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HOLISTIC CONTROL OF ENERGY AND MATERIAL FLOWS OF THE ELECTRIC ARC FURNACE

HOLISTYCZNA KONTROLA ENERGII I PRZEPŁYWU MATERIAŁÓW W ELEKTRYCZNYM PIECU ŁUKOWYM

Conventional control of arc furnaces is essentially pattern driven, with patterns based on the input of electric energy. Closed-loop control, which uses the actual furnace conditions, is at best left to some insular solutions. The system presented in this paper is the first control system which offers closed loop holistic control for power and media input.

ARCCESS X-MELT FEOS is a joint development by the Helmut-Schmidt-University and SMS DEMAG AG. The system includes the control of transformer tap, impedance operating point, reactor tap, burners and coal injection as well as replay and simulation of process scenarios for off-line studies and system optimization. In its design great stress was placed on transparency and maintainability using the latest design techniques available.

This paper will touch upon the basic control strategies used and will illustrate this with examples from the trials at Lech-Stahlwerke which were successfully conducted to demonstrate the performance and the reliability of the system.

Keywords: Holistic control, closed-loop control, artificial intelligence, energy control, media control

Typowe sterowanie piecami łukowymi zasadniczo jest oparte na mocy wejściowej energii elektrycznej. Sterowanie w obwodzie zamkniętym, które stosuje bieżące warunki piecowe jest w najlepszym wypadku wykorzystane do ograniczonych zastosowań. System przedstawiony w tym artykule jest pierwszym systemem sterowania, który oferuje holistyczne sterowanie obwodem zamkniętym mocy wejściowej.

ARCCESS X-MELT FEOS jest wspólnym przedsięwzięciem Helmut-Schmidt-University i SMS DEMAG AG. System zawiera kontrolę zaczepów transformatora, punktu sterowania impedancją, zaczepu dławika, palników i wdmuchiwania węgla, jak również oferuje powtórzenia i scenariusze symulacji procesu dla badań off-line oraz optymalizację systemu. Używając ostatnich dostępnych rozwiązań technicznych wielki nacisk został położony na przejrzystość i łatwość konserwacji.

Artykuł dotyczy podstawowych dostępnych strategii sterowania oraz przedstawia przykłady prób zrealizowanych w Lech-Stahlwerke, które demonstrują uzyskane osiągnięcia i niezawodność systemu.

1. Introduction

One of the essential factors in successful electric steelmaking is to be found in the continuous observation of and response to the process, taking all aspects of the process into account. It is thus surprising to find that in conventional EAF control much is still left to straightforward time- or electric energy- based open-loop control rather than using information on the actual state of the process. Many control systems are systems dedicated just to one specific task. An overall, holistic approach to the control of EAF operation, in particular the mass and energy flows, is not to be found in conventional EAF systems.

The absence of an integrated view of the melting process and insufficient regard to the furnace conditions must inevitably lead to sub-optimum operation which fails to fully exploit the potential of the furnace with regard to energy consumption and productivity. It is this which prompted the development of ARCCESS X-MELT FEOS, where FEOS stands for Furnace Energy Optimising System.

After a series of preliminary studies, SMS-DEMAG AG entered into a cooperation agreement with the Helmut-Schmidt-University in Hamburg for the definite development and realisation of the system. This work proceeded at record speed and the control system which shall be presented in the following has by now suc-

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cessfully proven its concept in a series of tests at the Lech-Stahlwerke GmbH in Meitingen.

2. Objectives

The list of objectives to achieve the smooth and optimised operation of an electric arc furnace, while not causing increased maintenance, is long. Foremost among the points to be considered are

- high electric power input
- avoidance of critical temperature levels
- fast reactions
- low switching frequency
- process- rather than time-dependent control of power and media
- efficient use of media and electric energy
- reproducible and transparent furnace operation

3. System structure

The hardware concept developed is shown in Fig. 1.

