STATCOM SYSTEM IMPLEMENTATION INCREASES ELECTRIC ARC FURNACE PRODUCTIVITY

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Introduction

It is well known in the industry that; reactive power compensation is beneficial to the productivity of an Electric Arc Furnace (EAF). In some cases, is even necessary. The role of reactive power compensation is to regulate the voltage and keep it from dropping too much. Over the past decades, the use of passive harmonic filters has been the norm to provide reactive power and harmonic mitigation. However, given the ON-OFF nature of the EAF process, passive harmonic filters are limited in the amount of power that can be installed. The use of power electronics for reactive power compensation is not yet broadly adopted. In most cases where SVCs or STATCOMs have been installed, they were required by the utility due to issues related to flicker or grid code compliance. It is the purpose of this document to present the economic viability of installing such equipment.

EAF's Reactive Power Requirements

Electric Arc Furnaces are essentially a place where we can produce and control large electric arcs, which electrically speaking are just variable resistors. The arc itself consumes only active power. Reactive power is consumed in the circuit inductances: lines, cables, transformers, and reactors.

Average Power

Power factor of furnaces usually ranges from 0.75 to 0.9, measured at the MV side. The following measurements are from an EAF with a 120MVA transformer without any compensation.

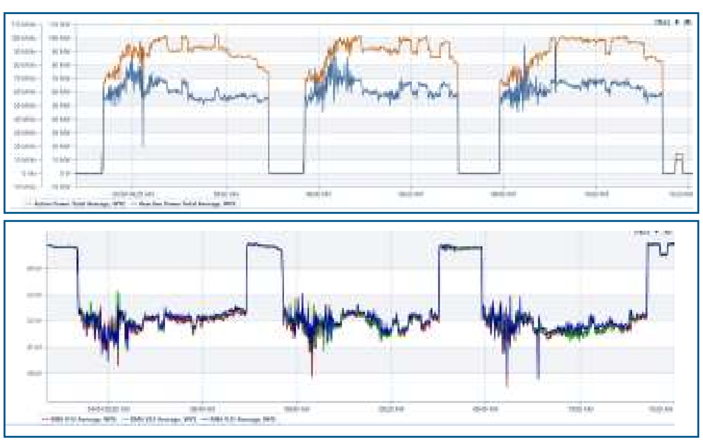

Figure 1

Maximum Power & Unbalance

The past section showed the ***average*** three phase power measurements. The average calculation gives us a good value to compensate for power factor on a long-time interval. This would be the amount of power required to have a good power factor on our revenue meter. However, conditions in an EAF are not at all average. Power is changing dramatically at the beginning of every heat. The following figure shows the maximum and minimum reactive power consumption of the furnace.

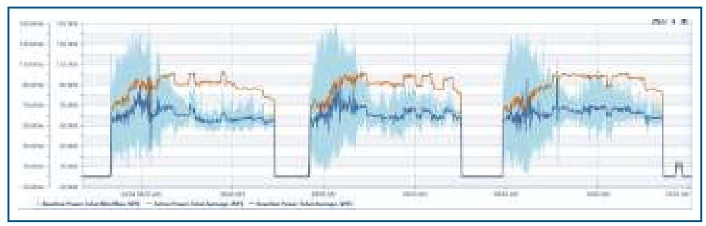

Figure 2

As we may see, fast reactive power requirements are much greater than the average. Also, the problem gets a little more complicated, since so far, we have only discussed ***total three phase*** power measurements, but individual phases change just as much.

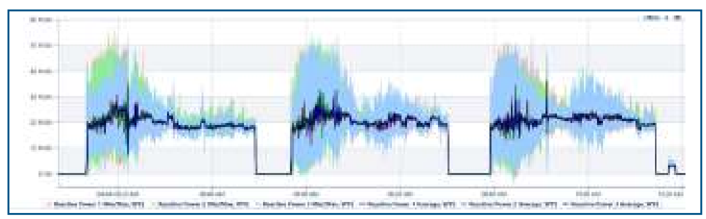

Figure 3

It is important to make this distinction because, looking at Figure 2 we could assume that the total amount of reactive power consumption is 140MVAR, or 46.67MVAR per phase. As we can see in **Figure 3**, this assumption would leave us about 5MVAR per phase short, or 15MVAR total (10%).

