DEVELOPMENTS IN ADVANCED FURNACE CONTROL

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ABSTRACT

Software-based furnace resistance controllers for submerged arc furnaces were introduced during the 1990s. The controller software automates the process of achieving and maintaining the required furnace MW and electrode resistances or electrode currents, bringing consistency to the operation and allowing for rapid recovery from upsets, optimising power input and reducing furnace downtime.

Since the introduction of furnace resistance control software, ongoing development work has resulted in the introduction of additional features and capabilities. Furnace automation has been enhanced to provide automatic slipping, electrode baking after long slips and electrode sounding. The controller provides access to important operational information in a variety of easy to read graphical formats, allowing operators to analyse large amounts of data by studying trends and recorded events.

KEYWORDS: *Furnace control, automation, software, optimisation, slipping.*

1. INTRODUCTION

Today's control room operators are overloaded with information. This requires controllers to be user friendly and operator non-intensive. Tenova Pyromet are experts in the design and development of submerged arc furnaces. They have extensive experience in the Ferro Alloy industry and all associated processes.

Tenova Pyromet's development division has been developing a furnace control system since 1989 and is continually improving it. The control system has incorporated all this experience to meet the requirements and demands of Ferro alloy furnace industry operators of today.

To date the furnace controller has been installed on FeMn, SiMn, Si metal, PGM, Ferrochrome, Rock Wool and Nickel furnaces around the world. In has also been modified to operate on a ladle furnace.

2. AUTOMATIC FURNACE CONTROL

Figure 1 displays the overview page of the Tenova Furnace Controller.This screen will provide a complete view of what is happening in the furnace to management and the operator.

Graphical elements are used to provide the maximum amount of useful information to the user.

The page is broken up into 3 sections:

- General
- Transformer
- Electrodes

Each of these sections displays the following data:

