# ARCCESS® FEOS – OPTIMIZED ENERGY INPUT INTO THE EAF*

*Wolfgang Linden*[1]
*Keshav Kumar Gaur*[2]

**Abstract**
One of the most important factors in successful electric steelmaking is the continuous observation of the process and the reaction to it. Traditional electric arc furnace control uses mainly direct controls which are based on the electric power input. Not considering the furnace conditions will necessarily lead to suboptimal operation in terms of energy consumption and productivity not fully utilized. The ARCCESS X-PACT® FEOS **Furnace Energy Optimization System** includes the simultaneous control of the transformer tap, impedance operating point, reactor tap, burner and carbon injection, DRI charging control, post combustion-oxygen injectors, as well as a reproduction and simulation of process scenarios for the purpose of making offline studies and for system optimization. FEOS has proven in practical operation benefits of high melting yields, no interruptions through switch offs in borderline temperature area, rapid reaction, reproducible and efficient electrical energy input and short tap-to-tap times [1]. (1).
**Keywords:** Electric steelmaking; Technological control system; Energy-efficiency; Optimization.

1 *SMS Group Ivo-Beucker-Strasse 43, 40237 Düsseldorf Germany*
2 *SMS Group, India.*

ISSN 1982-9345

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

## 2 MATERIAL AND METHODS

### 2.1 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

This is exactly where the development of ARCCESS X-PACT® FEOS system aimed at, with the term FEOS standing for "Furnace Energy Optimizing System".

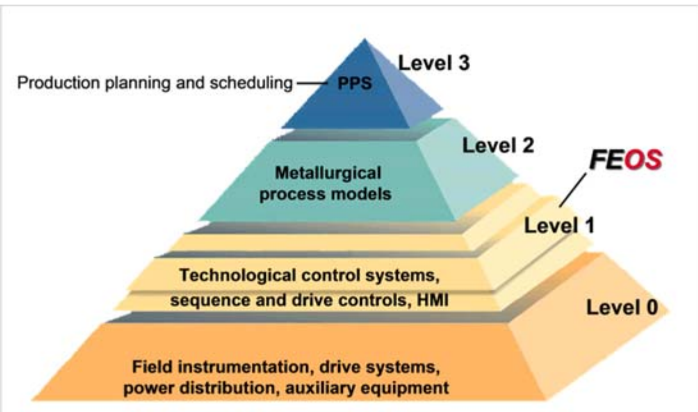


**Fig. 1**: FEOS as ADD ON control system 1

**FEOS** can be added to an existing Level 1 automation system and complements the Level 2 process models.

## 2.2 Hardware configuration

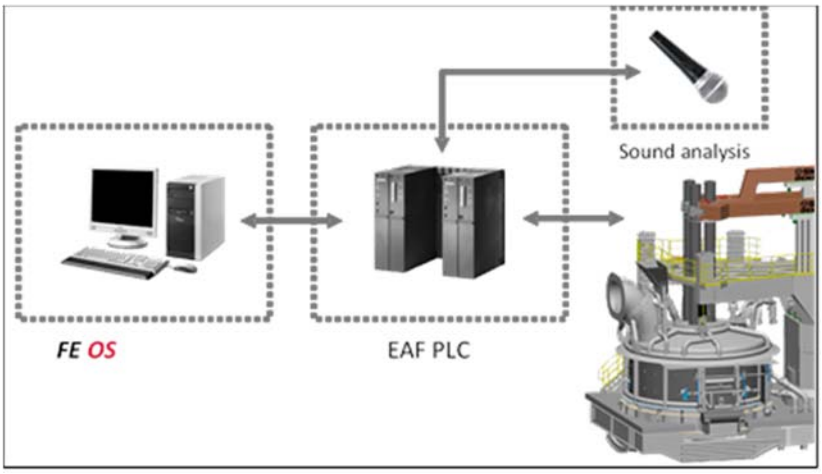


**Fig. 2:** Hardware structure

The hardware concept is shown in Fig. 2.
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 monitors gets 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. 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 will be additionally integrated in main HMI displays.

