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SUPRACOK™ LEVEL 2 SYSTEM FOR COKE OVEN PLANTS[1]

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Abstract
Level 2 system has become an essential part in coke oven plants operation. Nowadays, higher flexibility and top level of performances are required during plant operation in order to fulfil today's market requirements. An advanced powerful support system to operational personnel is therefore essential, and Supracok™, Paul Wurth Level 2 automation system for coke oven plants, was indeed designed and developed to achieve such purposes. This paper highlights the main features and latest developments of Supracok Level 2 system and how the operators can successfully cooperate with the same. Supracok Level 2 system integrates mathematical models and supervision functions, aiming at the thermal control of the battery, the monitoring of the coking process, the scheduling of charging / pushing operations, on the basis of production requirements, actual process data, and also taking into account anomalous conditions such as production stops, delays and maintenance of single ovens. The interaction between the operator and the various models and functions is carried out by means of a comprehensive user-friendly Human-Machine Interface. Supracok is highly flexible and can be customized in accordance to actual Customer requirements.
Key words: Level 2; Coke oven plant; Models; Process control.

SUPRACOK TM – SISTEMA DE AUTOMAÇÃO NÍVEL 2 PARA COQUERIAS

Resumo
Sistemas de Nível 2 têm se tornado uma parte essencial da operação de uma bateria de coque. Atualmente, uma elevada flexibilidade e uma performance de alto nível são exigidas durante a operação da planta visando atender às exigências de mercado. Um sistema de suporte potente capaz de dar suporte ao pessoal de operação é, portanto essencial, e o Supracok™, sistema de automação de Nível 2 para coquerias da Paul Wurth, foi concebido e desenvolvido para atingir tais metas. Este artigo destaca as principais características e os mais recentes desenvolvimentos do sistema Supracok Nível 2 e como os operadores podem cooperar com sucesso do mesmo. O Sistema Supracok Nível 2 integra modelos matemáticos e funções de supervisão, visando o controle térmico da bateria, o acompanhamento do processo de coqueificação, a programação de enfornamento/desenfornamento, tendo como base os requisitos de produção, dados reais de processo e considerando também as condições anormais tais como paradas de produção, os atrasos e manutenção de fornos individuais. A interação entre o operador e os diferentes modelos e funções é realizada por meio de uma Interface Homem-Máquina completa e amigável. Supracok é um sistema altamente flexível e pode ser customizado de acordo com exigências do cliente.
Palavras-chave: Nível 2; Baterias de coque; Modelos; Controle de processo.

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1 INTRODUCTION

An advanced, powerful, user-friendly Level 2 automation system has become an essential part in modern coke oven batteries, aiming to support operational personnel in plant operation and process control.
Although cokemaking plant operation and process control have achieved over the years a consolidated status, based on proven and worlwide accepted theoretical background, as well as on widespread application of the “best” operation practices, on-line process control tools and relevant application software are not, so far, always fully exploited and really accepted as an essential component of the plant. This could be ascribed to some deficiencies of former generation systems, such as lack of flexibility or of ease of usage, as well as poor adaptation to local practices and operators’ customs. Less stringent operational needs played a role in the above scenario, as well.
These considerations, along with changing market requirements, spurred Paul Wurth on developing Supracok ™ Level 2 system, and on constantly updating the same, up to the present day.
Today’s coke and coking coal market scenario requires higher flexibility and top level of performances during plant operation and supervision of the coking process, to successfully and constantly reach a full, effective, safe exploitation of the plant capacity, under possible changing conditions, such as different raw materials qualities, or adoption of more stringent emissions requirements, or variations of productivity levels. Figures 1 and 2 summarize recent market surveys.[1,2]

