc Length Index	mm/KA	4.2	4.2
Reignition Voltage	Volts	402	517
SC Current	KA	122.3	79.3
Harmonic Factor	%	30%	20%
SCVD	%	3.86	3.57
<i>Arc Length</i>			
Length	in	9.3	9.2
Power Profile Slope	MW/KA	0.6	0.0
RM	MW/cm	16,650	16,352

As it can be observed on this table, the main differences between these two points are the harmonic contents, the re-ignition voltage, and the Power profile slope (M. Watts per K. Amp.)

The re-ignition voltage concept is best exemplified on figure 3 and 4

FIGURE 3.-

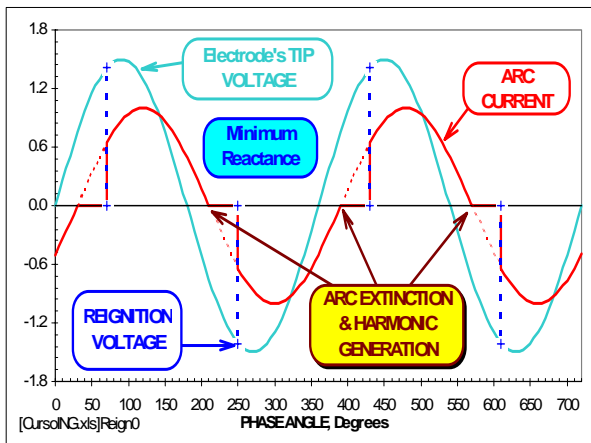
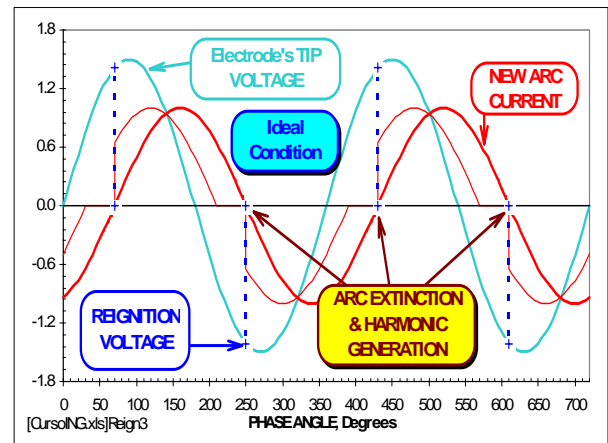


FIGURE 4.-



As the current lags the arc voltage, when the current passes through zero, the arc extinguishes, and waits until enough voltage builds up in the electrode tip to re-strike.

Depending on the system impedance, the more the current lags the voltage (higher impedance), the greater the voltage on the tip of the electrode when the current goes through zero. This minimizes the wait time, and the harmonics generated.

The “High Impedance” concept allows to operate with lower currents, better arc stability and lower flicker levels, which in many cases prevents the need to use dynamic compensation equipment (SVC).

However, the main challenge is to operate at much longer arcs.

This requires a better practice of slag foaming, and an automatic control system that can protect the furnace walls when the arc is exposed.

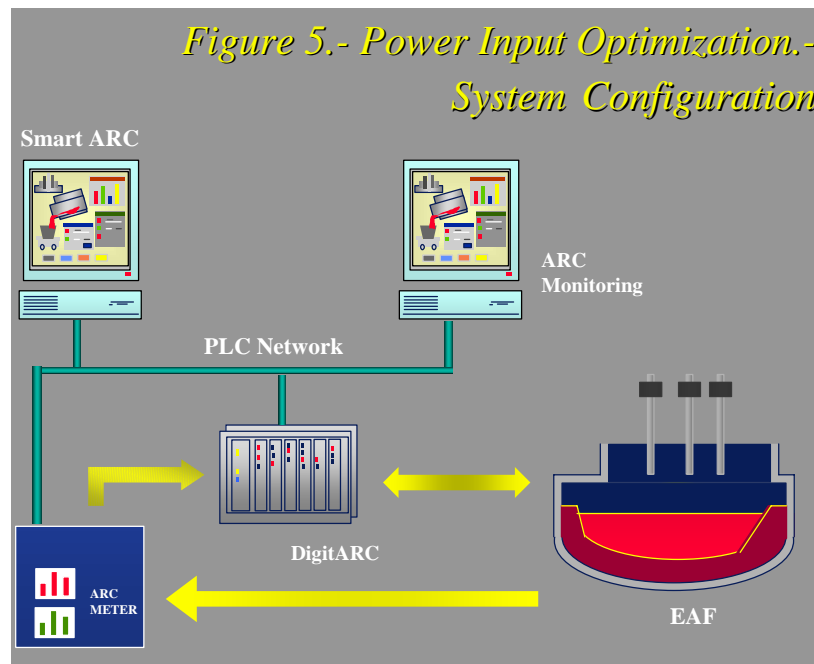
AMI's "Power Input Optimization System"

