OPERATION RELIABILITY, SAFETY AND FLEXIBILITY ENHANCEMENT USING ONLINE FURNACE AND FLAME MONITORING SYSTEM WITH THERMOGRAPHICAL ANALYSIS: CASE STUDY AT 300 MW_{EL} OIL- & GAS-FIRED BOILERS IN KUWAIT

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The continuous rising energy demand, the aged fleets of thermal boilers with their dual/mixed firing systems together with the severe local ambient conditions make the power generation in the state of Kuwait and other countries in the middle-east a challenging task. Moreover, a not well-tuned combustion process caused by flame displacement and impingement, low burn-out rates, fuel leakages and ignition problems have a significant influence on boiler reliability, availability and safety.

The Ministry of Electricity & Water in Kuwait (MEW) decided to renew and upgrade aged and non-functional furnace camera systems to maintain safe operation and allow continuous monitoring and optimization of the boiler operation. The main requirements for the monitoring system foresees an online visual monitoring and a thermographical analysis of the combustion processes inside the furnace with highest resolution and a 24/7 availability. The system shall keep close track of the process under varying fuel types (e.g. natural gas) and burner combinations facilitating operating conditions like start-up and shut-down and identifying potential hazard operation conditions early in advance to prevent unwanted and negative consequences (e.g. oil leakage). The information shall be analyzed and visualized in the control room.

In order to ensure failure free operation under the severe operating conditions in the Middle East countries sufficient cooling performance is required and realized by specially designed closed cooling circuit.

The paper addresses the application of EUvis online furnace and flame monitoring systems in 8 x 300 MW_{el} oil- & gas-fired boilers at Sabiya Power Station in Kuwait. It describes the challenges of the application in detail and explains the operational benefits achieved. In particular, the definition and clarification of requirements in close cooperation with Babcock Borsig Steinmüller in Kuwait (BBS) and MEW, the engineering support provided for installation using a model-based approach as well as the execution and support processes are demonstrated.

1 POWER GENERATION IN KUWAIT

The State of Kuwait is an Arabic country situated in the northern part of the Persian Gulf and extends over an area of about 18,000 km² with a population of over 4 million people. Its harsh climatic conditions go from a hot, dry and dusty summer (e.g. over 40 °C) to a warm/cool winter with some rain. Kuwait´s main resources are oil and natural gas, thus more than 90% of the gross domestic product (GDP) is generated by the oil export [1], [2], [3]

With one of the highest energy consumption rates mainly due to its severe climatic conditions, highly subsidized energy tariffs and booming economy, and with the projection to grow over 66 TWh by 2020, power generation in Kuwait is both an essential responsibility as well as a challenging task. Its power generating capacity is estimated to touch even 17 GW by 2020 [2].

The government and the Ministry of Electricity & Water (MEW) is constantly working on new solutions to maintain and improve operation of existing fleet of power plants as well as investing founds to install new energy capacity with conventional and renewable power stations to meet this rising energy demand [2].

When talking about power generation in Kuwait, the fundamental role and primary source of fresh water for drinking and domestic purposes through the desalination of sea water cannot be overlooked, too. Kuwait's power stations are indeed the major source of drinking water production in the country. Thermal desalination technology requires energy for the separation process which is supplied to the system generally by electrical power [2], [3].

2 CASE STUDY AT SABIYA POWER STATION

This study refers to all of the eight oil- & gas-fired 300 MW_{el} units of Sabiya I power and desalination plant situated in the north of Kuwait. Sabiya I entered service in April 1998 and produces a total of 2,4 GW_{el} for the base load and up to 55 Mio. l/d of drinking water [2], [3]. Together with Sabiya II, the whole plant represents about 1/6 of the total water desalination industry of Kuwait [4].

Each of the eight units have a two-pass boiler with front firing and a total of 16 fixed burners distributed in four rows of four burners each. The fuels used are generally heavy oil and natural gas with dual/mixed firing system. Sometimes crude oil or gas oil are used too. The almost square (11 x 11 m) furnace works at an overpressure level of about 50 mbar and its operating temperature can rise up to 1,600 °C. Environmental ambient temperature outside the furnace reaches up to 60 °C during extreme summer weather conditions.

From each control room the plant personnel monitor and operate two units at the same time. All the boilers were equipped from their erection (started in 1996) with one furnace camera at 25,2 m level at the left side wall for continuous monitoring of the firing system inside the furnace. Thus, two overview pictures are available at each control room.