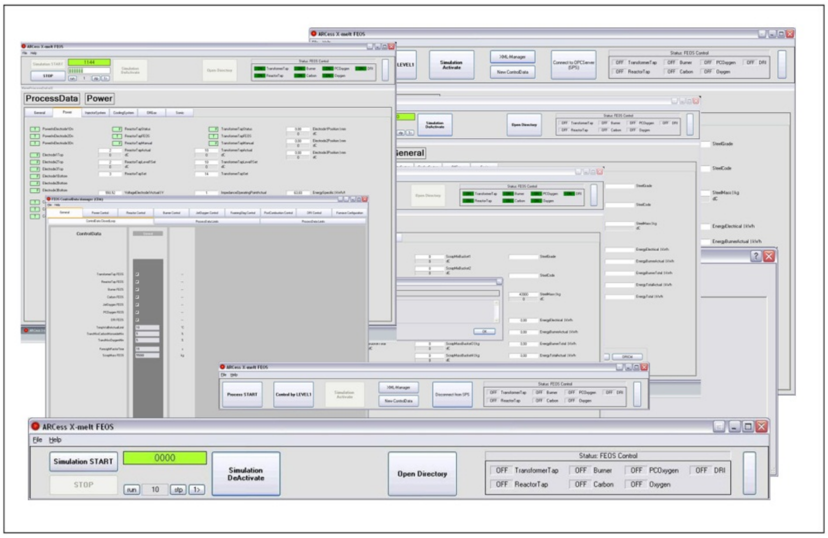

**Fig. 3:** HMI components of the FEOS engineering interface

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

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

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.

## 2.3 Control modules

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

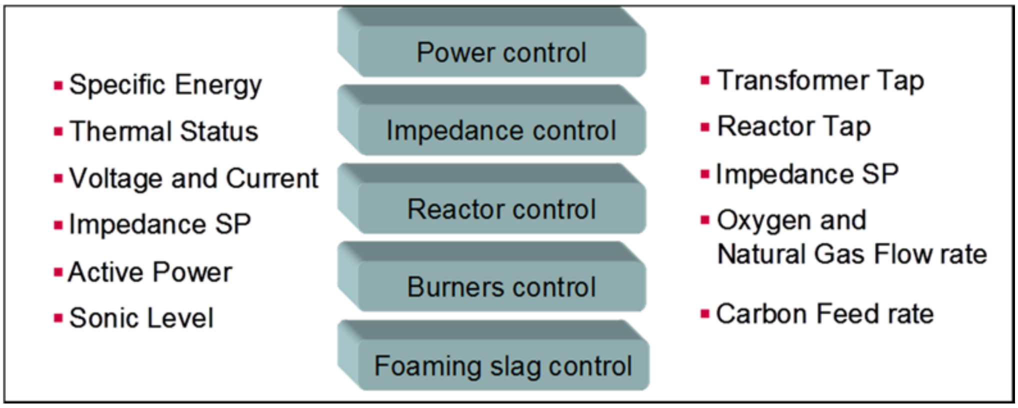


**Fig. 4:** Control modules

## 2.4 Power control module

The **power control module in the ARCCESS X-Pact® FEOS** determines the transformer tap and the impedance operating point. The special features of the transformer tap calculation are

- dynamic calculation of the limit levels by taking into account the general thermal development and the process status
- prediction of the temperature curve
- avoidance of frequent tap changes

Figure 5 shows the results of the **transformer tap control under ARCCESS X-PACT® FEOS** along with the temperature curve near the electrodes. In normal furnace operation conflicts may arise between achieving a high power input and minimizing the risk of excessive furnace wear. Control of the transformer tap indeed keeps temperature losses within defined limits and emergency power-offs due to excessive temperatures are reduced, thus attaining a higher average power input per heat