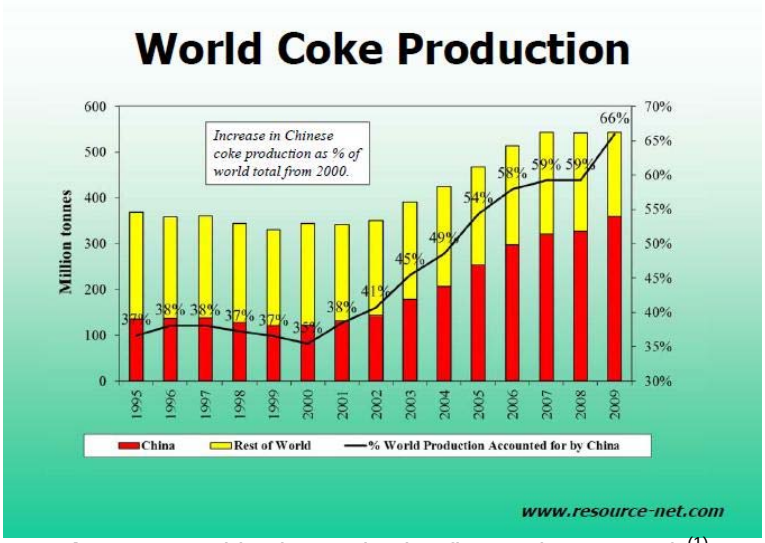

Figure 1. World coke production figures (1995-2009).[1]

Production, process and quality requirements, along with relevant variations of the operational conditions, must be promptly, but smoothly, managed by skilled operators, constantly adopting the ‘best’ practice, and properly supported by adequate instrumentation, automation, and process control tools. Aim of these tools is to provide operators with accurate and useful information, to easily implement repetitive tasks, to improve and optimize the process supervision and control, in compliance with real process conditions. Based on these considerations, we can conclude that, nowadays, Level 2 is even more profitable than it was in the past.

ISSN 2176-3135

Supracok, Paul Wurth Level 2 automation system for coke oven plants, was indeed designed and developed to fulfil above requirements, and better meet coke producers' expectations. It combines the best available process know-how and extensive expertise in cokemaking plants design and equipment, with state of the art automation and process control technologies.

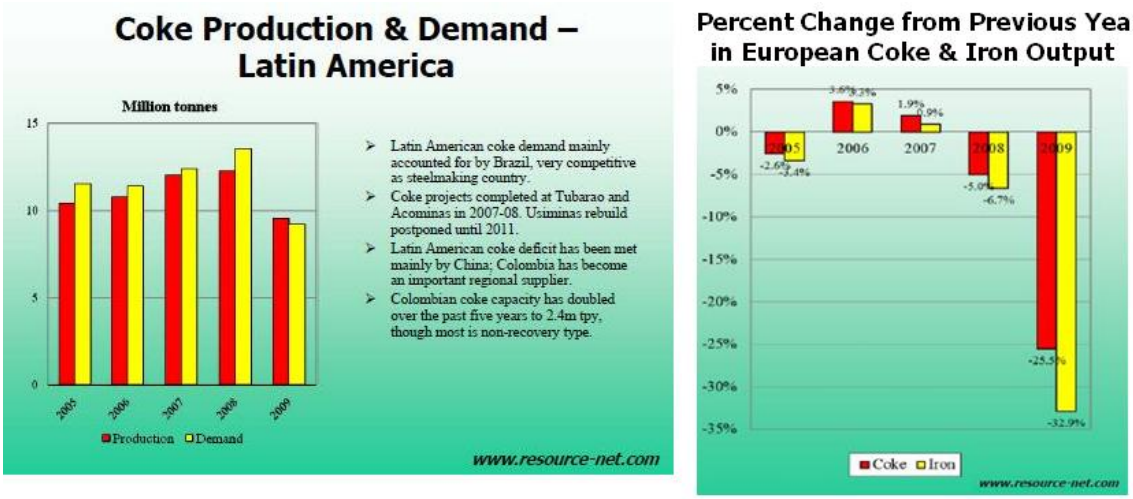

Figure 2. Production figures: coke production & demand in Latin America (2005-2009) and percent change from previous year in European coke & iron output (2005-2009) .(1)

This paper highlights the main features and latest developments of Supracok Level 2 system and how the operators can successfully cooperate with the same.

