Using Mobile Measuring Technology for Process Optimisation in Chinese Coal-fired Power Plants

Kurzfassung

Einsatz mobiler Messtechnik zur Prozessoptimierung in chinesischen Kohlekraftwerken

Die Bundesrepublik Deutschland unterstützt ein deutsch-chinesisches Entwicklungsvorhaben mit dem Ziel der Wirkungsgradsteigerung und Emissionsminderung in chinesischen Kohlekraftwerken.

Das Vorhaben wird von deutscher Seite de facto als Kooperationsprojekt zwischen der Deutschen Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH und der KfW Entwicklungsbank im Auftrag des Bundesministeriums für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ) durchgeführt. Die KfW Entwicklungsbank hat die Lieferung von sechzehn Messwagen finanziert. Das Konsortium E.ON Engineering GmbH/STEAG AG konnte die Ausschreibung gegen internationale Konkurrenz für sich gewinnen. Der fachgerechte und nachhaltige Einsatz der Messwagen wird im Rahmen der Technischen Zusammenarbeit (TZ) von der Deutschen Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH unterstützt.

Das Konsortium E.ON Engineering GmbH/ STEAG AG war in den vergangenen Jahren im Rahmen verschiedenster Aktivitäten, wie Trainingsmaßnahmen, Beratungsmaßnahmen und Seminaren in China und in Deutschland stark in die Durchführung der TZ-Aktivitäten eingebunden.

Inhalt des Kooperationsprojektes ist ein umfangreicher Transfer von Technologie und Know-how durch die Lieferung von insgesamt sechzehn Messwagen an elf chinesische Forschungsinstitute und die Ausbildung von chinesischen Fachkräften sowie der Aufbau eines marktwirtschaftlich orientierten Energiedienstleistungssektors für den reformierten chinesischen Stromsektor.

Die Messwagen mit modernster mobiler Messtechnik (MPO – Mobile Process Optimisation System) sind für feuerungs- und maschinentechnische Untersuchungen ausgerüstet. Die feuerungstechnischen Messmodule sind für brennstoff-, luft- und rauchgasseitige Messungen an Kohlefeuerungen ausgelegt. Mit den maschinentechnischen Messmodulen werden Betriebs- und Abnahmeversuche an Kraftwerksaggregaten (z. B. Pumpen, Turbinen) durchgeführt.

Die Messwagen werden von den Forschungsinstituten zur Überprüfung und Optimierung in zahlreichen Kraftwerken eingesetzt. Durch diese Optimierungsmaßnahmen können der Brennstoffverbrauch vermindert und so die Emissionen von CO_2, Staub und SO_2 verringert werden.

Der Einsatz der mobilen Messtechnik kombiniert mit der umfangreichen Schulung der chinesischen Fachkräfte leistet einen essenziellen und nachhaltigen Beitrag zum Technologie- und Know-how-Transfer zwischen Deutschland und China.

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Introduction

The energy demand in the P. R. of China will increase continuously during the next few years, because of its outstanding economical development. Currently, two-thirds of the electricity is generated in coal-fired power stations. Since the present technology at many Chinese power station sites is not state-of-the-art, power conversion processes cause considerable environmental problems. The environmental pollution with particulate matter and sulphur dioxide (acid rain) as well as the high CO_2 emission in already highly contaminated metropolitan areas is particularly very serious. Today, China is worldwide the second largest CO_2 emittent and could already take the first position with almost one third of the worldwide CO_2 emissions in quite a few years.

Increasing the power plant efficiency is one of the most effective and economical ways of providing power: Less coal is required for the generation of the same amount of electricity. Natural resources are saved and harmful emissions for health and climate are minimised.

Project Description

Against this background, the German Government works together with the P. R. China in the Chinese energy sector on several projects aiming to enhance environmental- and resource protection. Among others, since 2001 a German-Chinese development project for efficiency increase and emission reduction in Chinese coal-fired power plants is supported.

On behalf of the German Federal Ministry for Economic Co-operation and Development (BMZ) this project is carried out as a co-operation project between the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and the KfW Entwicklungsbank (KfW Development Bank).

The KfW Entwicklungsbank financed the delivery of measuring vehicles in the framework of a project within the financial co-operation (FC-Project). The consortium E.ON Engineering GmbH/ STEAG AG was awarded the contract against international competition. Lead by E.ON Engineering GmbH (EEN) altogether 16 measuring vehicles had been delivered to 11 Chinese Research Institutes of electric utilities. The provinces of the measuring vehicles´ customers are shown in Figure 1.