ISSN 1982-9345

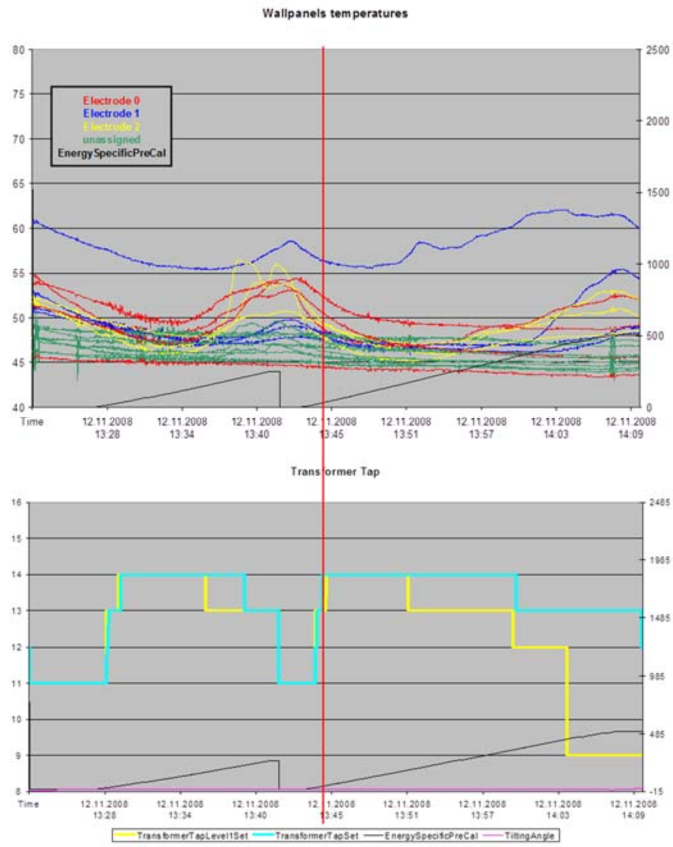


**Fig. 5:** Transformer Tap control 1

An adjustable hysteresis allows the switching frequency of the transformer tap to be limited. In addition, parameters take the thermal status of the furnace into account. (Fig. 6)

Benefits of **ARCCESS X-MELT FEOS** will result in higher melting rates due to shorter tap-to-tap times, prevention of excessive tap switching and consequent reduced wear of furnace breaker equipment. Potential versus conventional pattern rises up to 3 to 5 % enhanced life time of the furnace breaker equipment due to decreased switching operations.

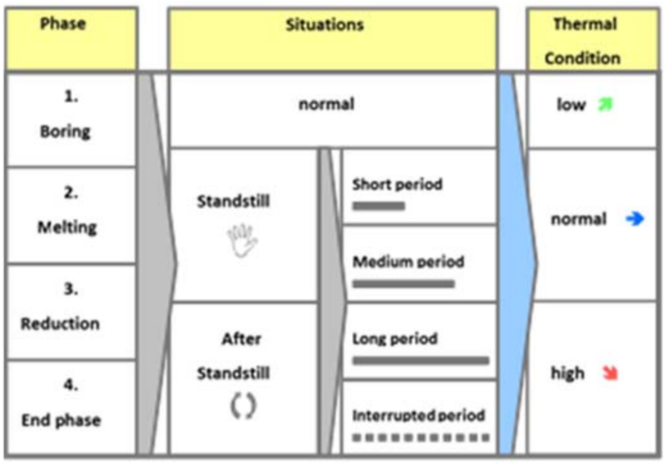


**Fig. 6:** Hysteresis setup for tap control

## 2.5 Impedance control module

**The impedance control under ARCCESS X-PACT® FEOS** 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. 7 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.