At the time of this study, MEW could not take any more advantage of these systems due to their outdated design, poor image quality and inadequate system availability basically caused by unavailability of some spare parts. Moreover, MEW had the additional requirement to monitor and analyze continuously all the new retrofitted burners.

2.1 REQUIREMENTS FOR ONLINE FURNACE AND FLAME MONITORING SYSTEM [5]

Each boiler furnace shall be provided with minimum two sets of furnace video cameras to monitor continuously the combustion process under all the different fuels adopted with 24/7 availability. The cameras shall be water cooled and equipped with a suitable retracting unit in case of any alarm or unit trip. The furnace camera system shall withstand furnace operating conditions up to 1,600 °C as well as the harsh ambient temperature conditions and radiation heat generated by the furnace at the place of installation (i.e. > 60 °C).

The positioning of the furnace cameras shall be installed to be able to show completely all the 16 burners as well as individual burner mouths and the bottom of the boiler, too. Additionally, the cameras shall cover flames up to the rear wall to detect long flame impinging the rear wall. The locations for installation of the cameras shall be designed and documented with a complete set of layout drawings and detailed engineering drawings. Only side walls are allowed for camera installation.

The furnace and flame monitoring system shall be designed for online visual monitoring and thermographical analysis of the combustion processes inside the furnace with highest image resolution. The system monitor(s) shall be installed in the control room, all remote signals like alarm(s) and measurement(s) shall be available in the control room too. From the field control unit(s) fiber optical cables allows image and signal transfer to and from the control room.

2.2 PRE-EVALUATION AND DEFINITION OF SCOPE

Operating in the region since almost half a century, Babcock Borsig Steinmüller (BBS) in Kuwait works hand-in-hand with clients like MEW at all stages of the plant life cycle: From engineering, procurement, construction and commissioning services through to maintenance and efficiency enhancements, as well as expansion, conversion or shutdown. BBS needs to rely on the cooperation and support of strong technology suppliers and partners to be able to provide always the right products and services to their local customers.

MEW assigned BBS to define and provide a suitable solution that met their latest needs for the mentioned task. After a preliminary investigation verifying the technical and financial feasibility, BBS relied on EUtech Scientific Engineering GmbH (EUtech) and the EUvis furnace monitoring and flame analysis system. This decision was corroborated not only based on technical and financial aspects for the specific enquiry but also based on design, engineering and service skills and expertise.

The project started with the pre-evaluation and recapitulation of all of MEW´s requirements and needs at all the plant levels (i.e. operation, maintenance and management) with the help of an established guideline. The relevant plant issues and objectives can be summarized as follows:

- burner tuning and combustion optimization in relation to unburnt fuel and emissions levels,
- online combustion monitoring with complete overview of the furnace including walls and hopper,
- start-up procedure and
- safety aspects

At the same time, the technical situation and boiler operation were assessed on site, covering boiler set up and accessibility, firing system and control strategy, available and required plant equipment (media availability and supply), status of already installed furnace cameras, communication from and to DCS system to name a few. These evaluations were done on-site by a dedicated team of qualified engineers and supported by available information and data.

All the objectives and information found have been analyzed and used for the definition of the best and most robust configuration, always keeping in mind the economic role of the investment.

2.3 MODEL-BASED APPROACH & ENGINEERING SUPPORT

The complete design process was supported and facilitated by using a model-based approach with extended use of CAD 3D models and simulations. Working with a model of the physical application provides a convenient way to experiment and assess various design and application concepts. The philosophy is simple and straightforward:

- build/adapt the CAD 3D model of the boiler with all relevant components,
- simulation of the expected combustion flame shape according to information,
- design of the specific application with the use of EUvis camera 3D model(s),

- validate the system configuration by using field of view simulation under different conditions,
- document the system layout and application with related appearance and interface drawings

Moreover, further advantages achieved in this project were the fast and accurate design phase, the direct and clear information sharing as well as the straightforward and simplified communication between the parties in Germany and in Kuwait. Thus, the system outcomes were available, clear documented and validated before any work was even started on site. Figure 1 shows the high correlation between the field of view simulated during the design phase and the real camera picture available after commissioning.