Reactive Power Effect

We've seen that EAFs consume large amounts of reactive power, but if the grid has enough capability to supply it, why is it important that we compensate it? Reactive power is strongly related to the voltage. There are many processes that, as long as the voltage stays within a range, the production output doesn't really change. This is not the case in EAFs. Active power is directly proportional to the square of the voltage, therefore any change in voltage will have a larger effect on the furnace power and, ultimately, on its productivity.

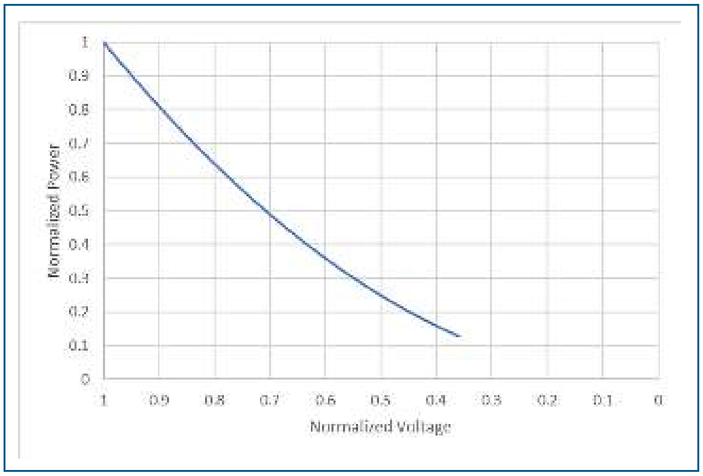

Figure 4

Passive Reactive Power Compensation

In the past section, we discussed the consumption of reactive power of an EAF and its effect on the real power. Even if the grid can supply the reactive power, it is desirable to provide reactive power compensation to be able to use the full power capacity of our electric system. In our example, **Figure 3** shows that we need around 53MVAR per phase, or 160MVAR total, to completely compensate the furnace. Installing harmonic filters is a "cheap" option to provide reactive power compensation. Typically, a set of filters are installed with tuning frequencies around the 2nd, 3rd, and 4th harmonics. Other frequencies like 5th, 6th, or even higher orders are also common depending on the total power requirement, type of furnace, grid's power quality requirements and the expected characteristic harmonics.

Limitations

Harmonic filters have a big limitation: it is very hard to switch them on and off rapidly. So, usually the filters stay connected even when the furnace is off. Under this condition, our problem is exactly the opposite. Since the furnace is not consuming the reactive power supplied by the filters, the facility becomes a net producer of power, sending it to the grid. Just as consuming reactive power lowers the voltage, producing reactive power will rise it. The total voltage rise will depend on the total amount of reactive power installed and the short circuit level of the system.

This limitation sets the maximum amount of passive reactive power we can install. In our example, let's set a maximum voltage rise of around 5%. In this case, the maximum amount of reactive power would be 5% of the short circuit power. The EAF's short circuit power is 900MVA, so our compensation system gets limited to 45MVAR.

Installing 45MVAR is not ideal, but it does improve the furnace operation:

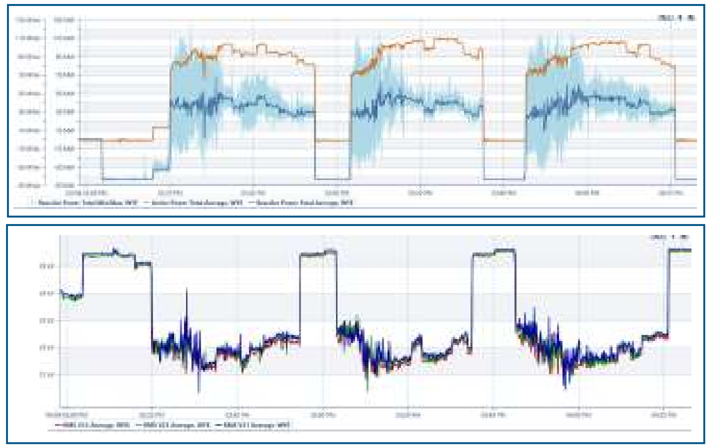

Figure 5

From **Figure 5** we can notice the following:

- 115MVAR are still needed to fully compensate the furnace
- Voltage increases near our maximum limit during the Power-OFF periods
- Real Power increased around 10% (10MW) from our No-compensation case

