The Evonik Steag Road to the High-efficiency Power Plant

Kurzfassung

Der Evonik Steag-Weg zum hocheffizienten Kraftwerk

Das hocheffiziente Kraftwerk wird kurz-, mittel- und langfristig im Mittelpunkt der modernen Energieversorgung stehen. Dies hat mehrere Gründe. Zum einen trägt es dem Gedanken der aktuellen Klimadiskussion Rechnung, wobei zu beachten ist, dass jede nicht produzierte Tonne CO_2 aufgrund hoher Effizienz nicht transportiert und auch nicht gespeichert werden muss und keine Gefahr besteht, dass durch eine Leckage in den nachfolgenden Jahren dieses CO_2 wieder entweicht.

Zum anderen ist die hocheffiziente Kraftwerkstechnik attraktiv für die kommenden Industrieländer wie Indien und China, die durch ihre hohen Zuwachsraten im Energiebereich in Zukunft den Welt-Primärenergieverbrauch bestimmen werden und damit auch maßgeblich zum Klima beitragen. Ein ganz wichtiger Aspekt dabei ist, dass die Hocheffizienztechnik bei der Ressourcenschonung der fossilen Energieträger einen erheblichen Beitrag leistet, d.h. die Reichweite der begrenzt vorhandenen fossilen Energieträger wird gestreckt und nicht wie durch die CCS (Carbon-Capture-Sequestration)-Technik verkürzt.

Effizienz bezieht sich hierbei nicht nur auf die Auswahl des Kraftwerksprozesses und seiner Parameter, sondern auch auf die Betriebsführung. Auch die Planung, Errichtung und Abwicklung eines solchen Kraftwerksprojektes muss effizient erfolgen, wenn sie erfolgreich sein soll. Schließlich kann der Wirkungsgrad im täglichen Betrieb auch durch intelligente Betriebsführung und Einsatz moderner Softwaretools besonders hoch gehalten werden.

Introduction

The high-efficiency power plant will be the focus of modern energy supply in the short, medium and long term. There are several reasons for this. One is that it accords with the spirit of the current climate discussion, and one must note that every tonne of CO_2 not produced because of high efficiency does not have to be transported and does not have to be stored, and there is no danger that leakage will allow this CO_2 to escape again in the years to come. Another reason is that high-efficiency power plant technology is attractive for future industrial countries like India and China, which due to their high growth rates in the energy sector will determine world primary energy consumption in the future and consequently will influence the climate in a major way. But such technology is also attractive for countries with high energy consumption, like the USA. A very important aspect is that high-efficiency technology makes a substantial contribution to the conservation of fossil energy sources. That is to say, the range of the limited fossil energy resources is extended and not shortened as it is by the CCS (Carbon-Capture-Sequestration) technology. As a result, high-efficiency power plant technology by itself or as an element of CCS technologies is capable of making a major contribution to reducing the greenhouse effect, but also to conserving resources.

The following describes the Evonik Steag road to high-efficiency power plant technology and reports on the experience gained in this area. It covers the insights gained from recently built power plants in foreign countries, the procurement of power plant systems under current market conditions, the answer to the question what high-efficiency power plant technology expects from materials engineering, and the special measures which have to be taken during the planning, building and commissioning of a power plant. This refers in particular to quality assurance. In addition, the connection with the current CCT (Clean Coal Technology) and CCS debate is discussed. Finally, the paper shows how efficiency can be preserved on an especially high level in everyday operation through intelligent technical management and the use of advanced software tools.

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Experience from Current Foreign Power Plant Projects

In a phase in which no new hard-coal-fired power plants were built in Germany, Evonik Steag was able to gather valuable experience in projects abroad. They include the Termopaipa power plant put into operation in Colombia in 1999, the Sugözü power plant on the Bay of Iskenderun in Turkey in operation since 2003, and the Mindanao power plant in the Philippines, officially inaugurated at the beginning of 2007.