2 SUPRACOK™

Supracok, Paul Wurth Level 2 automation system for coke oven plants, aims at providing an advanced comprehensive support system to operational people, and helping to achieve, by means of its profitable usage, top class performances in terms of operation stability and safety, quality of produced coke, reduction of gas consumption, compliance with environmental requirements, better use of the plant equipment and consequent increase of battery life time.

Supracok Level 2 system, formerly named "Coke Oven Plant Coordination and Optimization System", was firstly installed and successfully put in operation for the new 45 ovens battery at Lucchini works, Piombino (Italy), in 2002.(3) This new battery was designed and built on a turn-key basis, and the first coke was pushed in June 2002. The overall automation and control system was included in the scope, as well, and developed in close cooperation with process specialists and operators.

In recent years, Supracok system has been revamped in accordance with state of the art technologies, and a "new generation" release is going to be installed in two major cokemaking plants under design and construction by Paul Wurth:

- Bhushan Steel Ltd., Meramandali, State of Orissa (India); new coke oven plant No.2, battery No.1, 74 ovens, first coke planned in 2012;
- PT. Krakatau Posco, Cilegon (Indonesia); new coke oven batteries No.1 and No.2 (42 ovens each), first coke planned in 2013.

The main technical data of the above plants are shown in Table 1.

ISSN 2176-3135

Table 1. Technical data of above mentioned cokemaking plants

	New "45 ovens" battery LUCCHINI Piombino (ITALY)	New coke oven plant No.2 Battery No.1 BHUSHAN STEEL LTD. Meramandali (INDIA)	New coke oven batteries No.1 and No.2 PT.KRAKATAU POSCO Cilegon (INDONESIA)
Coke production [t/y]	430,000	1,306,500	1,321,000
Number of ovens	45	74	42 + 42
Battery type	Gun type	Under jet	Under jet
Charging type	Top charging	Top charging	Top charging
Oven dim. H x L x W [m]	6.2 x 13.2 x 0.45 (cold)	7.25 x 20.0 x 0.55 (hot)	7.25 x 20.0 x 0.55 (hot)
Oven useful volume [m3]	32.8	79.75	79.75
Level 2 platform	Windows 2000 Server Windows 2000 Prof.	Windows Server 2003 Windows XP / Windows 7	Windows Server Windows 7
Level 2 database	Oracle 9i	Oracle 10g	Oracle 10g
Network	Ethernet	Ethernet	Ethernet
Comm. with other systems	Level 1 (RTDB) Area computer	Level 1 (OPC server) Laboratory, Lev.3	Level 1 (OPC server) Laboratory, Lev.3

The system integrates mathematical models and supervision functions, aiming at the thermal control of the battery, the monitoring of the coking process, the scheduling of charging / pushing operations, on the basis of production requirements, actual process data, and also taking into account anomalous conditions such as production stops, delays and maintenance of single ovens. The above models and functions are implemented by means of well-known programming languages and basic software packages, and are able to run on standard hw & sw platforms available on the market. The system is conceived to be easily integrated into the overall plant network, and connected through ethernet with the Level 1 automation system, as well as with laboratory or other corporate computers. Data communication with Level 1 is based on OPC technology, today's worldwide leading communication standard in industrial applications. A key component of the system is the relational database, which is used to collect data from external sources, as well as to store the calculated output results. The application software is made up of the following major modules (Figure 3):

- Thermal Control Model;
- Coking Process Monitoring Model;
- Scheduling of Charging / Pushing;
- Data communication with Level 1 automation system (based on OPC technology);
- Data communication with other computers (i.e. Laboratory, Level 3);
- Human-Machine Interface;
- Web reporting;
- Daily processing of production, quality and process data;
- Alarms and events logging.