The system developed by AMI "Power Input Optimization", addresses this concerns, to optimize the power input into the furnace by selecting dynamically then best tap and arc length as the conditions in the heat change.

The "PIO" system has a modular structure, to allow an step implementation.

The four main building blocks are the DigitARC, the ARCMeter, the Monitoring System, and the SmartARC.

Figure 5, shows the configuration of the system. Basically, the DigitARC is a software algorithm implemented in a PLC, that monitors the voltage and current and moves each electrode up or down to control a given arc reference.



The ARCMeter, is a dedicated system that monitors the secondary voltage and current and very fast calculates true RMS values, and sends these values to the PLC as feedback.

The monitoring system is a PC connected to the network that monitors and displays the electrical parameters to the furnace operator. This screen, also allows the operator to preset power profiles to use, or to select the operation mode between a manual mode, where the operator selects the arc reference, the "Auto" mode, where a Power profile is followed, or the "Smart" mode, where the SmartARC dynamically selects the optimum Tap and arc length reference.

The main functions of the SmartARC computer are to provide a tap reference to the EAF transformer, a tap reference to the reactor if equipped with an on-load tap changer or to switch it off, and to set the arc length reference.

Also, when continuous DRI is feed to the EAF, the SmartARC will set the DRI feeding reference automatically.

Results

The results to be expected of this system vary from furnace to furnace. Results of applying the system in five different cases are presented.

- SMI Seguin
- Chaparral Steel
- Cascade Steel
- Nucor Utah (2)
- Birmingham Steel, Seattle

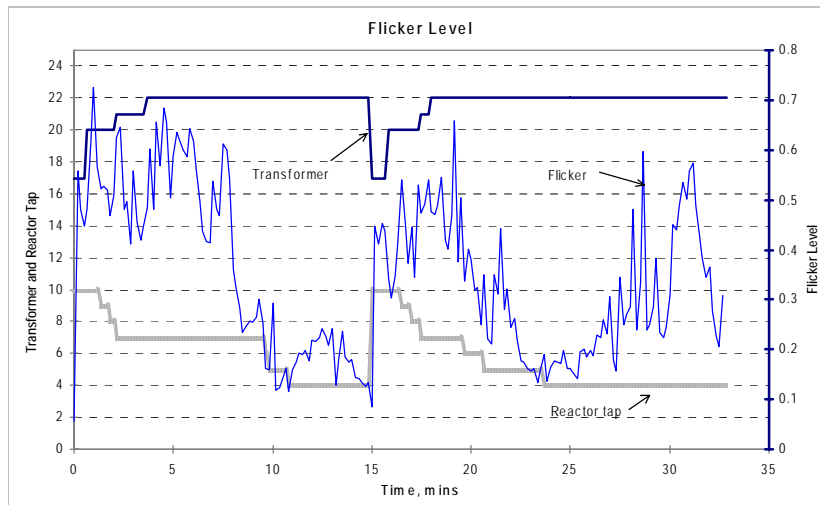
Case No. 1.- SMI Seguin

SMI Seguin furnace is installed in an extremely weak utility network. Their biggest problem is the generation of flicker. Over the years they have done many enhancements to the EAF primary circuit to minimize these negative effects.