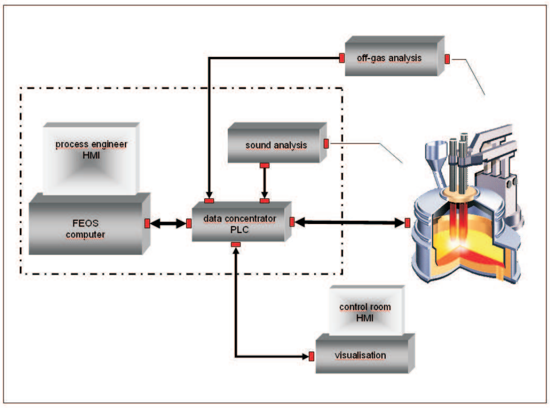

Fig. 1. Hardware structure

The actual FEOS computer runs the control system software package, which analyses the data and stores them for testing and simulation purposes as well as for extended analysis of the control algorithms used. Furnace configuration and the control parameters are also set and kept on this computer. The process engineer in charge of the system can not only monitor the performance of the control system software from here but he is given an overview of the process as a whole at the same time.

All data traffic to and from the FEOS computer passes through a PLC which serves as a data concentrator via an OPC server communication interface. Data are read from and written to this PLC with a cycle time of 1 s. The data concentrator links the FEOS computer with the furnace control system.

Attached to this data concentrator is another integral part of the ARCCESS X-MELT FEOS system, a computer for sound analysis which serves to monitor the state of the foaming slag. An off-gas analysis system can also be linked to the PLC as well as the visualisation computer for the control room operators. Visualisation can on the other hand also be fully integrated in the other control room displays.

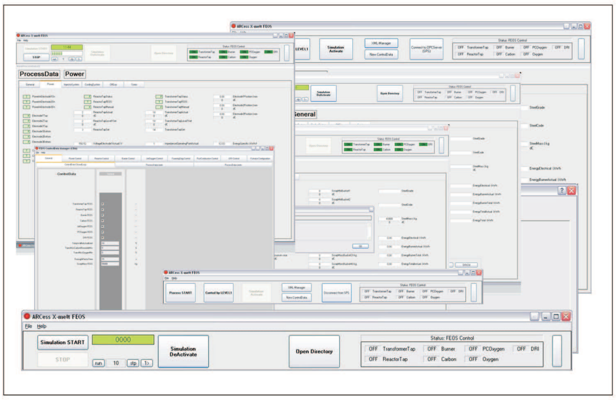

Fig. 2. HMI components of the engineering interface

Great care was taken to develop a structure which fulfils all requirements regarding transparency, easy maintenance, user friendliness and performance. The software package which was programmed in C# is characterised by the following underlying design criteria

- modular structure of systems and algorithms
- cascading graphic interface (fig. 2)
- communication with PLC using OPC-Server-Technique
- software aids for
  - furnace configuration
  - control parameters and limits
- object- and pattern-oriented architecture (fig. 3)
- simulation environment

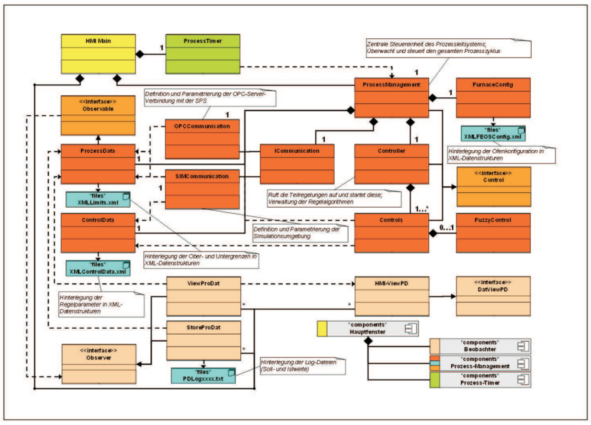

Fig. 3. Object oriented software structure

All data received and transmitted by the control system are recorded. In simulation mode an interface to these files takes over the role of the data concentrator PLC. Situations can be replayed and new scenarios can be created by editing these data files. This is an important tool to parameterise the system during commissioning and to explain the actions taken by the system to the user in the steel work.