Bearing in mind the protection of fuel reserves and CO_2 reduction, these power plants make a major contribution to a secure energy supply in the countries concerned. The yardstick we are applying is relative, of course. Compared with the power plants operating in the respective countries, large improvements in efficiency are achieved. But if the availability of each new plant is to be maintained at high levels, the standards aspired to today in Germany are out of the question. For whenever these up-to-date plants are not operating, the oldest plant in the country goes into operation again, and its efficiency and environmental performance are appreciably poorer. And if these reserve capacities are lacking, too, service may even be entirely cut. The capacity of the local networks likewise restricts the basic output, as in the case of the power plants in Colombia and the Philippines. Because of this, highest steam parameters for the power plant process are not practicable. The situation is different at our power plant in Turkey, but here, despite seawater cooling, the effect of high cooling water temperatures on efficiency must be taken into account. The significance which such power plants have for the security of supply and the average efficiency of a country is shown by the fact that Sugözü alone supplies 7 % of Turkey's electricity.

Another important aspect in the realisation of these power plant projects is the experience gained with foreign manufacturers, which must be taken into consideration for projects in Germany too, under the given market conditions today, if such projects are going to be realised with any measure of success.

Current Power Plant Projects and their Handling

The high-efficiency power plant has special significance for our company in Germany. With the development of the CCEC concept (Clean Electricity from Coal), at an early stage a modular construction kit for hard-coal-fired power plants was designed which permits making allowance for local site conditions and building economically very efficient hard-coal-fired power plants with the components of any manufacturer. At the Duisburg-Walsum site the construction of

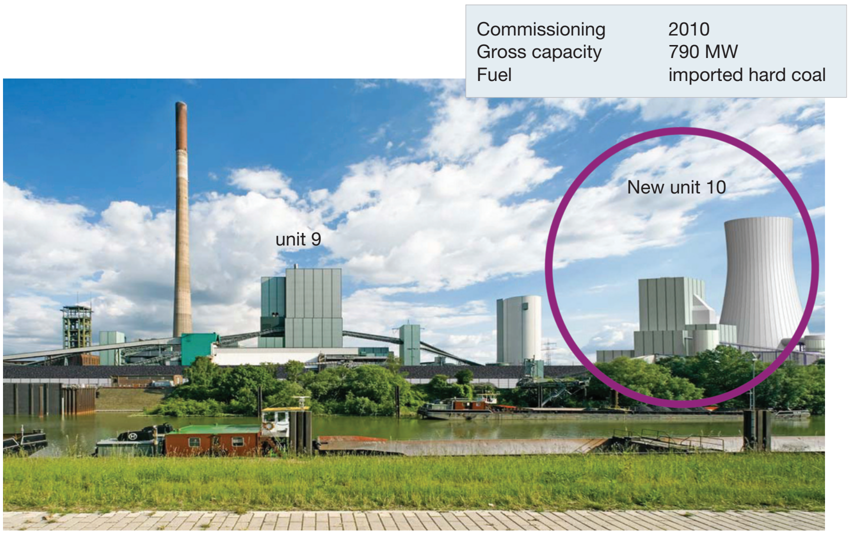


Figure 1. New unit Duisburg-Walsum power plant.

such a power plant of the 750 MW class already has entered an advanced stage (Figure 1). With a net efficiency of well over 45 percent, this plant will be the most up-to-date hard-coal-fired plant in the world among plants with comparable parameters.

This net efficiency is achieved among other things by an efficient cooling tower, higher steam pressures and temperatures (275 bar, 600 °C/620 °C), and the optimising of station service load. The 180 meter tall cooling tower effectively cools the water and so permits a high degree of steam utilisation in the turbine. The higher temperatures and higher pressures in the boiler of the Walsum 10 unit can be achieved owing to the use of advanced materials. They include austenitic steels for the final-stage superheater (Super 304H, HR3C), but also martensitic steels like VM12-SHC and P91 and P92. 7CrMoVTiB10-10 is used for the membrane wall. The amount of electricity used in-plant was reduced by a great many individual measures, for instance through improvements in plant equipment and an up-to-date flue gas desulphurisation concept. In their sum these measures lead to higher efficiency, i.e., better utilisation of fuel. While employing the same amount of fuel, the unit will feed about 12.5 percent more electricity into the power network compared with other units.