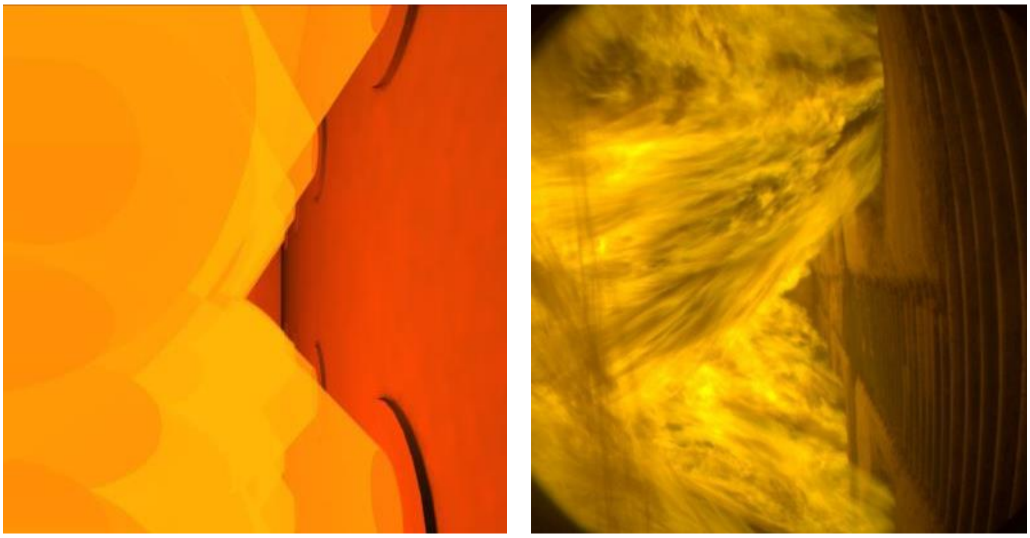

Figure 1: EUvis - field of view simulated (left) and after commissioning (right)

The requirement for burner tuning and combustion optimization was met by applying two new EUvis camera systems with a horizontal orientation close to the burner wall: One camera between the first two burner levels (A & B) on the left side wall and the second between the last two rows (C & D) on the right wall side as depicted in Figure 2.

Thus, all the burner mouths are visualized and continuously observable at the same time from the control room. If the unburnt fuel and the emission levels increase (e.g. black smoke out of the sole chimney), the plant personnel can directly find out which boiler and then which burner(s) are mistuned. Before the EUvis system was installed, this matter was handled by the plant personnel manually using the available peepholes on site.

Additionally, with this configuration the oil firing start-up procedure could be improved, too.

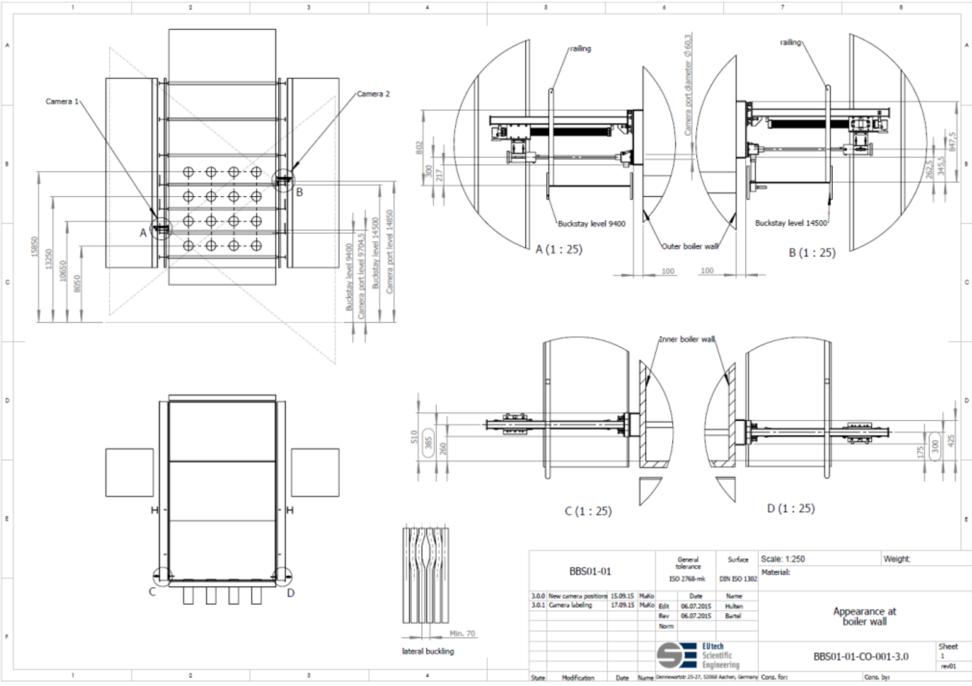

Figure 2: EUvis - camera position and appearance at boiler wall

At the time of this study it was common use to switch on all the burners of one row at the same time even if in the control logic those were linked only in pairs: the outer (#1 & 4) and the central burners (#2 & 3) respectively. Doing the starting oil firing procedure sequentially, the start-up procedure and the safety aspects could be addressed and improved too.