The professional and sustainable application of the measuring vehicles is assured by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH in the frame-

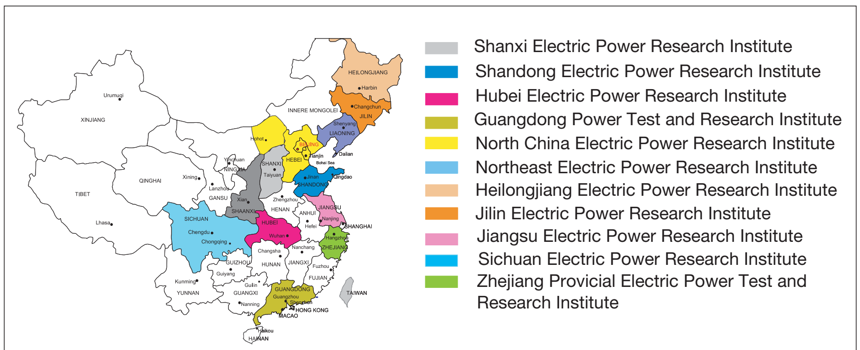


Figure 1. Project Partners in China.

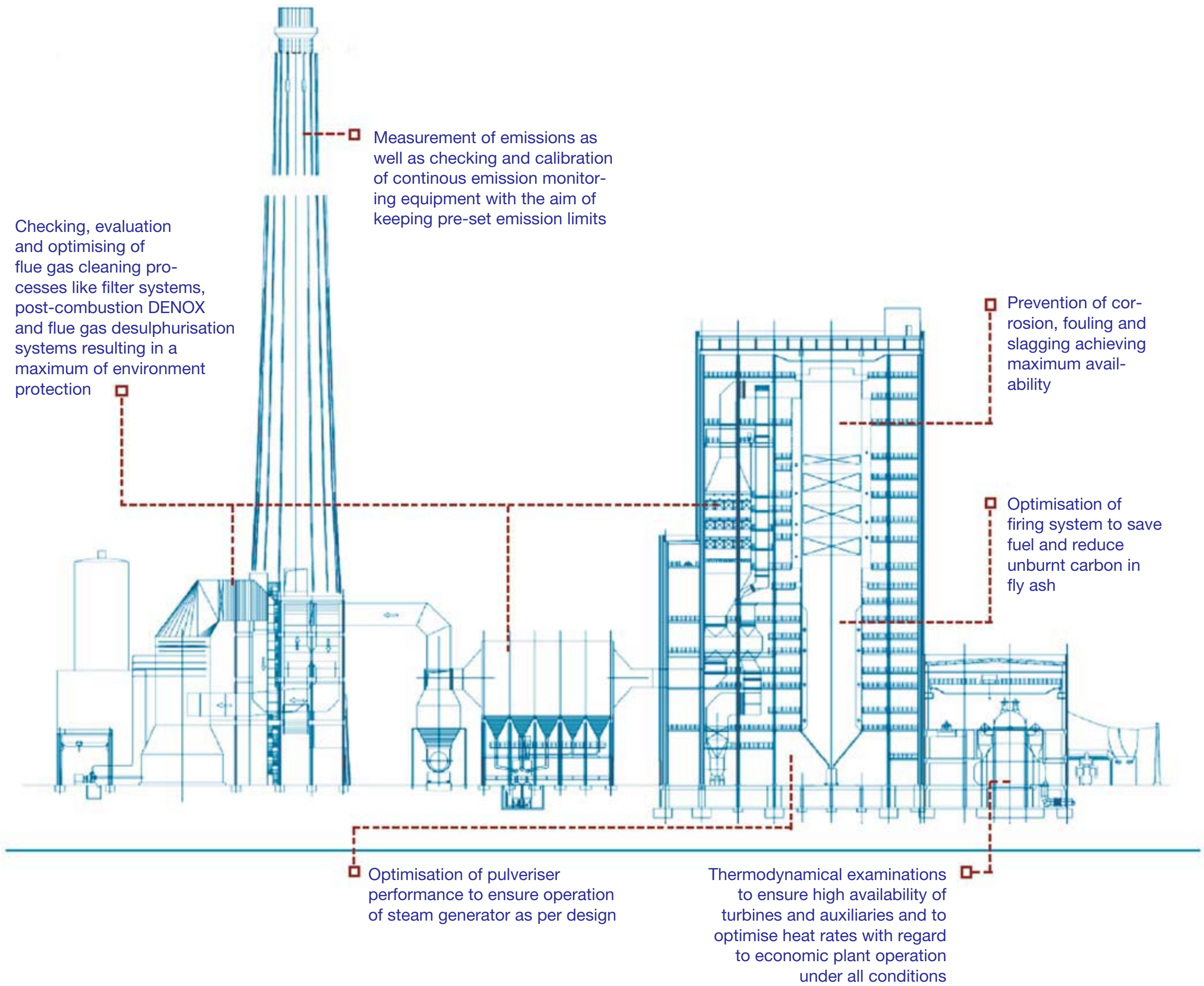


Figure 2. Application of the MPO-System for Process Optimisation.

work of a project within the technical co-operation (TC-Project).