The interaction between the operator and the various models and functions of Supracok is carried out by means of a comprehensive user-friendly Human-Machine Interface. This one has been recently revamped, to incorporate state of the art solutions in software engineering, as well as concepts and conclusions from ergonomic studies, conducted by Paul Wurth about the use in iron & steel plants of Human-Machine interfaces by control room operators. The above conclusions have

ISSN 2176-3135

been firstly experienced with reference to blast furnaces and applied to BFXpert™, Paul Wurth Level 2 system for blast furnaces.(4)
Within this renovation framework, the reporting module has been extended, to include the possibility of web access to the reports. Trends generation and displaying module has been upgraded, as well, to extend online configuration capabilities.

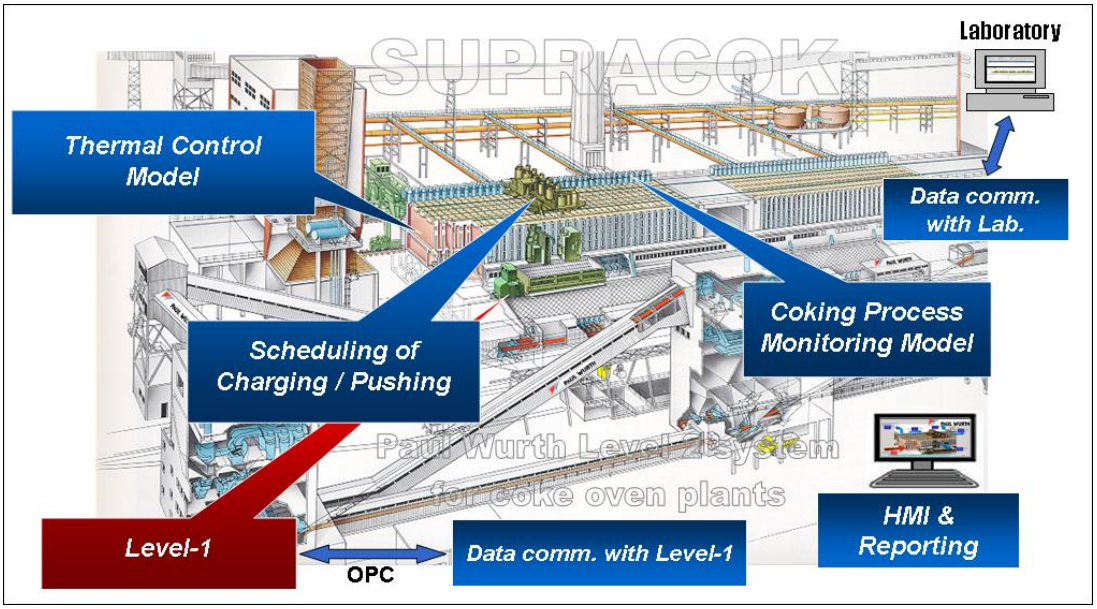

Figure 3. Overview of Supracok Level 2 system showing major models and functions, as well as interfaces with external systems.

Further new additional features, recently developed to take advantage of latest software technologies, include the management of login and access rights, the multi-language, the “look & feel” settings.
Major design and implementation criteria are modularity, easy configurability, highly customizable, ergonomics, state of the art hw&sw platform, and all of these have been beneficially supported by process know-how and plant expertise, along with the worldwide presence of Paul Wurth, which gave the opportunity to discuss the needs of operators in multiple plants and consolidate wide experience from several installations.
Supracok is highly flexible and can be customized in accordance to actual project requirements. Its updating, extension to new features or incorporation of state of the art technologies, is an ongoing process.