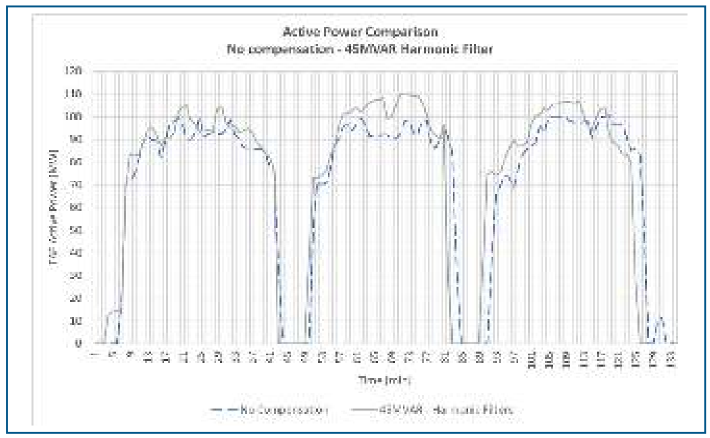

Figure 6

Figure 6 clearly shows an increment in power and a reduction of the Power ON time.

Variable Compensation

To solve our voltage regulation problem, thus enabling us to install the total amount of required reactive power, variable reactive power compensation is needed. As we stated before, rapidly switching harmonics filters is not a viable option. There are two commercially available technologies to provide variable compensation: Static VAR Compensator (SVC) and the Static Synchronous Compensator (STATCOM).

- **SVC**: Consists of a set of passive fixed filters and a variable reactor, called Thyristor Controlled Reactor (TCR). The reactor consumes the reactive power that the furnace doesn't consume.
- **STATCOM**: The main component of an STATCOM, is the Static Voltage Generator (SVG). This is a voltage/current source that generates the amount of reactive power the furnace requires. It can also be coupled with fixed harmonic filters to reduce overall costs.

We will not cover the use of SVCs because they have several limitations and short comings against STATCOMS, such as:

1. **Area**: SVCs require a lot more area per MVAR than the equivalent STATCOM.
2. **Cost**: A decade ago, STATCOM prices made their use almost prohibited. However, over the years Power Electronic prices have come down. STATCOMs with a capacity of 80-100MVAR or less will be cheaper than the SVCs of the same rating.
3. **Harmonics**: The TCR branch of SVCs is a large harmonic generator. Facilities installing SVCs can't expect a substantial reduction in harmonic content. STATCOMs, on the other hand, cancel significant amounts of harmonic currents using a function called Active Power Filtering (APF). In some cases, the STATCOM alone is enough to provide reactive power compensation and harmonic filtering (no passive filters are required).
4. **Speed**: SVCs use a power electronic component called Thyristor. Thyristor can be turned ON by the controller, but they can't be turned OFF. It turns OFF automatically when the current passes through zero. So, the maximum speed of change for an SVC is once every half cycle (8ms). STATCOMs use a component called IGBT (or similar), which can change its output in a much shorter amount of time. This is helpful to control Flicker. Experience shows that SVCs have a Flicker reduction factor of around 1.8. Whereas STATCOMs may have a reduction factor of 5.0.

There can be several ways to design a 160MVAR STATCOM combining Harmonic Filters and SVG. The SVG can't have less than half of the total system capacity since is needs to consume the reactive power from the Harmonic Filters. However, it can be more than half, for example: SVG: 80MVAR and HF: 80MVAR, or SVG: 100MVAR and HF: 60MVAR, or even SVG: 160MVAR and HF: 0MVAR. Adding Harmonic Filters reduces de overall cost, so the SVG is made as small as possible to comply with all the regulations. In our example, due to harmonic and unbalance regulations, the final configuration was SVG: 120MVAR and HF: 40MVAR.

Results

Figures 7a and **7b** show the results of the implementation of the STATCOM.