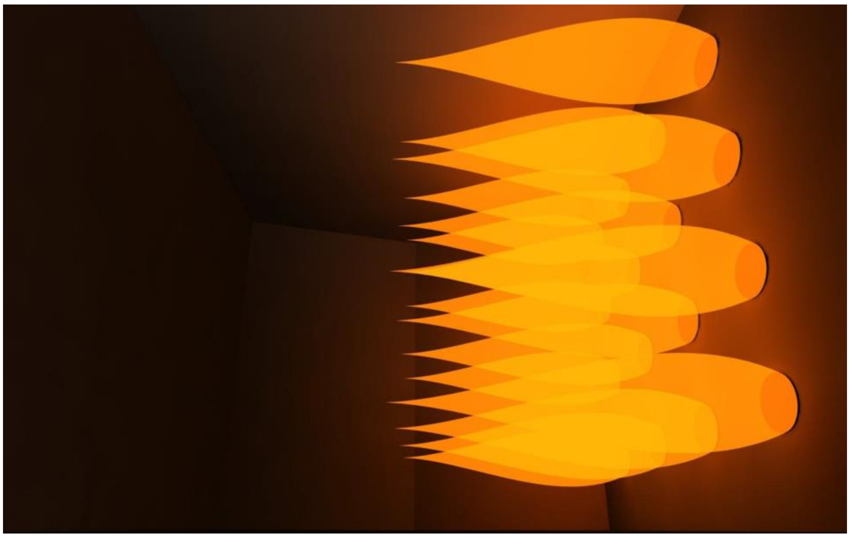

Figure 3: EUvis upgrade - field of view simulation

About the monitoring of the furnace and thus having a complete overview of the overall combustion process including walls and hopper, the solution adopted was to upgrade the already existing aged furnace cameras in relation to image quality, functionality, thermographical analysis and camera spare parts availability. The otherwise functional infrastructure (i.e. retraction system and control cabinet) remained in place so that the upgrade seamlessly slips into the existing environment. This position would grant the complete geometrical coverage of burner banks (c.f. Figure 3).

2.4 Erection, TiO & commissioning

Right after the design phase and related manufacturing clearance, the system production as well as the site preparation works began in parallel. In Sabiya power station the yearly outages are normally executed for each of the eight units for about 20 to 30 days sequentially between September and April. During this time all the erection, taking into operation and commissioning works took place (c.f Figure 4).

Figure 4: Tubes bending, refractory work with camera duct and camera mounting plate with EUvis air lock adapter

Figure 5 shows one EUvis system installed at the right boiler wall. Each camera including retraction unit comes along with its control unit. The latter is divided into two separated media and electrical control cabinets. In this specific case, to withstand the severe local ambient conditions, the installed cameras are water cooled. This allows safe operation during summer time and extreme operating temperature conditions up to 60 °C.

The EUvis communication and HD camera signal is transferred completely digital via Ethernet (fiber optics). Therefore, no additional and costly frame grabbers and separate communication link to cameras are required.

Figure 5: EUvis - control and retraction units (left boiler wall)

The state-of-the-art system technology using high resolution digital cameras, provides a stunning image quality and loss-free image transfer from camera(s) to monitor(s) at the control room.

About the retrofit of the already installed furnace cameras, the outdated components were seamlessly replaced and rejuvenated to fulfill the latest standards with no requirement for boiler outages. The functional retraction system and control cabinet remained in place. The upgrade covered new EUvis IP cameras with HD resolution, new optics and control components that allows complete digital communication and full integration into the EUvis system environment including thermographic analysis. Thus, all the installed three cameras per boiler are available through one EUvis software at the control room (c.f. Figure 6).

Figure 6: Online visualization in control room

The EUvis thermo flame monitoring and analysis software enhances the EUvis systems with a thermographic analysis algorithm. It allows determining the local temperature distribution and helps to identify and quantify irregularities in the combustion process supporting the plant personnel and engineers to maintain optimal boiler operation, adjust burner flames, observe deposit on furnace walls and hopper.