2.1 Thermal Control Model

Aim of the thermal control model is to calculate, cyclically, the optimum thermal flow rate to be supplied to the battery. The model is activated automatically by the system, with a time frequency comparable with the regenerative heating cycle of the battery; input data are automatically collected by the application, and the operator is therefore released from repetitive input tasks. The calculations are carried out taking into account production requirements, coal data, process measurements, as well as stoppages and not working ovens. Feedback corrections are also performed, based on actual battery temperatures and raw gas temperatures. The model results are downloaded to basic automation as control set-points, in terms of time duration of the variable pause between the regenerative heating cycles, and/or combustion gas flow

ISSN 2176-3135

rate, in accordance with actual process and plant constraints. The model input/output data, currently in use, can be accessed by the operator for analysis or monitoring purposes, by means of a dedicated HMI screen, to be opened on demand whenever desired.
The calculation algorithm is made up of the following steps: calculation of the heat theoretically requested by the battery, in steady state conditions, based on the thermal balance represented in Figure 4; correction of the nominal heat, to take into account scheduled stoppages and not working ovens; feedback corrections based on actual measured process data.

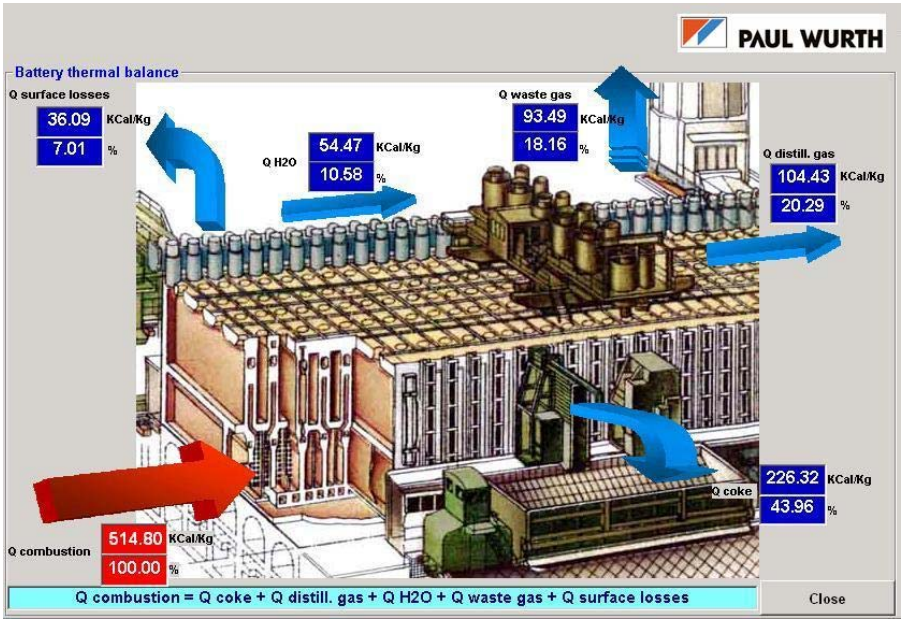

Figure 4. Representation of the battery thermal balance, implemented by the Thermal Control Model.

An overview of the above calculation algorithm is shown in Figure 5.

