New Training Simulators for State-of-the-art Coal-fired Power Plants at KWS PowerTech Training Center

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Kurzfassung

Neue Schulungssimulatoren moderner Kohlekraftwerke bei der KRAFTWERKSSCHULE E.V.

Die KRAFTWERKSSCHULE E.V. (KWS) betreibt seit mehr als 20 Jahren an ihrem Geschäftssitz in Essen Schulungssimulatoren für fossil befeuerte Kraftwerke. Zurzeit werden Simulatoren für Schulungszwecke betrieben, die das Spektrum gängiger 300-MW-Blockkraftwerke mit Steinkohle-, Braunkohle-, Öl- und Gasfeuerung sowie Gas- und Dampfturbinen-Kraftwerke abdecken.

Im Zuge der gegenwärtigen Neubauprojekte von Kraftwerken mit überkritischen Dampferzeugern der 800-MW- und 1100-MW-Klasse und hohem Nutzungsgrad entsteht auch ein immer größer werdender Bedarf, das Bedienpersonal dieser Kraftwerke an entsprechenden Simulatoren schulen zu können. Daher werden neue Kraftwerksimulatoren für die KWS in Zusammenarbeit mit Energieversorgern entwickelt.

Für insgesamt drei neue Simulatoren sind die folgenden Kraftwerke als Referenzkraftwerke auswählt worden:

- *Block F der in Bau befindlichen 2 x 1100-MW-Doppelblockanlage BoA 2&3 am Standort Neurath (Braunkohle) und*
  Block G im Kraftwerk Niederaußem, einem Block der 600-MW-Klasse (Braunkohle),
- *Block D der 2 x 800-MW-Doppelblockanlage des Kraftwerks Westfalen (Steinkohle) und*
- *Block 4 der 1100-MW-Monoblockanlage des Kraftwerks Datteln (Steinkohle).*

Die Besonderheiten der Simulatoren sind, dass mit dem Simulator für Braunkohlekraftwerke zwei Kraftwerke auf einer gemeinsamen Hardwareplattform nachgebildet werden. Des Weiteren wird die Schulungsbereitschaft der beiden Simulatoren für Steinkohlekraftwerke in einer Grundversion bereits vor bzw. während der Inbetriebsetzung der realen Anlagen erreicht; deren Prozessmodelle werden verfeinert und abschließend parametriert, nachdem die Kraftwerke ihren Betrieb aufgenommen haben und Betriebsdaten vorhanden sein werden.

Die Modellierungen der verfahrenstechnischen und der elektrischen Anlagen wird mit modernen Entwicklungsumgebungen vorgenommen. Für das Automatisierungssystem wird heutzutage ein virtuelles Kraftwerksleittechniksystem des jeweiligen Leittechnikherstellers eingesetzt. Somit kann der originale Automatisierungscode von der Referenzanlage vollständig übernommen werden.

KWS wird zur Schulung kundenorientierte Kurse in modernen Wartenräumen bei der KWS oder am Kraftwerksstandort anbieten.

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Introduction

For more than 20 years, KRAFTWERKSSCHULE E.V. (KWS – PowerTech Training Center) operates training simulators for fossil-fired power plants at its Essen headquarters. The initial spectrum of simulated plants comprised the common hard coal-, lignite-, oil-, and gas-fired 300 MW units with both, natural circulation and once-through steam generators. In 2000, a new training simulator for CCGT plants was developed, which started operations in April 2001. Not only German power producers use the simulators for personnel training, but also utility companies from other European countries, like Belgium, Italy, the Netherlands, Norway, and Austria, as well as from around the world. The simulators allow conducting training sessions for international trainees in various languages.

In the course of the construction of the new 800 MW and 1100 MW high-efficiency power plants with hypercritical steam generators, a growing demand for – even multilingual – training of operator personnel from such plants at simulators is arising. These needs result from the high rated power per unit and the associated high economic loss in case of a breakdown as well as from the growing complexity of plant automation. Thus, new training simulators are being built for KWS since the middle of last year. Furthermore, KWS will also be able to cover training needs for conventional 600 MW lignite-fired power plants with state-of-the-art control systems.

Hence, KWS becomes capable of meeting all required simulator training measures for practically any power plant in Europe.

The new simulators and their reference plants

Two new training simulators are currently being developed on behalf of KWS. An additional simulator being established on behalf of E.ON Kraftwerke GmbH will subsequently be made available to KWS for training purposes. These are:

- one simulator for lignite-fired power plants (600 MW and 1100 MW),
- one simulator for hard coal-fired power plants (800 MW), and
- one simulator for hard coal-fired power plants (1100 MW).