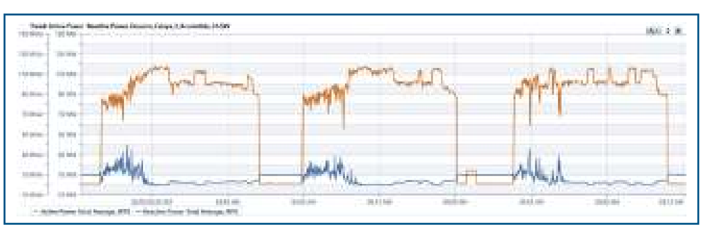

Figure 7a

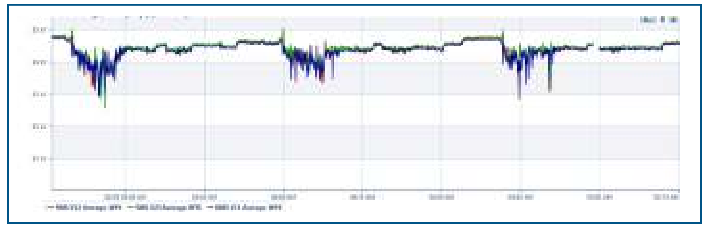

Figure 7b

We may observe that:

- Maximum real power reaches 120MW. About 9% more than the Harmonic Filter scenario. Average power increased 4.5%
- Voltage always remains higher than 33kV and higher than 34kV most of the time

It is important to consider that the main purpose of this project was grid code compliance, with very strict unbalance and harmonic limits. The later meant that a good part of the STATCOM's capacity is used for mitigating harmonics. Also, the STATCOM consumes about 10MVAR of reactive power that are being supplied by the rolling mill from a 13.8kV bus to the grid.

Comparison:

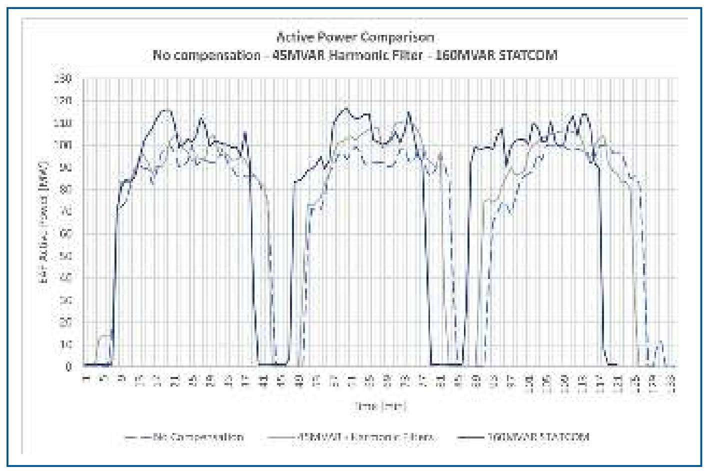

Figure 8

Not only higher maximum power is achieved. Most importantly, higher power is maintained during the early stages and throughout the heat. This allows a great improvement in melting time.

After 2 months of operation: Real power increased 4.5%

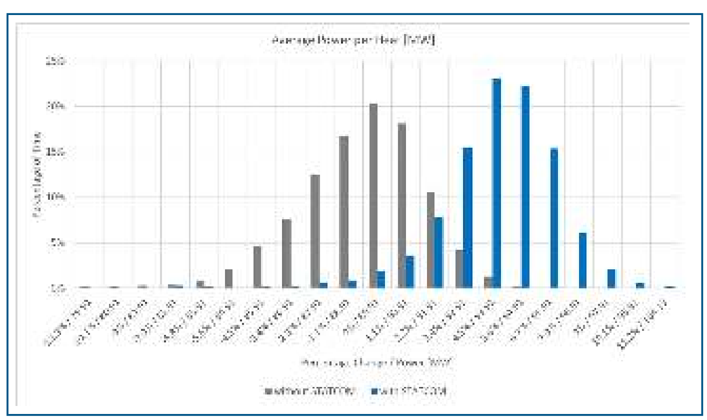

Figure 9

Power On decreased 4.5% to 5.5%.

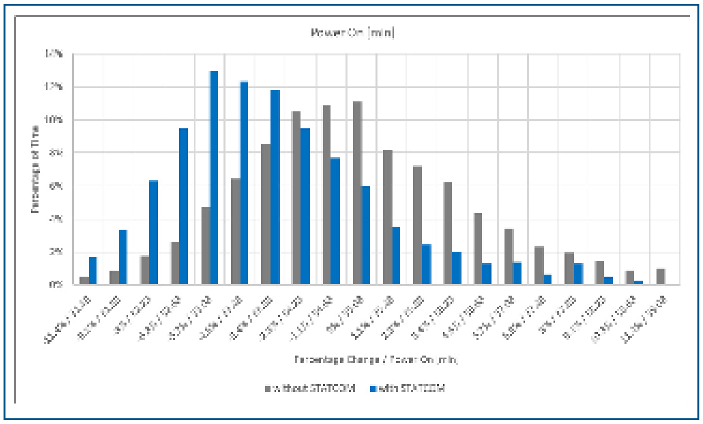

Figure 10

Productivity increased 6.85%. From 28.13 heat per day to 30.12.