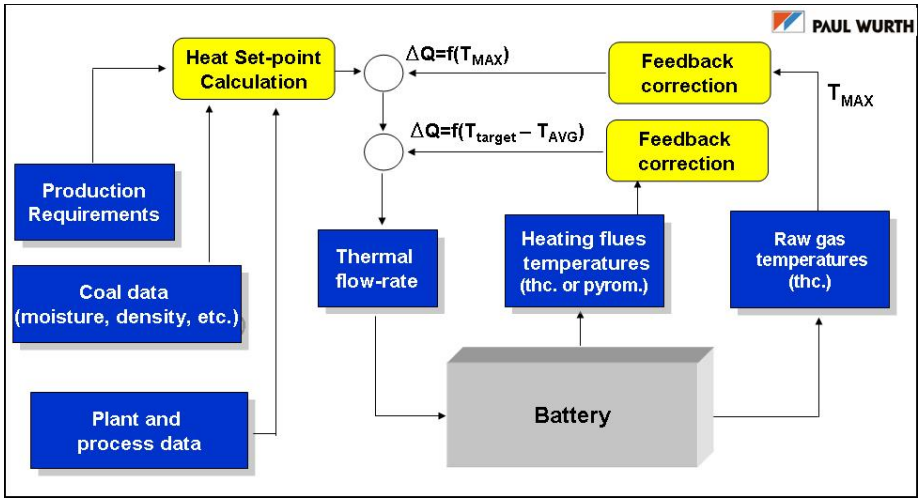

Figure 5. Overview of Thermal Control Model algorithm.

Effects of feedback corrections can be suitably tuned, in accordance to actual availability and reliability of relevant sensors on the specificic plant.

ISSN 2176-3135

2.2 Coking Process Monitoring Model

Aim of this model is to support the operators with graphic intuitive indications about the progress of the coking process for each oven, and provide proper recommendations on the coking end time and consequent pushing permission.
The monitoring of the coking process is carried out on the basis of reliable continuous measurements of the raw gas temperatures at the stand pipes. The trend of this temperature is representative of the coking progress. Taking into account suitable threshold temperatures, correlated to the distillation end time, as well as to the end time of coke temperature stabilization, the following process phases are detected on-line by the model (Figure 6):

- coking in progress (“red lights”);
- stabilization of temperature (“yellow lights”);
- pushing allowed (“green lights”).

Figure 6. Typical trend of raw gas temperature with corresponding coking process phases.

The current oven status is displayed on the dedicated HMI screen (Figure 7) accordingly: “red lights”, “yellow lights”, or “green lights”, with reference to the next start of pushing.

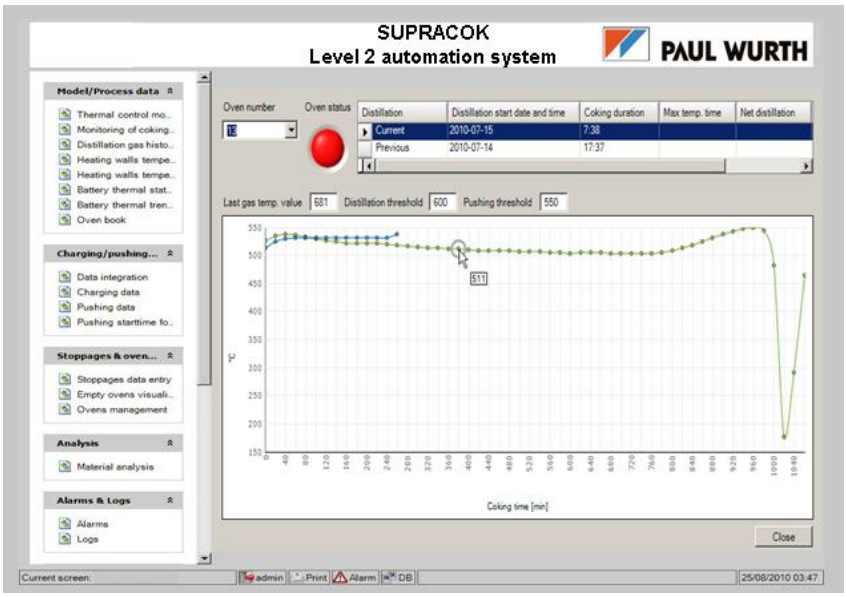

Figure 7. Typical HMI screen for monitoring of coking process, showing, for the selected oven: oven status, time information, current ongoing and previous raw gas temperature trends.

ISSN 2176-3135

2.3 Scheduling of charging / pushing

The calculation of the scheduling of charging and pushing times is one of the major functions of Supracok system. It is based on productivity requirements, expressed in terms of number of daily pushing operations, or coke daily production, or nominal net coking time, as well as on current production and plant data, such as stoppages or delays, ovens status, coal yield. The scheduling is calculated with reference to a future time period, that can be defined by the user (typical period from 3 to 15 days). Input data are mostly automatically collected from the database, at every run of the scheduling, and manual data entry is limited to desired variations of the calculation options, such as variation of the required productivity level, or of the reference scheduling period. Figure 8 shows some details concerning input data by the operator.