4. Control strategy and results

Integrated in the system are at present the features shown in fig. 4. Modules for DRI and post-combustion are awaiting their performance tests.

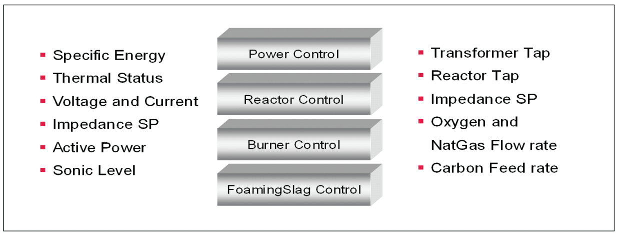

Fig. 4. Control modules

The system was tested at the Lech-Stahlwerke GmbH in Meitingen, Germany. The data of the furnace are

- AC furnace with 75 MVA transformer
- 550 mm electrodes
- 120 t tapped weight
- 64 wall panels
- 3 natural gas – oxygen burners
- 3 coal injectors

The power control module determines the transformer tap and the impedance operating point.

Features of the transformer tap calculation are

- dynamic calculation of limits taking the general thermal development and the state of the process into account
- prognosis of temperature development
- avoidance of frequent tap changes

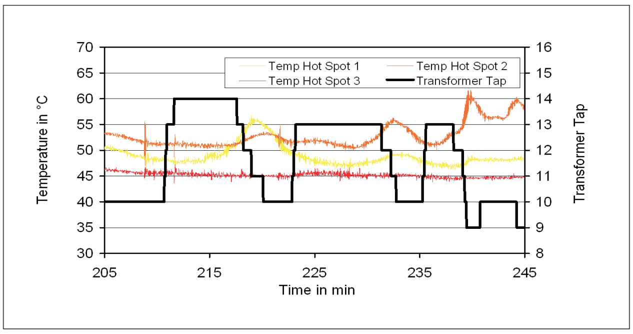

Fig. 5. Transformer tap control – results

Fig. 5 shows results of the FEOS transformer tap control, together with the temperature development in the proximity of the electrodes. There is a conflict in normal operation between achieving high power input and keeping the risk of excessive furnace wear low. The transformer tap control in effect keeps the thermal losses within defined limits and emergency electricity shut-downs due to excessive temperatures are avoided whilst a higher average power input per melt is achieved.

The impedance control enables the operation of the furnace while maintaining a constant current. Here, as in transformer tap control, smooth operation without frequent changes is the goal.

Fig. 6 shows how much better impedance control, which responds to the process rather than following a rigid pattern, performs. The current remains within a narrow band until it approaches the end of the process. Here, the lowest operating point (highest impedance) had already been chosen and a further response was thus not possible. The preset level 1 pattern, however, would have stepped up the operating point and thus further increased the current.

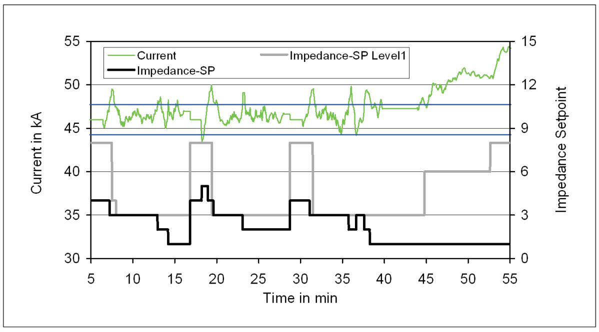

Fig. 6. Impedance operating point control – results

The reactor tap control analyses the relative operating reactance as a measure of the electrically smooth running of the furnace. Based on this analysis and on the state of the process the reactor tap is calculated. Results are shown in fig. 7.