Efficiency not only refers to net plant efficiency, but also to economics and the time required to complete such projects. Owing to the projects abroad, mentioned earlier, Evonik Steag gained experience both with turnkey contracts for entire power plant projects as well as contracting by construction packages or lots, formerly practiced over a long period.

Based on this experience the optimum contract award model can be selected depending on the possible boundary conditions. For the power plant unit in Duisburg-Walsum, which is being built jointly with EVN of Austria, the turnkey model was chosen, with success. The engineering-procurement-construction company there is Hitachi Power Europe. As the market situation tightens up due to the large number of new construction projects in Germany and the surrounding European countries, suppliers evidently are less inclined to pursue the turnkey model. As a result, it is advantageous to be able to pursue other contract award strategies, too.

Efficiency also refers to project handling, starting with the development phase and proceeding through the implementation phase to the construction phase. Here the efficient cooperation of Evonik Steag's various specialist disciplines – engineers, contract preparation experts, purchasers, lawyers, permitting specialists, financiers, etc. – has proven especially valuable. This has particular importance for an IPP for achieving success on the market.

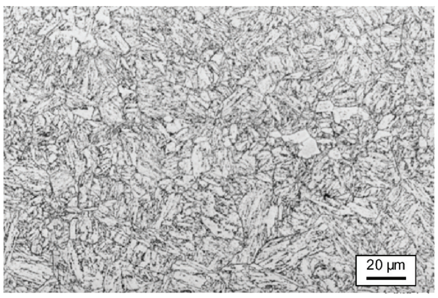
Materials

The high-efficiency power plant process necessitates the use of advanced materials, some of which are still in the certification phase. Without improved austenitic and

	C	Si	Mn	P	S	Al	Cr	Ni	Mo	V	Nb	Ti	W	N	B	Co
X10CrMoVNb9-1 P 91	0.08-0.12	0.20-0.50	0.30-0.60	≤ 0.020	≤ 0.010	≤ 0.040	8.00-9.50	≤ 0.40	0.58-1.05	0.18-0.25	0.06-0.10	----- -----	----- -----	0.030-0.070	----- -----	----- -----
X10CrWMoNb9-2 P 92	0.07-0.13	≤ 0.50	0.30-0.60	≤ 0.020	≤ 0.010	≤ 0.040	8.00-9.50	≤ 0.40	0.30-0.60	0.15-0.25	0.04-0.09	----- -----	1.50-2.0	0.030-0.070	0.001-0.006	----- -----
VM12 SHC	0.08-0.18	0.20-0.60	0.10-0.80	≤ 0.020	≤ 0.010	≤ 0.040	10.0-13.0	≤ 0.60	≤ 0.80	0.18-0.30	0.030-0.060	----- -----	1.00-1.80	0.030-0.090	0.001-0.010	0.50-2.00

VM12-SHC (special high corrosion resistance)

Tempered martensite, ≤ 2% δ-ferrite



Source: Vallource&Mannesmann, Hitachi Power Europe

Figure 2. Chemical compositions – new materials.