In order to build a training simulator, technical and operational data of an actual power plant – a reference plant – are required. The reference plants for the new simulators were chosen in accordance with the following guidelines:

- applicability to a wide range of customers,
- shared features among plant areas of different power stations, these simulators are provided for,
- availability and accessibility of technical and operational data.

The simulator for lignite-fired power plants will feature two training variants, one for the conventional 600 MW plant units, and one for the lignite-fired power plant units with optimized technology, the so-called BoA plants.

The two simulators for hard coal-fired power plants shall be used for personnel training already before or during the commissioning of 800 MW and 1100 MW plants currently under construction. Simulators will therefore be established prior to the commissioning of their respective reference plants using design data for software programming. In general, these basic versions will reproduce start-up and shutdown procedures, normal load operations and load changes in a qualitatively correct manner. Once both reference plants have commenced operations, the process models of both simulators will finally be fine-tuned and adapted to current implementation and operating data from the plants so that comprehensive training will be assured.

In future, KWS will operate these new simulators and will make them available to all interested utility companies or academic institutions.

With the new simulators, the well proven training courses with regard to recent power

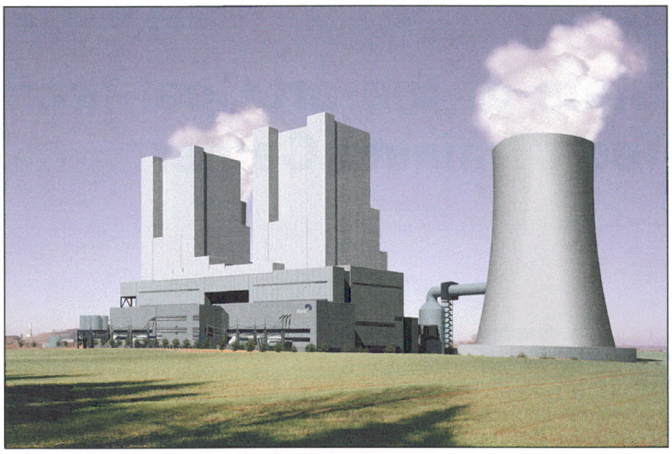

Figure 1. Construction of BoA 2&3 twin unit at Neurath power plant (Courtesy of RWE Power AG).

Figure 2. Niederaußem power plant (Courtesy of RWE Power AG).

plant technology and state-of-the-art control systems will be conducted primarily at KWS in Essen. On request, simulator training may also take place on-site at any power plant of the customer, for on principle the new simulators are designed transportable.

Simulator for lignite-fired power plants (600 MW and 1100 MW)

This training simulator will replicate the following RWE Power AG reference plants in two variants:

- Unit F of the 2 x 1100 MW BoA 2&3 twin unit under construction at the Neurath site, and
- Unit G of the Niederaußem power plant, a 600 MW unit,

each including shared power plant areas.

The two with Rhenish lignite-fired power plant units F and G (BoA 2&3), currently under construction at Neurath (Figure 1), are designed for a gross output of 1100 MW_{el} each, at an electrical total efficiency of more than 43 percent. The once-through steam generator will operate at raised pressure and temperature levels of live/reheated steam (272/55.5 bar and 600/605 °C). In base load operations, raw lignite will be fed tangentially into the furnace via eight beater-wheel mills with pre-crushers. The main distributed control system (DCS) for the units will be the SPPA-T3000 instrumentation and control (I&C) system, provided by Siemens AG.

Commissioned in the fall of 1974, Niederaußem's lignite-fired units G and H (Figure 2) have a gross output of about 630 MW_{el} each. Their DCS's, turbines, and boilers will be retrofitted in 2008/2009. In the course of the DCS update, both units will be upgraded with the SPPA-T3000 I&C system from Siemens AG. These units feature a once-through steam generator with single reheating and water separators for the start-up phase. The steam generators currently run with live/reheated steam pressure and temperature parameters of 171/30 bar and 530/530 °C. They are operated in sliding pressure mode. In base load operations, raw lignite is fed into the furnace by side fired burners using up to eight beater-wheel mills with pre-crushers. The plant is laid out with two air and flue gas paths. The steam generator is a single-pass boiler with attached open pass.

The unit G simulator variant is expected to be ready for training in the fall of 2009, the BoA variant approximately in early 2012. Simulator location and training site will either be the Niederaußem plant or the KWS training center in Essen.