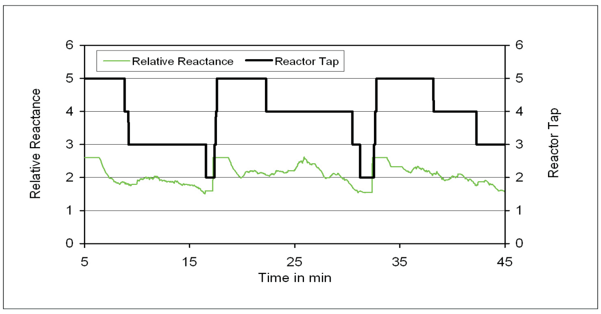

Fig. 7. Reactor control – results

Burner control in ARCCESS X-MELT FEOS ensures a problem-free start at the beginning of a bucket, during which it could also react to the rare event of flame reflection. It then monitors the efficiency of the burner operation. If the efficiency is still high, the burner will continue its operation even if a control pattern would have turned it off. If, however, scrap above the burner is melted down very quickly, the burner is turned down fairly early in the process ensuring the optimum use of natural gas and oxygen. Fig. 8 shows a heat under burner control which demonstrates this point.

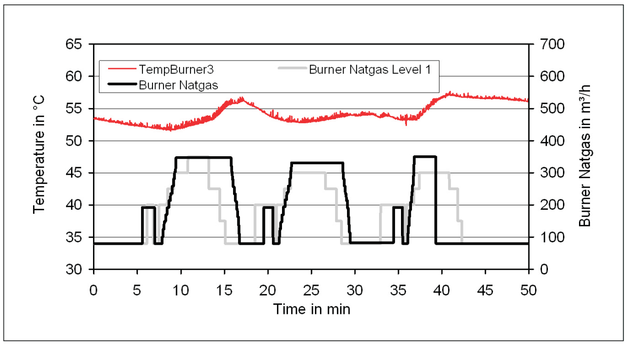

Fig. 8. Burner control – results

The control of slag foaming determines the correct rate of carbon injection. SMS-DEMAG have gathered experience in sound analysis over a long period of time. The resulting sound analysis system has already successfully demonstrated its performance and its reliability in judging foaming quality. The carbon injection rate is set by this control system on the basis of the signal from the sound analysis system. Fig. 9 shows the output of the foaming slag algorithm, this time produced by a simulation run. The carbon injection was pulsed to inject the precise dose of carbon.

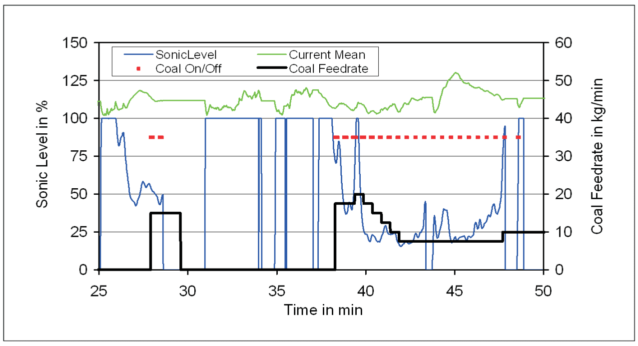

Fig. 9. Foaming slag control – simulation results

5. Conclusions

The control system presented has been jointly developed by the University of the Federal Forces, Hamburg, and SMS DEMAG AG as a system to monitor and analyse the steel melting process in order to respond directly to the requirements of the process at any time. The focus on the state of the process together with the integral approach of ARCCESS X-Melt FEOS results in an optimised use of electrical energy and media leading to a greater efficiency in electric steelmaking. The tests of the new system demonstrated an excellent performance and sound reliability so that it has now progressed from a development project to a commercial product.

The authors would like to thank Lech-Stahlwerke GmbH for their encouragement and support.

Received: 3 April 2008.