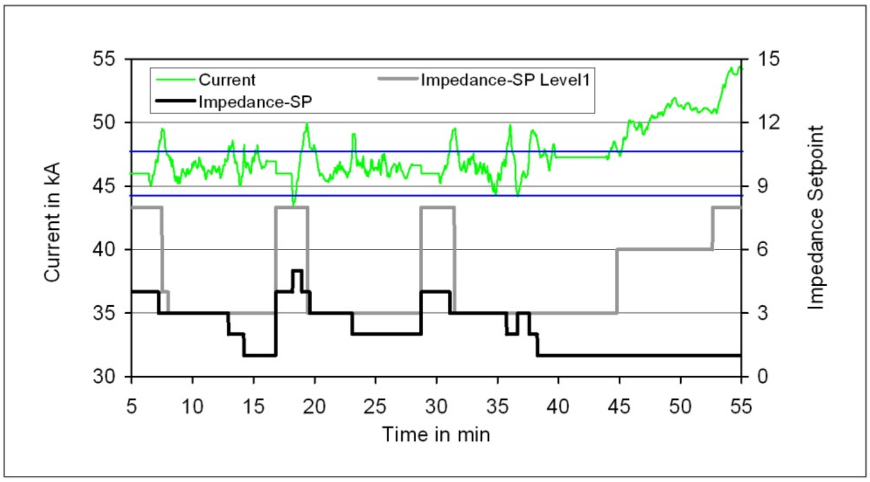


**Fig. 7:** Impedance operating point control - results

## 2.6 Reactor tap module

**The reactor tap control under ARCCESS X-PACT® FEOS** 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. 8.

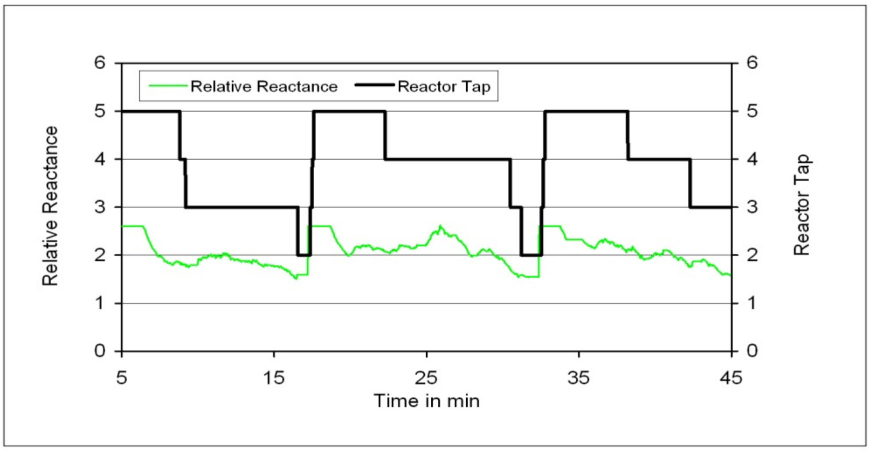


**Fig. 8**: Reactor Controls - Results

Benefit of Reactor control will result in Adaption of reactance to actual process phase, Smoothing furnace operation during scrap melting, Maximization of furnace active power in liquid bath and Minimization of network disturbances. Potential of reactor controls through **ARCCESS X-MELT FEOS** versus conventional pattern control will show reduced network disturbances or higher active power rating (1-2 %) by same disturbances, depending on the desired switching mode.

2.7 Burner control module

**The Burner control under 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. 9 shows a heat under burner control which demonstrates this point.

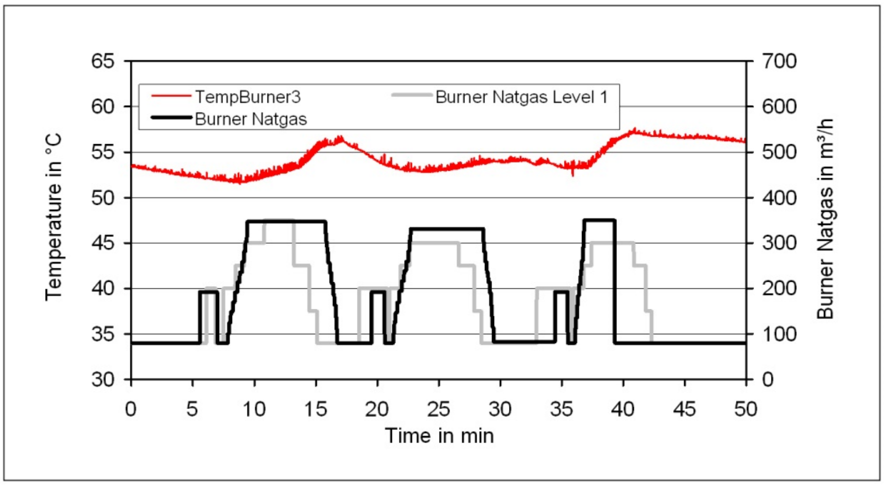


**Fig. 9**: Burner control – results

**Benefit will show higher e**fficient use of fuels, with reduced fuelgas consumption of approx. 3% through **ARCCESS X-MELT FEOS** versus conventional pattern control
2.8 Slag foaming control module

**Control of slag foaming under ARCCESS X-PACT® FEOS** establishes the correct amount of carbon to be injected. SMS Group can draw on a wealth of experience gained in sound analysis.
One of the most important prerequisites for an efficient transfer of the electric arc's energy into the molten metal in the electric arc furnace is the existence of foamy slag. Foamy slag covers the arc and thus minimizes less radiation into the walls.
Covering arcs with foamy slag also reduces the sound energy reflected by the arcs, so that the measurement of the sound intensity provides a significant measure for the assessment of arc sheathing. The sound measurement system uses the phenomenon of variable acoustic radiation with variable degree of sheathing of the electrodes in order to produce a

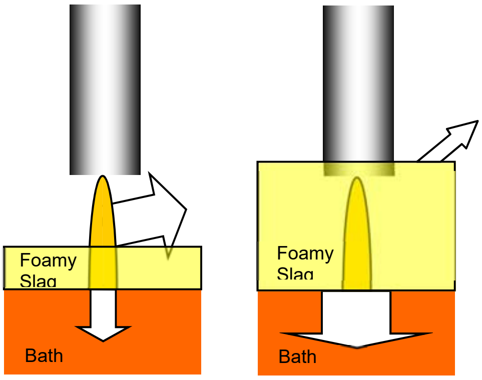


**Fig. 10:** Covering arcs with foamy slag

signal that can be used to control the supply of injected carbon. The supply of injected carbon can thus be used efficiently without affecting the efficiency of the transmission of the electric arc energy. The sound signal at the EAF is a signal which shows stochastic behavior, but is influenced by the formation of foamy slag during the flat-bath phase. It is possible to obtain quantitative information on and make an assessment of the slag formation during the flat-bath phase of the EAF process. The system for acoustic detection of the degree of arc sheathing basically consists of sensors to pick up the sound, signal amplification and evaluation circuit, plus a visualization unit. The sensors used are electrostatic microphones. The microphones are encased to protect them from mechanical influences.
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. 11 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.