3 RESULTS

Boiler availability, efficiency and safety have been strengthened and improved at Sabiya I power station introducing state-of-the-art furnace camera systems. The EUvis furnace camera system with its high-resolution video monitoring and thermographical analysis supports online 24/7 combustion monitoring, burner tuning and optimization as well as safety aspects. Thus, well-tuned air-fuel-ratios and combustion parameters are the standard operating conditions now.

In case of suboptimal and unclear furnace conditions the whole personnel and performance engineering teams can observe, discuss and perform together parameter adjustments and even immediately react to critical situations avoiding major issues and thus increasing plant safety. Since their commissioning the number of unforeseen boiler outages have been reduced, too.

Additionally, the new camera system can visualize oil leaks through out of service burners nozzles. Sometimes oil shut off valves are passing and unburned oil will accumulate inside furnace; this is a highly potential risk of explosion and already happened in Doha West Power Station few years before.

Figure 7 shows the results achieved about image quality with the retrofit of the aged furnace camera system at 25,2 meters with the EUvis upgrade kit. The retrofitted furnace camera system is now good as a new one for a fraction of the costs. With the improved image quality, there is a clear and full coverage of complete flame extent. Thus, long flame impinging the rear wall are easily detected. Even sooted boiler walls and hopper deposits can be clearly monitored due to the high-resolution images.

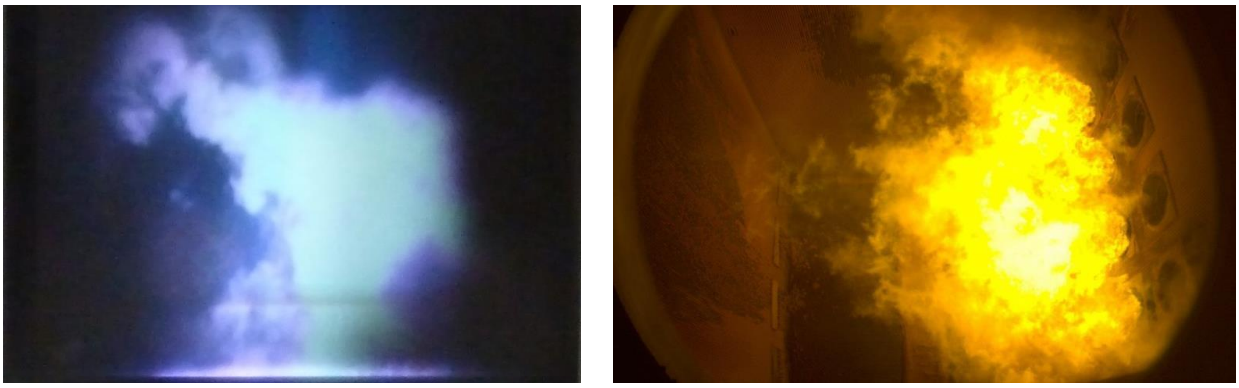

Figure 7: Camera image before (left) and after (right) EUvis upgrade

4 SUMMARY AND OUTLOOK

The condition of the boiler has a significant influence on the reliability, availability and safety of a power plant unit. Early detection of malfunctions, abnormal deposits and unforeseen changes in combustion quality can increase plant quality and safety due to immediate reaction to critical situations. In some cases, it may even be necessary to change the boiler operating settings substantially (e.g. load, fuel type, air-fuel-ratios, etc.) to avoid unscheduled boiler failure and consequent outages.

MEW decided to renew and upgrade aged and non-functional furnace camera systems in order to maintain and improve operation of existing fleet of power plants to meet the rising energy demand in Kuwait. BBS relied on EUtech and the EUvis furnace monitoring and flame analysis system to solve this task at Sabiya I power station. Using a model-based approach the design and engineering phase have been significantly optimized. The adopted solution consisted in the introduction of two new EUvis furnace cameras for online monitoring of all the burner nozzles and the retrofit of the aged and non-functional furnace camera installed with the EUvis camera upgrade kit.

The furnace camera systems have been installed and successfully commissioned in all of the eight units between June 2015 and June 2016. Based on this reference and the achieved results at these harsh climatic conditions, MEW awarded BBS and EUtech to supply the EUvis furnace camera systems at the eight units at Doha West Power Station, too. The system for the first unit (unit #6) with extra specially designed closed cooling circuit has been already successfully commissioned. The erection and commissioning work for all the remaining seven units will be terminated at the end of 2018 or latest beginning of 2019 based on effective outage plan.

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