The most distinctive characteristic is that they have a primary reactor with an on-load tap changer.

Figure 6 shows how the SmartARC monitors the flicker, and depending on it changes the Transformer and Reactor taps to apply power as fast as possible, without exceeding allowable Flicker limits.

FIGURE 6.-



Later in the heat, when flicker is no longer a concern, the system optimizes the power by lengthening the arc when the slag conditions allow a long arc operation.

The SmartARC system has been in operation at SMI since May 1994.

The recorded results from May 94 to October 95, account for an increase in average power of 3%, reduction of Kwh/Ton of 1.5 %, reduction of Power On-Time of 5.1 %, and a reduction of electrode consumption of 7.1 %.

SMI lost their SVC since October 1995. Since then, the SmartARC has played an even more important role, to step the power input into the furnace as the conditions and restrictions allowed.

Even under these conditions, the people from SMI have been able to break their old production records and reach the 33 heats a day record. The SmartARC is a tool that has contributed to this success.

Case No. 2.- Chaparral Steel “B” furnace

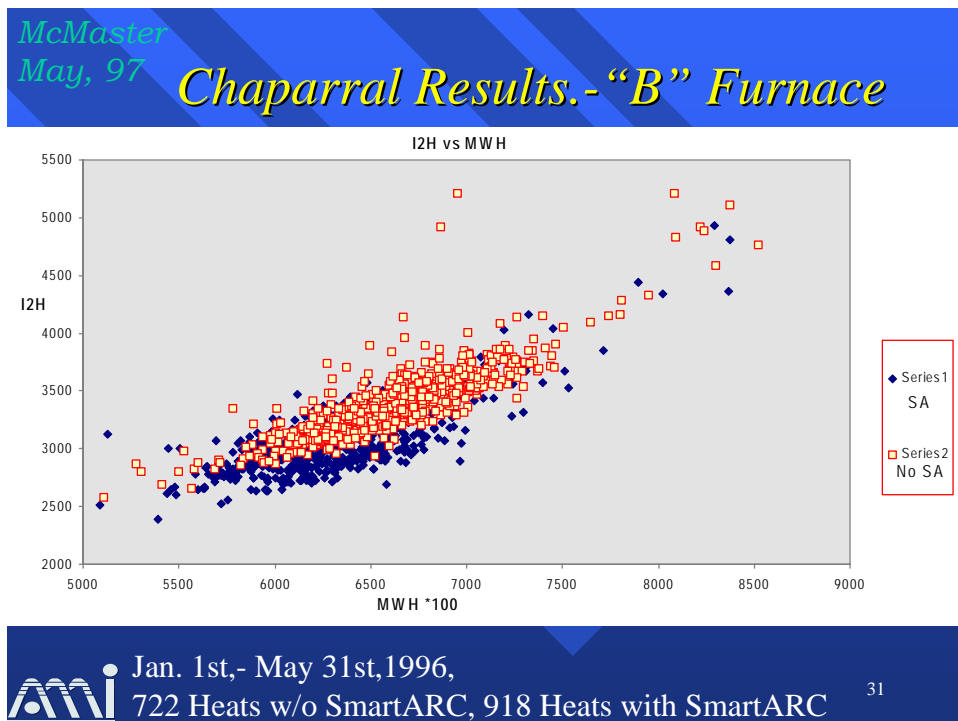
This furnace is a very well run, low impedance / high power furnace, where they were running at their maximum tap of 1000 volts.

The project was to implement a complete PIO system, and compare it with their existing operation.

After 5 months of operation, 1500 heats were compared with and without the use of the PIO system.

Figure 6 shows Energy versus I2H (related to electrode consumption) for these heats.

FIGURE 7.-



As can be seen from the darker points, the use of the PIO resulted in heats with a total lower energy and electrode consumption in average

Case No. 3.- Cascade Steel

Cascade EAF was running with a reactor in the primary of the EAF and a maximum secondary voltage of 833 volts.

After two months of trials, figure 7 and 8 show how the operation with the PIO system resulted in less KWH/Ton, and less electrode consumption (I2H).