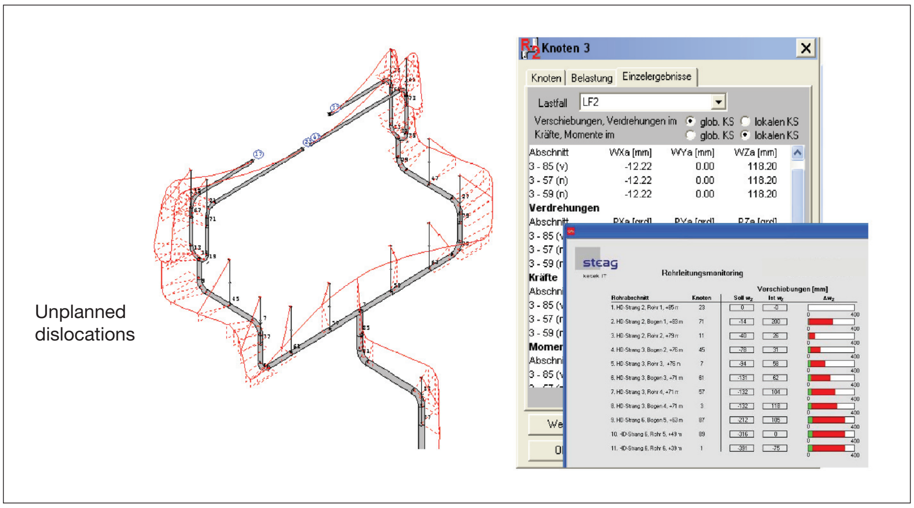


Figure 3. SR 1 – online lifetime monitoring of thick-walled components of the boiler and the turbine and pipings.

martensitic materials a net efficiency greater than 45 percent would be unattainable. In design and quality assurance, special allowance must be made for these materials. Possibly, provisions must be made in the planning for the replacement of assemblies during the lifetime of the power plant. So care must be taken now, during the planning phase, to ensure particularly good access. The new materials themselves require special attention, meaning individual certification and supervision in all phases from the production of the material and the semi-finished product to the manufacture of the final product. Additional reference samples are required for materials like VM12-SHC, P91 and P92 (Figure 2).

In many cases the modern materials no longer reveal their ageing through changes in microstructure. On the other hand, as they increasingly age they show changed creep characteristics. This makes special monitoring of pipe systems particularly important in the advanced high-efficiency power plant. Our subsidiary Ketek IT has developed software suited for this particular purpose. It compares the actual deformation in a pipe system with the design state of the system. In addition, the useful life of highly-stressed components like headers and fittings is monitored online. Pressures and temperatures and the duration of loads are constantly recorded. Based on the data the creep rupture strength and the fatigue strength under alternating load can be established and the remaining life of the relevant components determined (Figure 3). This software module thus provides information about the current fatigue situation of advanced materials and the pipe systems built with them, while allowing the control room operator to compare the current load state with the permissible load. For new materials like VM12SHC, such service life recording is not yet fully possible at present owing to the lack of data.

High Efficiency Versus CO_2 Capture

The current climate discussion and the subject of CO_2 reduction are highly emotional topics at present. If one takes the climate topic seriously, then allowance has to be made