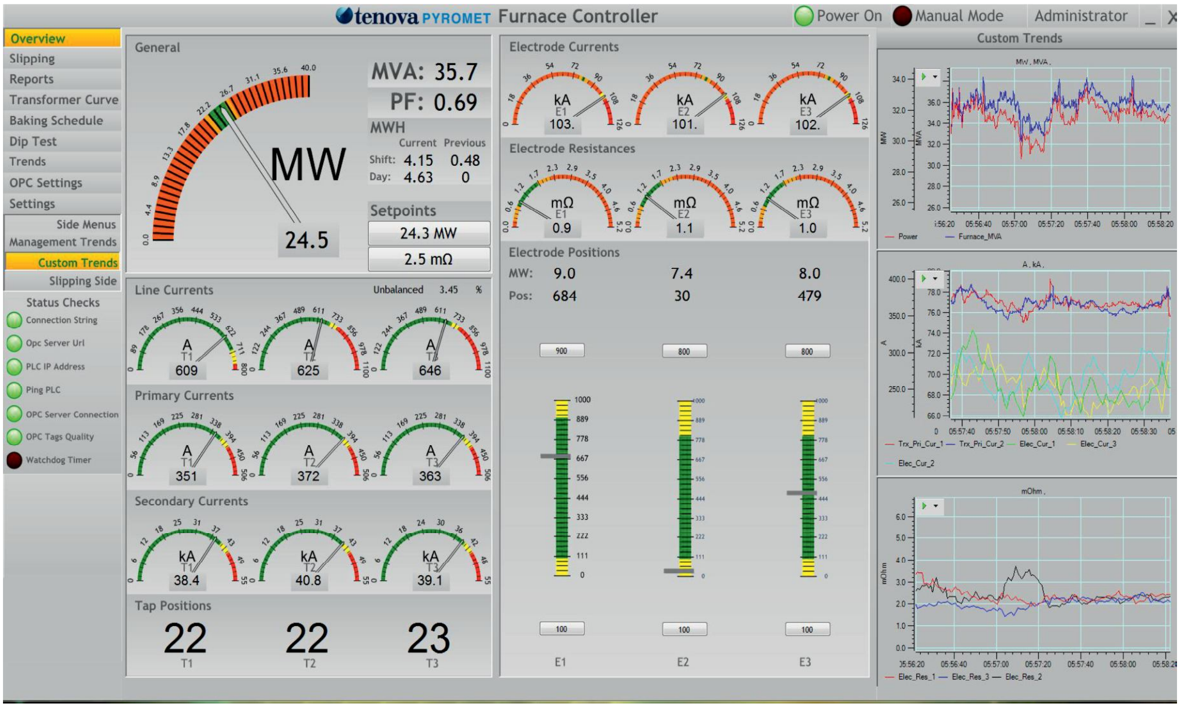

Figure 1: Overview Page

2.1. General

- Furnace MW
- Furnace MVA
- Power Factor
- Current and previous shift MWh
- Current and previous day MWh
- Setpoints (MW,MVA,mΩ and kA)
- MW Coarse High, Coarse Low, Fine High and Fine Low deadband
- Star / Delta connection

2.2. Transformer

- Line Currents
- Primary Currents
- Secondary Currents
- Unbalanced Current %
- Safe operating zones
- Safe overcurrent
- Max overcurrent

2.3. Electrodes

- Electrode Currents
- Electrode Resistances
- Electrode MW

- Electrode Positions
- Electrode Mechanical Limits
- Electrode software limits
- Resistance Setpoints
- Current Setpoints
- Resistance coarse high, coarse low, fine high and fine low deadbands
- Current coarse high, coarse low, fine high and fine low deadbands

The controller uses two control methodologies, firstly the manipulation of the transformer tap positions and secondly electrode regulation. Changing tap positions affects the furnace power (furnace MW) whilst regulating the electrode affects the electrode resistance and current. The deeper the electrode is in the bath, the lower the resistance. The higher the electrode is in the bath, the higher the resistance.

The Tenova Controller bases its control logic on these methodologies to stabilise and maximise furnace power input.

The base control logic layer aims to provide consistent stable furnace operations. Furnace control systems must be able to react to any disturbances in the furnace while maintaining stability and maximum power input.

The Furnace Controller is designed to react to the furnace conditions and take the most appropriate control actions to maintain stability for that particular instance. There will be different levels of control depending on the furnace stability. For example, if there are large disturbances caused by an electrode break or fine feed, the controller will react to re-establish stable running conditions as quickly as possible.

Most furnace operations are required to operate as close to the furnace limitations as possible. The controller maximises the furnace potential by allowing it to run as close to its safe limitations as possible. When running close to the limits, the controller adopts a new approach to control. In this approach the potential of each control decision to push the furnace over its limits and into an unsafe operating zone is determined.

Then the action which will improve furnace stability, maximise power input and keep it in a safe operating zone most effectively will be taken. In some furnace operations it is required that electrodes have a bias towards either moving up or down depending on the process and operation.

Data shown in figure 2 is from a ferrochrome furnace in South Africa. This gives a good demonstration of MW control from the Furnace Controller. The furnace MW is on average within 0.6MW of the setpoint of 30 and 34 MW.

Data shown in figure 3 is from a ferrochrome furnace in South Africa. The data shows a resistance setpoint of 2.4 mOhm, it can be seen the controller keeps the resistance within 0.2mOhm of the setpoint.

The Tenova furnace controller can be set up to accommodate such situations. In ferrochrome furnaces there is a requirement to put more emphasis on the electrode down movement than on the upward movement. This practice ensures the electrodes always have good bath penetration, and discourages the development of false tops.

3. AUTOMATIC SLIPPING

One of the biggest challenges for operators of a ferroalloy furnace with Søderburg electrodes, is electrode management. It is challenging to balance slipping rate and electrode length, whilst ensuring that the electrode is sufficiently baked.

Badly managed electrodes will result in unbalanced furnace operations due to electrodes not being equal lengths, electrode breaks or electrodes being too long or too short. These unbalances have costly consequences as they can result in furnace trips, furnace downtime and tap hole blockages. Managing electrodes effectively and consistently can prove to be a difficult task as there are many variables that play a role in electrode health. The Tenova Pyromet Controller provides effective consistent electrode management that requires minimal operator input.