FIGURE 8.-

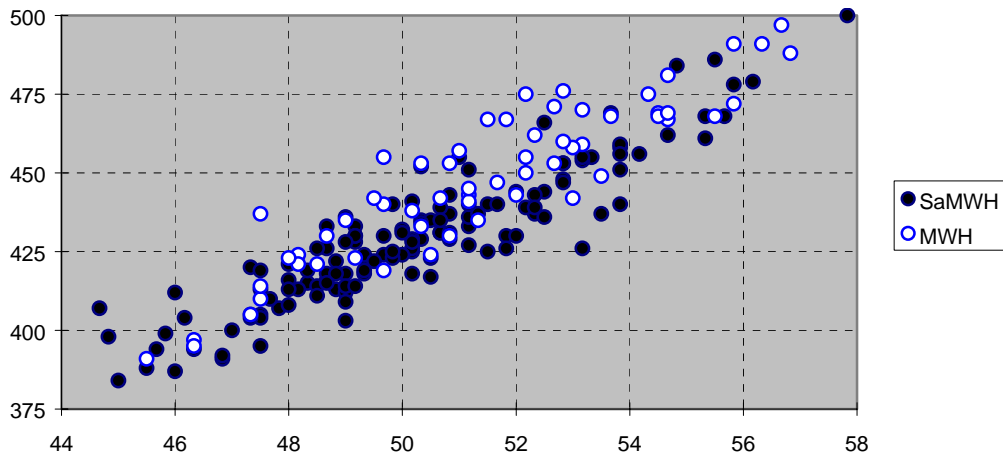
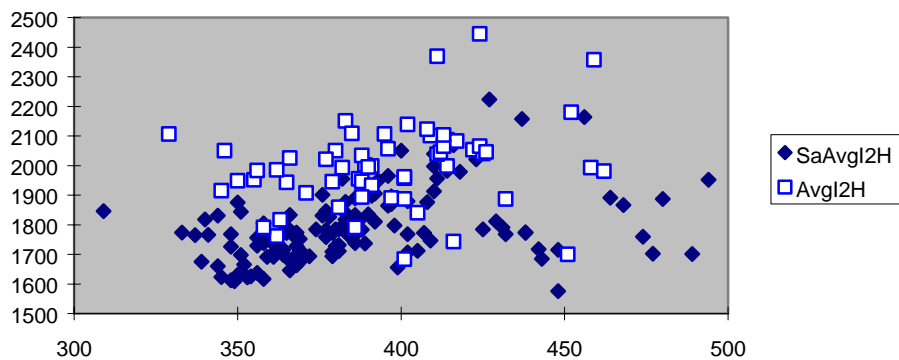


FIGURE 9.-



Case No. 4.- Nucor Utah

These furnaces were revamped by Fuchs to change the electrode mechanism to hydraulics, and the arms to Current Conducting arms. As part of this project a complete PIO was installed for each of the two furnaces.

Results for the complete project were reduction in their power on-time, reduction in their electrode consumption, and a significant reduction in gunning material, and an increase of delta life.

Case No. 5.- Birmingham Steel, Seattle

This is a new Fuchs furnace installed in 1995. This furnace has an reactor with off-load tap changer, and a transformer with a maximum voltage of 1200 volts.

The project was to install a SmartARC system to the existing DigitARC to speed up the furnace.

As part of the evaluation, it was demonstrated after the first heat the potential benefits of the system, allowing to stay on higher taps longer in the heat, as compared to a pre-programmed power profile.

The main benefits achieved were:

- Lower Kwh/Ton .- 1.3 %
- Reduction in Power On-time 4.2 %
- Reduction in tap to tap time: 2.3 %
- Increased heats per day: 5 %
- Reduction in Gunning material: 38 %
- Electrode consumption reduction: 3 %

Conclusions:

The “high impedance” power system concept has proven to be very beneficial in the operation of EAFs.

AMI's Power Input Optimization has demonstrated to be an excellent tool to help the operating personnel to maximize the potential gains to be obtained for each particular electrical system.

Every furnace and every operation are different. Flexibility to tailor the system to each furnace particular circumstances is a key element for success.