This project is aiming at the reduction of the specific fuel consumption of Chinese coal-fired power plants and support of the development of an economical orientated energy service sector for a reformed Chinese energy market by intervention on several levels. At the implementing level the measuring vehicles fulfil an important contribution. Before starting the project, the GTZ stipulated the intended measurable project results and the necessary project activities together with the then political partner, the Chinese Ministry of Electric Power.

Since the beginning of the project in April 2001, GTZ has been supporting different institutions in the Chinese energy sector with professional and management know-how, which will be introduced in seminars, education and training measures in China and Germany as well as in concrete consulting services for the improvement of the technical and operation management in Chinese power plants. Among the co-operation with Chinese governmental authorities, utilities, IPPs and Research Institutes, GTZ also co-operates with the German industry. So, among others, the consortium E.ON Engineering GmbH/STEAG was deeply involved in different activities in China and in Germany during the implementation phase of the TC-Project of the past few years. As a supplier for measuring vehicles both companies made an important contribution for the training of the personnel of the Research Institutes, so that by application of the measuring vehicles, power plant processes can be analysed and sustainably optimised.

Mobile Measuring Technology (MPO System) for Process Optimisation

The delivered measuring vehicles are so-called MPO Systems (MPO = Mobile Process Optimisation), used for the analysis and optimisation of power plant processes (Figure 2). The MPO Systems consist of measuring vehicles with different mobile measuring modules for analysing furnace and machinery systems in coal-fired power plants (Figure 3).

Combustion-technology Modules

With the Combustion-technology modules of the MPO System stated above, fuel-, combustion air- and flue gas side-measurements on coal-fired boilers can be carried out:

- Pulverised Coal Measuring Module for the optimisation of pulverisers,
- Fly Ash Measuring Module for checking the efficiency of precipitators and filter systems and for determination of particulate emissions,
- Flue Gas Analysing Module (O_2, CO_2, CO, NO, NO_2, SO_2) for optimisation of firing systems,
- Automatic Flue Gas Analysing Measuring Module for performing time saving grid-measurements in large flue gas cross sections,

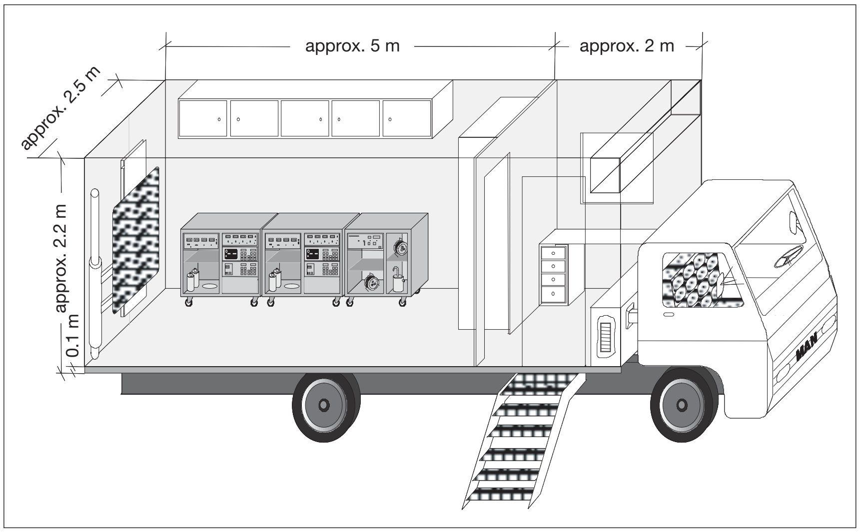


Figure 3. Measuring Vehicle.

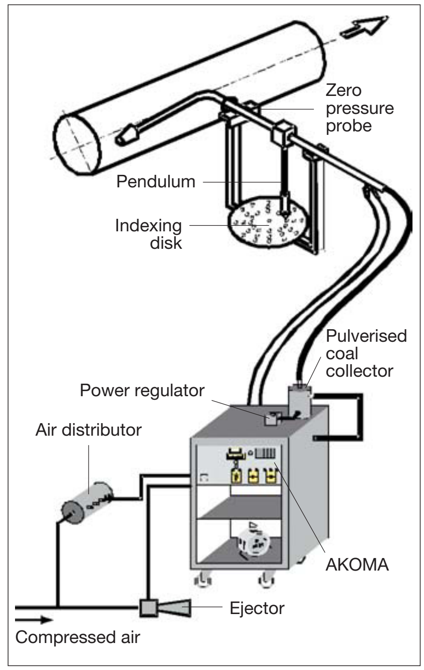


Figure 4. Pulverised Coal Measuring System.