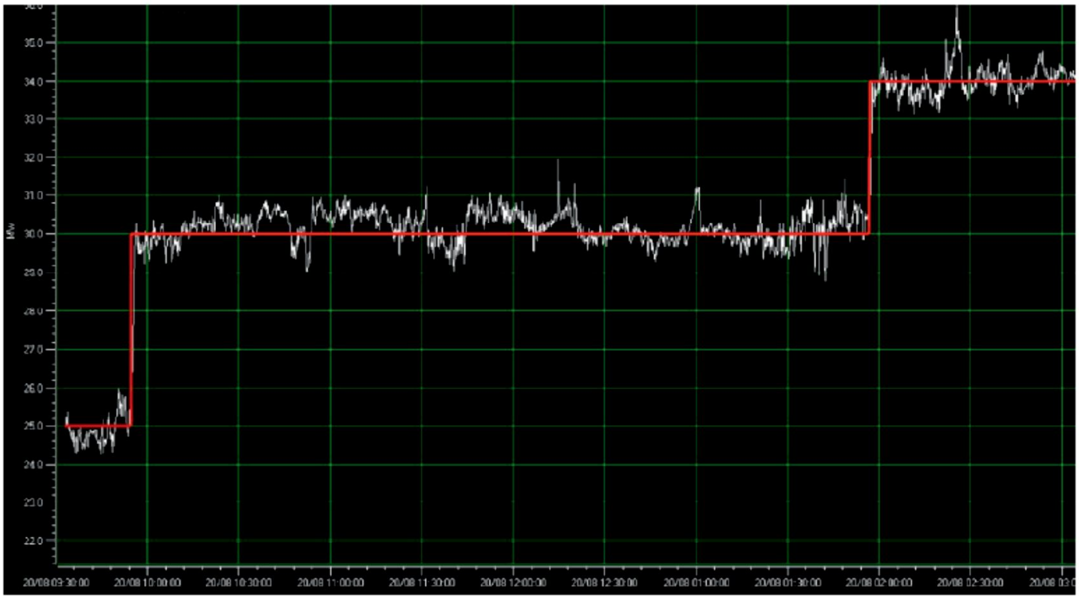

Figure 2: MW Control

SETPOINT
FURNACE MW

Figure 3: Resistance Control

The Controller can effectively manage electrodes with or without an electrode thermocouple. The electrode thermocouple can be a great aid in electrode management if maintained and used correctly. Unfortunately they are often damaged or not placed correctly after adding electrode casings. This results in unreliable data. To get around this common issue the Controller will only consider the thermocouple temperature if its value is determined to be reliable. If the thermocouple reading proves to be reliable it will be used to determine whether the electrode has been efficiently baked before initiating a slip.

Being able to monitor how much of an electrode is consumed is of critical importance when managing electrodes. Calculating the mm/MWh can be done by looking at paste consumption and total slip measurements over a given period of time. The Tenova Furnace Controller will monitor how much electrode is burnt off using the consumption rate. By using a combination of the electrode burn off, the previous slip distance and the furnace current operating conditions, it can be determined when a slip is required.

Figure 4 displays the typical electrode slipping page available on the Tenova Furnace Controller. This page will supply all the tools and display all the data required to effectively manage electrodes.