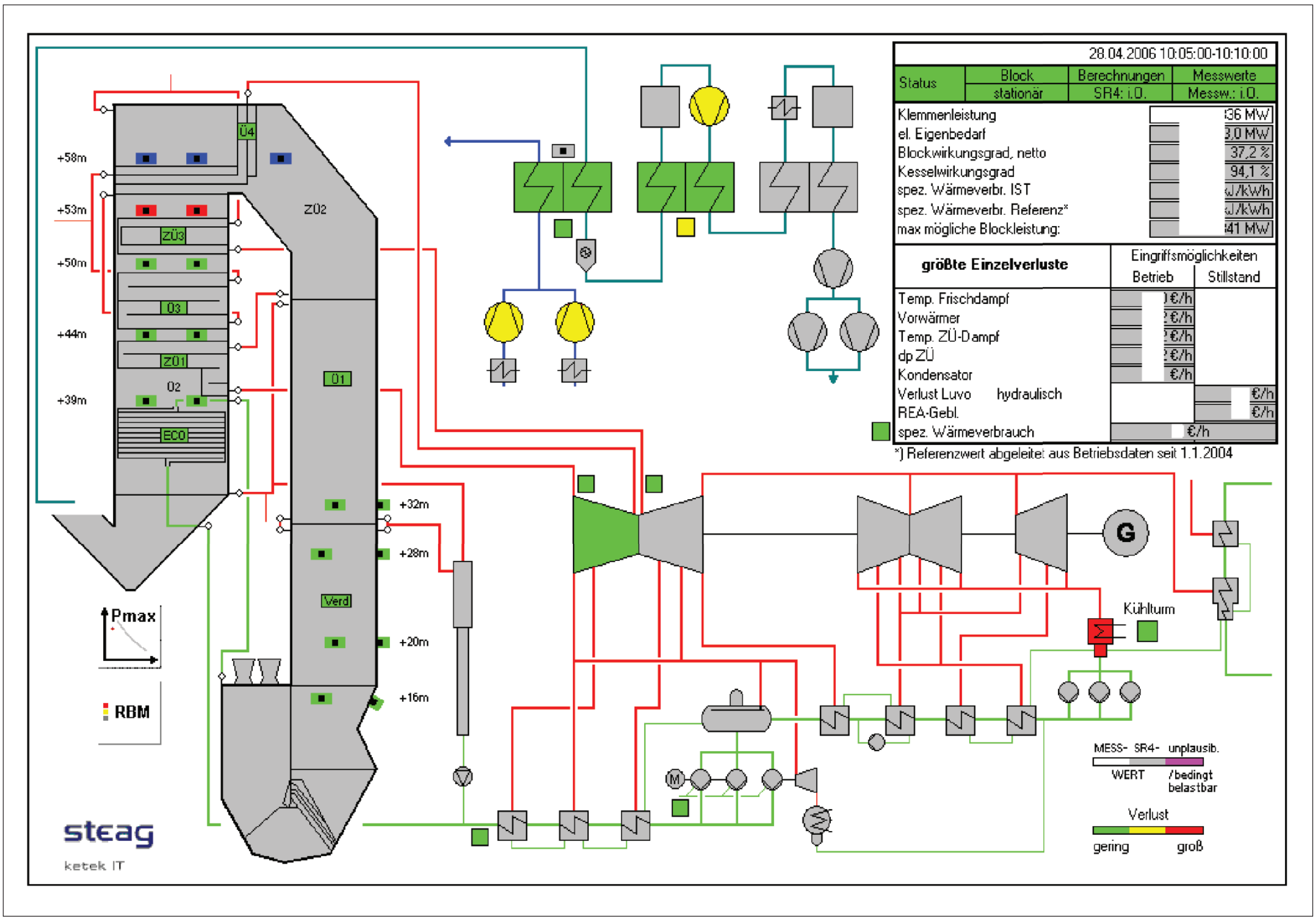


Figure 4. SR::EPOS – power plant performance monitoring and optimisation.

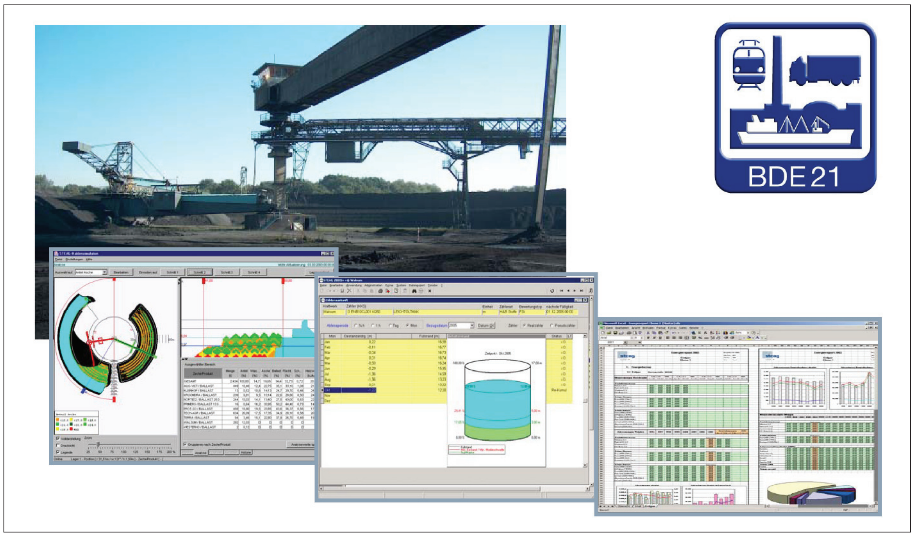


Figure 5. Integrated plant management.