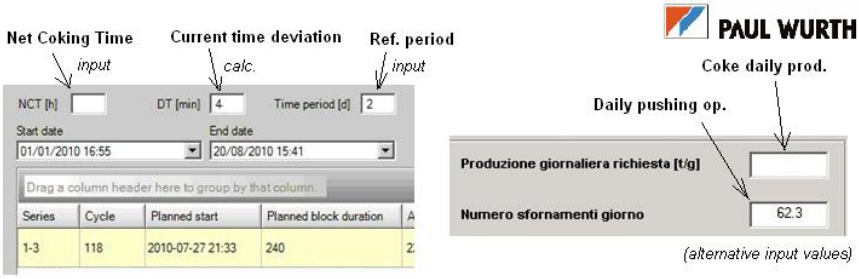

Figure 8. Scheduling: examples of Supracok HMI screen details, relevant to data entry options.

The results are displayed to the operator on the Level 2 HMI (Figure 9), for check and validation purposes, and downloaded to Level 1 automation system for further actions, in accordance with actual control strategy and operation mode.

Figure 9. Typical scheduling results: charging and pushing times, along with indication of ovens' current status (red, yellow, or green lights).

This function can be activated automatically, usually at the occurrence of the pushing event, or upon operator's request, by means of a dedicated HMI screen. The

ISSN 2176-3135

scheduling calculation is properly integrated with the coking process monitoring model, giving indications about the real coking progress, as well as with the machines coordination and control system.
As the above scheduling calculation is obviously strictly dependent on Producer's policy and plant constraints, the scheduling algorithm, implemented within Supracok, is prone to be customized, on the basis of local operation practices.

2.4 Other Functions

Various support and data processing functions are implemented within Supracok Level 2 system, to integrate the models calculations within a common well proven platform. They are designed to be easily configured and customized for the specific project constraints and requirements, and include: data communication with external systems, daily calculations, alarms & logs. They are not directly used by the operator, but are obviously necessary for the system operation; after installation and commissioning, their future maintenance, if any, will be a system manager duty.
Data communication with Level 1 automation system is implemented on the basis of OPC technology, i.e. Level 2 plays the role of OPC client, while the OPC server is implemented and running on the Level 1.
Data communication with Laboratory or Level 3 systems, if any, is usually carried out by means of direct sql access to the concerned database tables.
Daily calculations are carried out automatically on a cyclic basis, to compute and made available into the database relevant data for reporting purposes, such as production and consumption figures or process variables average values.
Alarms and logs, issued by Supracok models and functions, are associated to possible process or system reasons, and are integrated within the HMI; the operator is notified of a new alarm by means of a graphic indication on the bottom bar, and can access, on demand, the dedicated screen for further information and acknowledgement actions.

3 USE HIGHLIGHTS AND BENEFITS

Although modern information technologies and software tools allow nowadays the implementation of powerful easy-to-use applications, their effective and profitable use in control rooms of cokemaking plants is not always a consolidated practice. But, it can be reinforced, by taking into due consideration the operators' requirements, and demonstrating the benefits, they can get by the constant use of these systems.
Special care has been therefore dedicated to the "final user", and Supracok designed accordingly. Key points of Supracok Human-Machine Interface are: common interface for the various models; standard and ergonomic look & feel of the various screens; displaying of the models results, conceived for a clear and immediate interpretation of the same; multi-language; different style settings; prone to customization. Supracok main models are running on a cyclic basis, and do not require repetitive or redundant data entry. Operators' manual input is limited, and in any case not required for cyclic models calculations, but only in case of desired variations of a given input value. In case of use of the same data for different functions, relevant manual data entry is done only once, to avoid additional work and possible errors.
Supracok models and functions are accessible by means of the same common interface, upon selection of the corresponding item on the "navigation tree", placed