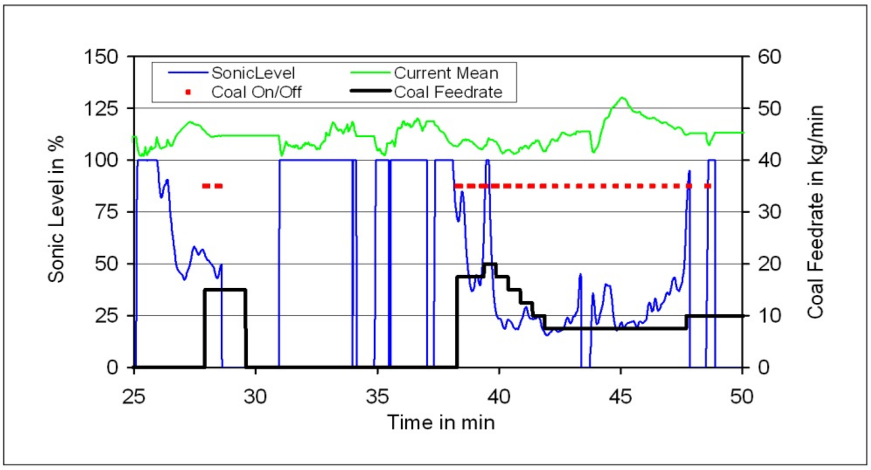


**Fig. 11:** Slag foam control - results

**ARCCESS X-MELT FEOS** benefit in smooth EAF operation with constant slag foam level and efficient and minimized use of carbon leading to efficient melting at high active power. Thereby productivity will increase by approx. 3% at reduced fine coal consumption by up to 10%

2.9 DRI feeding control module

The control concept for determination of the DRI feeding rate is based on the electrical active power and the current acoustic pressure level of the furnace. In case the feeding rate of DRI is too high or the electrical input power for melting is too low, there are high chances of so called “iceberg” formations; unmelted material under the electrode or mass agglomerations of DRI on the heat surface. This may result in fluctuations of the electric arc as well as in reduction of energy input into the heat and can be detected by an increase of the acoustic level in the furnace. Additionally, through the mass agglomeration of DRI on the surface the foaming slag collapses and may lead into further increase of the acoustic pressure level. By means of following inputs for control of DRI charging, such as electrical active power of three phases, actual current and voltage and acoustic level the set points for DRI feeding in kg/min will be determined.
Estimated increased productivity with DRI heats by 5% can be forecasted

## 3 RESULTS AND DISCUSSION

FEOS has proven its suitability for practical application. Reference installations show that electrical and chemical energy consumption as well as carbon injection could be reduced. The melting time was reduced at the same time. This means that the furnace yield can be increased by means of these software components alone.

The following goals are achieved with FEOS:

- High melting power
- No interruptions due to shutdowns in the temperature limit range
- Quick response while simultaneously reducing the switching frequency
- Efficient and reproducible input of electrical and chemical energy
- Shorter tap-to-tap times
- Control of injectors
- Process-dependent and not time-dependent
- Input of consumables
- Lower energy consumption due to optimized and reproducible furnace operating practices
- Increase in production due to shorter tap-to-tap times
- Short commissioning of modernization projects thanks to simple integration into the existing automation system

## 4. CONCLUSION

The control system presented has been jointly developed by the University of the Federal Forces, Hamburg, and SMS Group 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-PACT® FEOS** results in an optimised use of electrical energy and media leading to a greater efficiency in electric steelmaking. The tests of the system demonstrated an excellent performance and sound reliability, so that it has now progressed from a development project to a commercial product. Successful

ISSN 1982-9345

installation of gas analyser with reliable sampling system completes the holistic control system for furnace energy optimization.

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

## REFERENCES

1 1 HOLISTIC CONTROL OF ENERGY AND MATERIAL FLOWS OF THE EAF. Markus Dorndorf, Jens Kempken , Klaus Krüger , Peter Monheim , Norbert Uebber, Manfred Schubert. Krakow : s.n., 2008. EEC.

2 L. Voj, V.Y. Risonarta, H. Pfeifer, H.P. Jung, S. Lenz. Optimization of EAF Process at Deutsche Edelstahlwerke. Archives of Metallurgy and Materials . Issue 2, 2008, Bd. Volume 53.