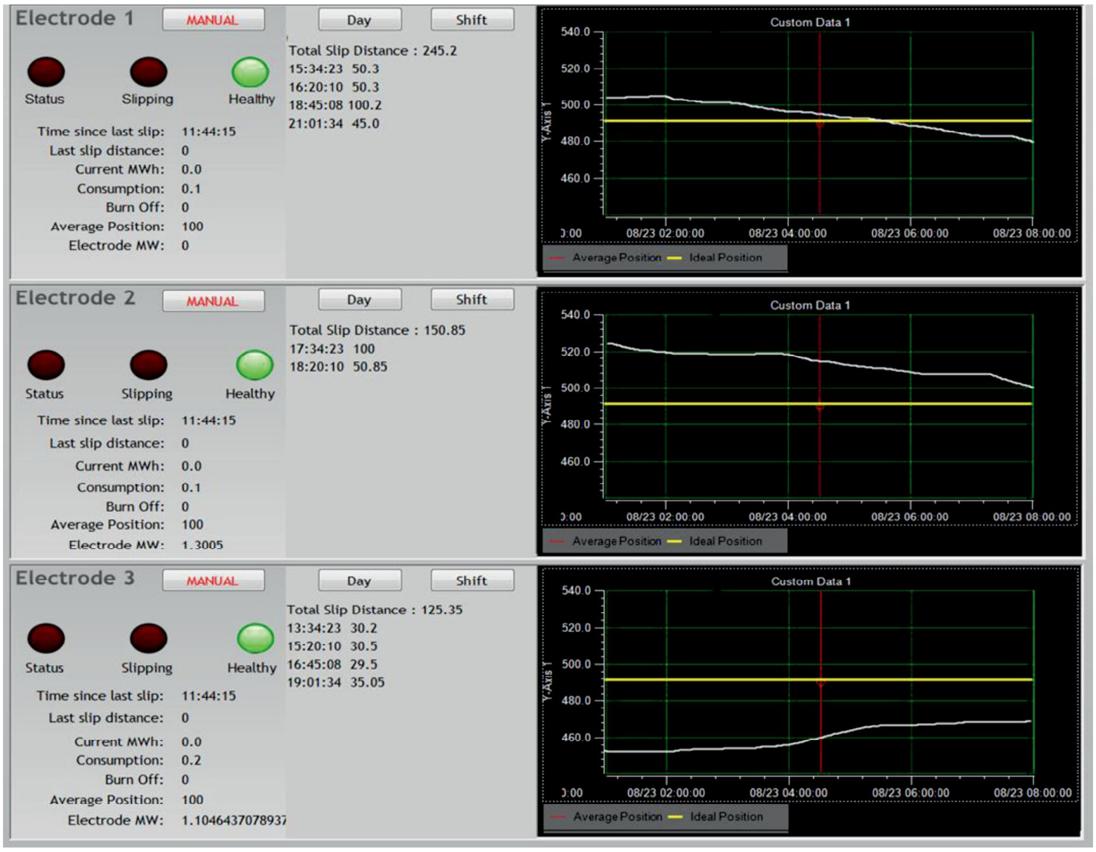

Figure 4: Electrode Slipping Page

The controller continually determines if the electrode is in one of three states - short, long or normal. The controller then uses these states in the following way:

- The electrode is short, the slip rate is accelerated to grow the electrode over a period of time
- The electrode is long, the slip rate is reduced in order to shorten the electrode over a period of time
- The electrode is normal, the slip rate remains the same

The controller autocorrects the applied slip rate to match the slip rate to the actual consumption.

The advanced automatic slipping algorithm looks at the average gradient of the hoist position over a certain period of time. The average gradient can provide valuable information:

- A positive gradient is expected when increasing the electrode length and a negative gradient when decreasing electrode length
- The steepness of the gradient will depend on the calculated consumption rate. The greater the positive difference between the actual consumption and calculated consumption the quicker the electrode will grow (Steeper the positive gradient)
- The closer the gradient is to 1, the closer the calculated consumption rate is to the actual consumption rate

Electrode management is made simple, consistent and more predictable using the advanced Tenova electrode management system. The system can cater for changes in process and bath conditions without requiring any operator input. This leads to more stable operating conditions and consistently baked electrodes.

4. INCREASING POWER

Since a marginal increase in power input can make a significant difference in profitability, the Tenova Pyromet Furnace Controller has in built functionality to maximise furnace power input. In most cases transformers, busbars and other electrical infrastructure are not used to their full capacity. The functionality takes advantage of this. Only once an audit has been done on all furnace electrical infrastructure, and it has been deemed safe to handle higher demands will this function be made available.

The Tenova Pyromet Control power boost function allows the line, primary, secondary and electrode currents to go beyond their normal operating limitations, while still maintaining balance. The limiting factor changes from current limits to temperature limits, the transformer oil and winding temperatures are monitored. If a specified high temperature is reached the currents and power are reduced to a safe operating range until the transformer has recovered to a safe operating temperature.