ISSN 2176-3135

on the left part of the screen. The different items are grouped within the navigation tree, according to functional, as well as ergonomic criteria.
Graphic objects for operator's actions and data sets selection, such as data filtering controls, action buttons, data grids, or graphs, are standardized with reference to their look, use and layout.
Two common important functionalities have been added to the new generation Supracok HMI, aimed at increasing flexibility and making customization easier: online management of multi-language and possible switching among different sets of "look & feel" style settings (Figure 10).

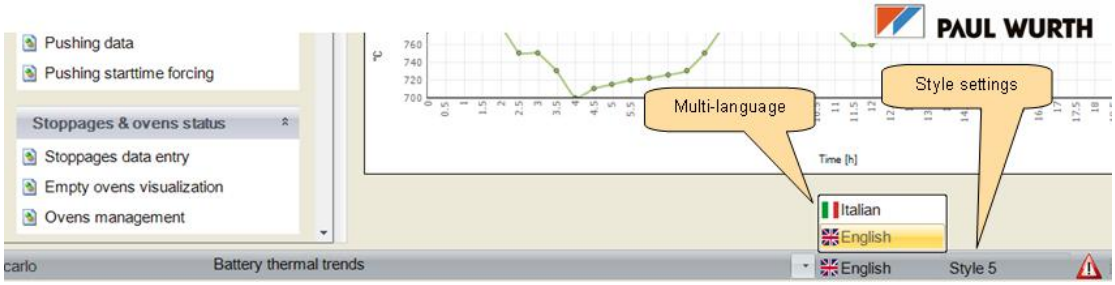

Figure 10. New functionalities of Supracok HMI: multi-language and style settings on-line selection.

Multi-language on-line management allows the user to choose one of the envisaged languages (usually two or three), without reinstallation or restart of the application. It applies to labels, legends, and other text controls on the screens. The chance to select a set of style settings (i.e. colours of standard graphic objects, text properties, etc.), among the ones defined during design and customization phase, is an online convenient feature, which can be used to even better meet user's customs, whilst preserving flexibility and easy configuration.
All the above factors positively contribute to make operators' daily work easier and more efficient. During normal operation, the operators can access "on demand" the HMI screens for results analysis, check and monitoring purposes, and focus their attention on the process supervision. Major benefits are expected from the possibility of early check of scheduling results, online monitoring of the single oven, configurable trending. Manual data entry is mostly required, apart from initial configuration, in case of anomalies or operating conditions variations. Suitable screens are envisaged for these purposes, such as: to enter stoppages data; to run a "re-scheduling" with new productivity targets; to complement charging / pushing data, in case of communication failure with Lev.1; to insert, or modify, materials analyses, in case of missing connection with laboratory.
Thanks to the application of above criteria to Supracok framework, along with suitable training, the operators can become more confident of the Level 2 system, and regularly use this powerful tool to improve the safe and cost-effective exploitation of the plant potential.

4 CONCLUSIONS

Supracok provides the coke oven plant operators with a powerful, accurate, easy-to-use support tool, which can be successfully used to improve operation performances, and to achieve the following benefits:

- improvement of operation stability and safety, thanks to advanced, online, supervision and control tools;

ISSN 2176-3135

- higher quality of produced coke, which can be constantly achieved based on better monitoring of the coking process;
- reduction of gas consumption, thanks to the optimization of the thermal flow-rate supplied to the battery, particularly beneficial in case of planned stoppages, restarts, empty ovens, as well as variations of productivity requirements or coal properties;
- easier achievement of environmental requirements;
- increase of battery life time;
- helpful, precise, duly organized information to the operators, conceived to positively support their process monitoring task, as well as prompt actions, in case of anomalies.

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