Simulator for hard-coal fired power plants (800 MW)

This training simulator will replicate the following RWE Power AG reference plant:

- Unit D of the 2 x 800 MW twin unit currently under construction at the Westfalen power plant, including shared power plant areas.

The hard coal-fired unit (Figure 3) will have a gross output of approx. 800 MW_{el} at a high net efficiency of power generation. Its once-through steam generator will operate at raised pressure and temperature levels of live/reheated steam (286/59 bar and 600/610 °C). The plant is laid out with a single air and flue gas path. The twin unit's main DCS will be the SPPA-T3000 I&C system from Siemens AG.

Simulator for 1100 MW hard coal-fired power plants

This training simulator will replicate the following E.ON Kraftwerke GmbH reference plant:

- The 1100 MW single unit 4, currently under construction at the Datteln hard coal-fired power plant.

The unit will have a gross output of 1100 MW_{el} with a high overall efficiency ratio (Figure 4). Its once-through steam generator will operate at raised pressure and temperature levels of live/reheated steam at 285/59 bar and 600/620 °C. The unit is laid out with two air and flue gas paths. Hard coal will be fed into the furnace by frontal firing (opposed-fired). This power plant will use the 800xA Industrial IT system in combination with AC870P control system from ABB AG.

In basic versions, the simulator for 1100 MW hard coal-fired power plants will be ready for training by late 2009, and the simulator for 800 MW hard coal-fired power plants by late 2010, respectively.

In finalized versions, the simulator for 1100 MW hard coal-fired power plants will be available for training in mid-2011, and the simulator for 800 MW hard coal-fired power plants in early 2012, respectively.

Simulation technology and scope of simulation

The deterministic simulation of the process engineering and electrical plant operations will be created using state-of-the-art development environments from different training simulator manufacturers. These development environments correspond to those well proven by KWS, which allow replications using graphic editors by means of configuration and parametrization. After delivery of a simulator, separate development platforms enable KWS to independently perform simulator maintenance and further development, and beyond that to create new process models.

Nowadays, for the replication of the automation processes a "virtual" version of a DCS (virtual DCS) from the given manufacturer is utilized, mainly consisting of:

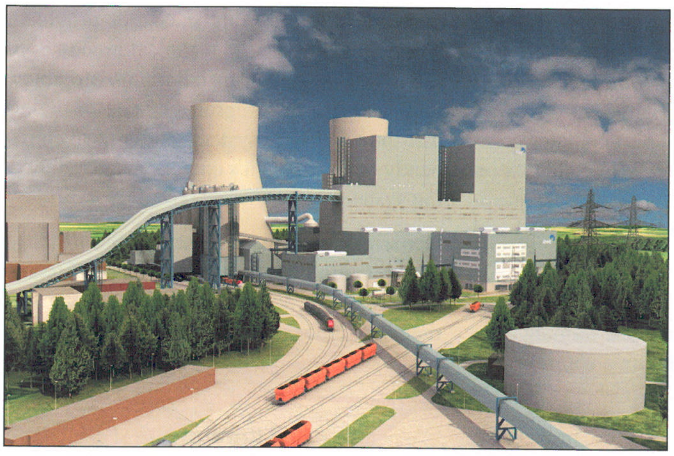

Figure 3. Construction of the units D and E at Westfalen power plant (Courtesy of RWE Power AG/Envi Con & Plant Engineering GmbH).

Figure 4. Construction of unit 4 at Datteln hard coal-fired power plant (Courtesy of E.ON Kraftwerke GmbH).

- the representation level incorporating original operation and monitoring components as a Human-Machine Interface (HMI),
- the processing level with applicable power servers for signal processing and conditioning including the engineering services,
- the automation level with its automation functions including the data acquisition level with process interfaces – in this case to the simulated power plant process.

Basically, a training simulator allows the replication of several reference power plants with similar automation technology, as in the case of the simulator for lignite-fired power plants.

Interlocks and automation functions of the main DCS' measurement and control systems are achieved by using an emulation approach. This allows the takeover of the reference plants' automation code. The ways of signal exchange within the virtual DCS and within the actual control systems are the same. Those simulators featuring Siemens automation technology incorporate SIMATIC S7 emulators with original operation and monitoring components and original processing servers from the SPPA-T3000 I&C system. The simulator with ABB automation technology uses the emulated AC870P automation system with the actual 800xA operation and monitoring system plus original system servers from the ABB industrial IT system.