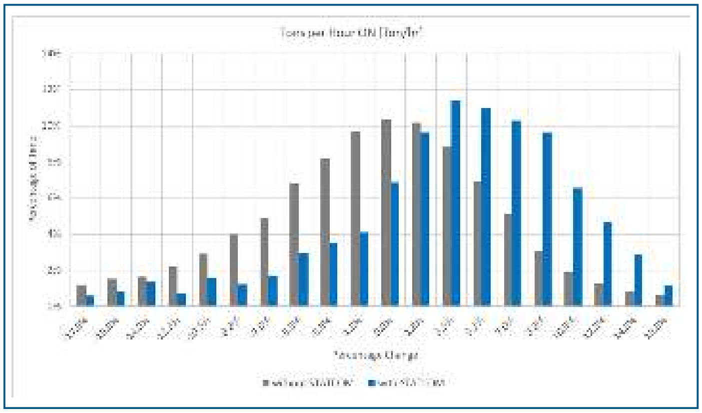

Figure 11

More Projects

To date, 6 projects have been implemented in Electric Arc Furnaces ranging from 40MVAR to 160MVAR. All of them have similar results in productivity.

Figure 12

Cost Benefit Analysis

After reviewing the data, is obvious that there is an improvement in the productivity of the furnace. However, this increment comes at a price. STATCOMs come in a variety of configurations. They will have different voltages, also can be connected in Wye or Delta, Water or air cooled, installed in a building or in containers. Different loads will require different configurations. EAFs are usually connected in 34.5kV and require Delta connection and water cooling. The following chart, shows the price of STATCOMs depending on the type of load and its capacity (not including installation):

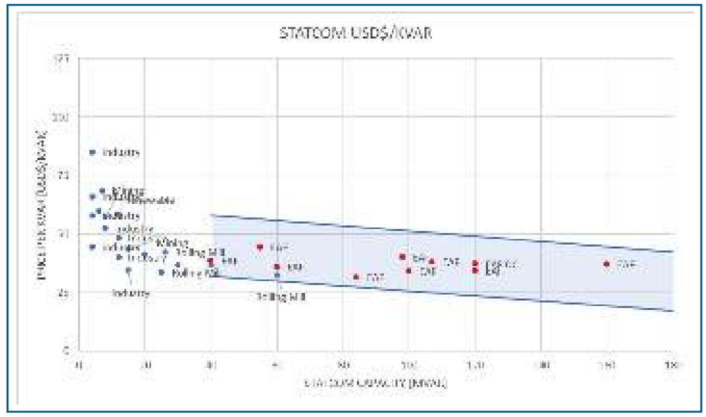

Figure 13

We can use the following "rule of thumbs" to estimate the cost of a STATCOM:

- STATCOM capacity needs to be about 130% times the capacity of the transformer.
- With the previous information we can estimate the cost of a STATCOM in about US$20,000 to US$60,000 per MVA

The following assumptions were made to calculate playback time:

Furnace Transformer Power	80	MVA
Furnace Capacity	80	Tons Capacity
Tons per year	726,000	Tons/year
Productivity increment	6.5%	
Additional tons per year	47,190	Tons
Profit per Ton of Liquid Steel (TLS)	$ 45.00	US$/TLS
Economic Benefit per Ton Capacity	$ 26,544.38	US$/year/Ton Capacity
Economic Benefit (80Ton)	$ 2,123,550.00	US$/year
STATCOM Capacity	105	MVAR
STATCOM cost per MVAR	$ 40,000.00	US$
STATCOM cost (80Ton)	$ 4,200,000.00	US$
Payback time	1.98	years

Conclusions

The implementation of STATCOM systems for Electrical Arc Furnaces has many advantages. The systems can mitigate most of the power quality issues that affect the grid and internal loads, improve voltage regulation and flicker, and most importantly, increase power and productivity.

Payback times can range between 1.7 to 2.5 years, and the life expectancy of the equipment is more than 15 years with minimum maintenance cost. This makes the investment convenient not only for grid code compliance but also economically.

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