for several aspects. CO_2 is a global topic, i.e., Germany cannot influence the world climate. Even if the posited 40 percent CO_2 reduction target were to be attained, worldwide CO_2 emissions would be reduced by only 0.6 percent. This is not to say that the CO_2 topic should be ignored in Germany, but serves to point out that technologies should be pioneered here which are copied in countries like India, China, but also in the USA, so that future power plant technologies there can make a substantial contribution to CO_2 reduction. It must be borne in mind that in China and India certainly no power plants can be built which cost 80 to 100 percent more than today due to CO_2 extraction and perhaps double the cost of electricity generation.

Another aspect that should be noted is that even if engineers successfully develop CO_2 capturing technologies involving minimal efficiency losses, it is still far from ensured that this CO_2 can be transported to possible sinks and that a permit for its sequestration will be issued. Lacking such a legal framework the development of capturing technologies becomes worthless. A reliable and important approach, as standalone or as precondition for CCS technologies, is the high-efficiency power plant described here.

Efficient Plant Management

The last part of this paper seeks to shed light on the important aspect of plant management. After all, for the environment, and fuel consumption, too, the decisive factor is not the design efficiency, but the efficiency in everyday operation. This efficiency must be maintained at a high level to achieve the economic and ecological goals. The advantage of this efficient plant management is that due to the use of intelligent software the specific cost of efficiency enhancement is lower than that of hardware for the corresponding purpose. The efficiency-boosting management instruments include intelligent maintenance. Through practice-oriented monitoring and organisation, high availability rates can be attained at minimal effort and expense. As already mentioned earlier, this ensures that the state-of-the-art high-efficiency power plant can be operated around the clock and that inefficient, environmentally harmful power plants do not have to be put into operation as substitutes.

SR::EPOS is the SR product for process quality monitoring and optimisation. Based on relevant daily parameters like temperature, fuel quality and plant condition, the power plant operator gets pointers for the optimum and therefore efficient operating regime (Figure 4). In five-minute cycles the programme continually monitors technical and economic aspects of the power plant process as well as the plant's measuring equipment.

Plant components are evaluated online and component efficiency ratings determined. Finally, in addition to this information SR::EPOS also supplies information serving condition-based maintenance. However, the essential aim is to propose an optimum operating regime with enhanced efficiency from the economic and ecological viewpoints and thereby reduce emissions and cost.

Fuel supply and the recycling of power plant by-products are particularly important for the high-efficiency hard coal-fired power plant. Hard coal is mined today throughout the world in a variety of regions and with a variety of characteristics and transported to the power plants. Optimum purchasing of these fuels ensures economic benefits, on the one hand. On the other hand, the fuel must be suited for the plant design so as not to reduce efficiency or give rise to additional cost. This task is handled with software modules like BDE 21 and Spice. With the software tool Spice, the evaluation of fuel providing meaningful information regarding possible output, efficiency and cost is possible even before the coal itself arrives at the plant and is burned.

BDE 21 (operating data capture for the 21st century) is the name of our tool that ensures the transparency of all material and energy flows in the power plant (Figure 5). It comprises

- optimum fuel management, from purchasing through procurement logistics to accounting;
- automatic recording, declaration and documentation of plant supply and disposal;
- accounting, drawing up of balances and company-wide data analysis for planning and optimising purposes; and
- an integrated reporting system.

Summary

In keeping with the motto of this year's VGB Congress, “Efficient power plant technologies! Our contribution to secure and climate-compatible electricity generation”, the road which Evonik Steag is taking has been described. Efficiency refers in this context not only to the choice of the power plant process and its parameters, but also to operation and maintenance and the efficiencies attained in daily operation. The planning, construction and project handling for such power plants also must be efficient if the projects are to be successful. Finally, the term “efficiency” as applied to net efficiency must be regarded in relation to the power plant efficiencies possible and attainable in each country. The high-efficiency power plant by itself or as an element of CCS schemes represents an important contribution to the conservation of fuel resources, but also to climate protection. □