The respective scope of simulation is technically determined by the extent of the automation code taken over from the reference plants. A complete takeover of the code requires a corresponding scope of the simulation for the process models, which results in a full-scope power plant simulator. Utilization of original operation and monitoring components in a simulator enables the trainee to become accustomed to an environment that reproduces the look and feel of his familiar workplace. In order to meet customer wishes for text display in the trainees' native languages, the user interface of the new simulators is prepared to be upgraded for multilingual operator interface.

The scope of the simulation is bounded in this respect: On one hand, a constant fuel supply of a definable quality from daily coal bunkers is considered as given or from the coaling station, respectively, if it is part of the reference plant's main DCS. On the other hand, it is assumed that the plant's output is fed into a power grid, of which the load can be set within a range between an isolated grid all the way up to the transnational European power grid behavior.

The simulation fidelity of individual modeled plant sub-systems is a measure that defines the qualitative extent of simplification. High fidelity simulation standards are fulfilled by replication of reality as detailed as possible. If required, lower simulation standards for individual power plant systems can be defined. They can be achieved by reducing simulation depth i. e. quantitative downsizing within a given sub-system, e. g. by a specific unit, or simplifying the algorithms regarding the fidelity of the simulation.

All essential main and auxiliary plant subsystems are simulated according to the highest fidelity standard, whereas plant sub-systems not necessarily relevant in terms of learning objectives will be simulated in lesser fidelity. Still, the result is a full scope, high fidelity training simulator.

So, the simulator is capable of reasonably reproducing any possible operating condition in a power plant and of realistically simulating the transient behavior of dynamic power plant operations.

A large number of operating conditions created during training may be stored at the simulator's instructor station and may be restored on request in order to serve as initial condition for creating new operating conditions.

Control rooms

The well proven design of KWS' already existing control rooms (Figures 5 and 6) serves as a guideline for the control rooms' design of the new training simulators.

Aside from familiarizing students with state-of-the-art power plant technology and distributed control systems, the control room's arrangement also enhances teaching well-organized interaction and communication in the control room.

Trainees may use up to five different screen-based operator stations, namely for power

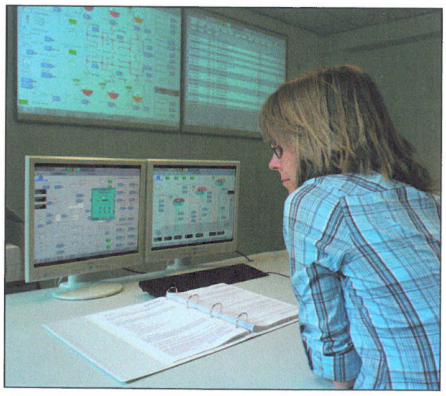

Figure 5. Operating station in the control room with large-screen display of the CCGT simulator.

Figure 6. Instructor station at the CCGT simulator.

plant operators and one for the shift supervisor. For big screen displays a two large-screen display system replaces the PC monitors. An acoustic annunciator system signalizes incoming and outgoing messages. In addition, printers are provided for hard copy and protocol printouts.

A separate operator station allows operations that, in a real power plant, have to be performed outside the control room. A switchpanel with hardwired emergency pushbuttons provides direct access to simulated protection systems. Hence, all failsafe functions can be actuated in the simulator in the same way as in the real power plant.

The control room is also equipped with an instructor station from which the trainer controls all the simulator functions.

Since considerable training demand is expected for the simulator for 800 MW hard coal-fired power plants, this particular simulator will feature two training platforms. That means that there will be two separate control rooms so that multiple training courses can be conducted simultaneously.

For the simulator for lignite-fired power plants, on the other hand, only one control room is required, which may be used either at the Niederaußem power plant or at the KWS training center in Essen. This simulator comprises two or even more reference plants on one training platform so that only the requested simulator variant needs to be loaded and started for training.

The simulator for 1100 MW hard coal-fired power plants also uses only one training platform. It will be equipped with a control room of its own.

Due to the complexity of their processing units, the new simulators' mobility will be somewhat restricted compared with the existing KWS simulators. Even so, on-site training courses at the customer's power plants will be offered with the new simulators as well.

Summary and outlook

The new training simulators round off KWS' offer in the field of hands-on-like simulator courses. These training measures provide a greater insight into the technical processes of the new power plant installations. Moreover, trainees learn to comprehend state-of-the-art distributed control systems and how to confidently handle a plant's operation and monitoring system.

Generic simulator concepts enable KWS to adapt its simulators in case of retrofits and updates of the actual power plants with only moderate labor and financial requirements.

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