Figure 5 demonstrates the power boost function in action.

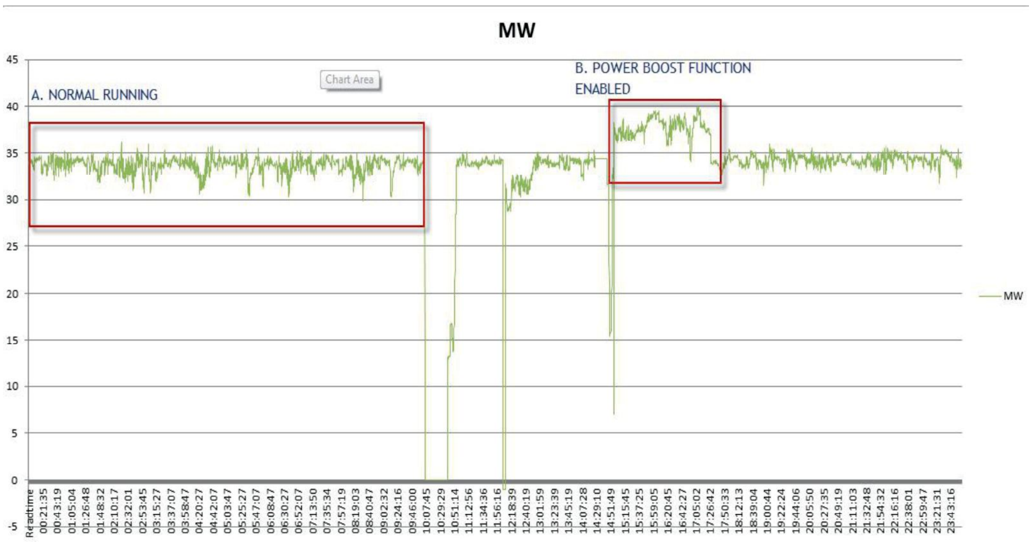

Figure 5: Power Boost

It can clearly be seen where the controller is in standard operating mode and where the power boost function has been activated.

While operating under such conditions, the average hoist position of the electrode will tend to increase, decreasing the immersion of the electrodes. Process changes will need to be considered to counter this phenomenon.

This functionality is not designed to run the majority of the time, but to give furnace operators the ability to increase production by increasing the MWh for a brief time period.

5. EXCLUSION OF ELECTRODE-TO-BATH MEASUREMENTS

Electrode-to-bath measurements are prone to error and equipment fault. In cases where voltage mats are used, there is no way of repairing a fault, as the voltage mats are situated in the hearth refractory. The furnace shell may also be used as a voltage reference point but determining the correct placement for this point is not a simple academic procedure. These methods are also prone to error due to the magnetic fields surrounding the high current secondary circuit components. This independence from electrode-to-bath measurements and the secondary circuit conductors, ensures that the controller operation is based on accurately calculated information, thereby providing better, more accurate control under all conditions [1].

6. HISTORIAN

Accurate information is always of the outmost importance when analysing systems and there processes. The Tenova Pyromet Furnace Controller has an inbuilt data historian that stores all data available to it. All data can be stored at intervals as short as 1 second for the lifespan of the Furnace Controller. Data historians available on site can often not provide such a high level of resolution for such a long period of time. The data historian provides site management and process managers a comprehensive data collection of their furnace. Having such long period high resolution data can help compare furnace operational and process changes, over various periods of time. This system does not require any database management as it is self-managed and maintained.

Historical data trending facilities are also available. Up to 10 different data types can be trended against one another. Trends can be exported to jpg or excel data files for further analysis.

7. CONCLUSION

The Tenova Pyromet Furnace Controller offers a complete solution to furnace automation, for both existing furnaces and those that are in the process of being built or planned. It not only offers furnace automation but also furnace management tools to provide the required information that is necessary to make good and well informed decisions. The minimal input required by the operator for the controller to function effectively allows for other tasks and operations to be given more time, all in the knowledge that the Furnace is running as optimally and effectively as possible.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

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