— Temperature Measuring Module for the determination of temperatures and temperature profiles in the air/flue gas path,

— Volumetric Flow Rate Measuring Module for measuring volumetric flow rates in the air/flue gas path.

Particularly the delivered coal dust- and flue gas analysing measuring modules had been developed by the test department of EEN and had been approved in practise for many years.

The measuring device (AKOMA), used by EEN for taking coal dust samples, works according the isokinetic extraction by means of a zero-pressure pendulum probe. For achieving a representative coal dust sample, the entire cross section of the dust pipe will be scanned with the pendulum probe. The scheme of the pulverised-coal measuring system is shown in Figure 4.

In order to determine the measuring accuracy, an independent engineering consultant was appointed to issue an expertise in co-operation with the University of Halle-Wittenberg. In line with these tests, 52 complete grid measurements had been carried out by using power plant typical particle sizes, flow velocities and loadings at homogeneous and inhomogeneous flow rates. To assess the results of the isokinetic extraction with the AKOMA-measuring system, the measured dust mass flow had been compared with the injected dust mass, which had been determined with the help of a high precision Coriolis-Measuring Instrument (accuracy < 1 % of the measuring value). The dust mass extracted with the AKOMA-measuring system could have been determined with a maximal deviation of 2 % of the nominal value.

In line with the further development of the AKOMA-measuring system, an automatic pendulum probe had been developed. With this automatic pendulum probe the entire cross section of the dust pipe can be measured equally with a continuous movement procedure. An increase of the reproducibility and a reduction of the measuring inaccuracy at dust pipes with insufficient inlet distances will be achieved by the automation of the pendulum probe procedure.

In order to carry out measurements on the flue gas side for combustion optimisation, a mobile flue gas analysing measuring module had been developed. This module contains the gas analysers (O_2, CO_2, CO, NO, NO_2), the gas conditioning system and an electronic integrating chart recorder (Figure 5).

Mechanical Engineering Modules

Thermodynamic analysis and optimisations of a power plant include beside the combustion-technology measurements also examinations of the water-steam cycle. For the determination of the energy flows precision measuring instruments will be used. With the modules of the above-mentioned MPO System, mechanical engineering measurements can be carried out:

— Power Measuring Module for active, apparent and reactive power measurements,

— Turbine Measuring Module for the determination of the internal efficiency of turbines,

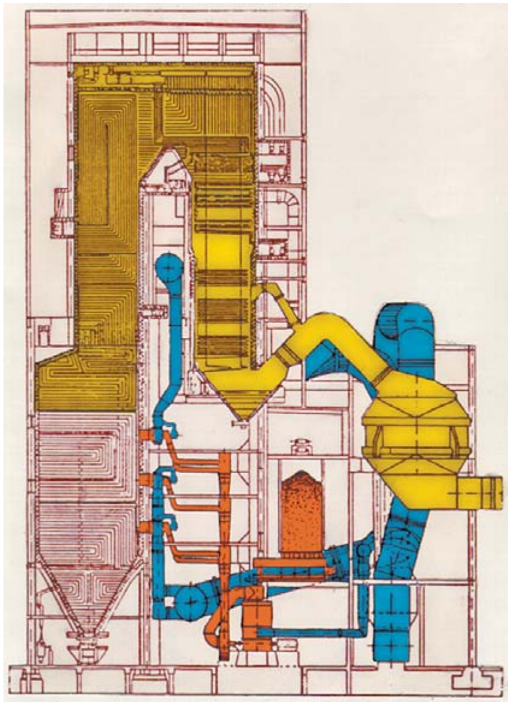
— Pump Measuring Module for measuring the pump efficiency according the thermodynamic method,

— Condenser Measuring Module for determining the operating parameters of condensers,

— Measuring Module for examination of wet cooling towers.

For that, electrical power, electrical power station internal load, pressures, differential pressures and temperatures will be measured. A Data Acquisition Module is required for processing the measured values. This module includes the data logging system, a PC and the associated software. All sensors (pressure, temperature) will be connected to the data logger and the measuring software of the PC will record the signals. The signal conditioning of the measuring values consists of a direct current supply and an isolating amplifier for pressure transducers and a cold junction for thermocouples. The calibration data of the calibrated sensors will be integrated in the measuring programme and will be used for further evaluation.

Figure 5. Mobile Flue Gas Analysing Measuring System.



– **Fuel:** adjustment of the distribution and fineness of the pulverised coal

– **Combustion air:** air balancing and adjustment of the air distribution at the burners

– **Flue gas:** optimisation of the excess air, flue gas analysis on furnace walls and determination of air preheater leakage and emissions

Figure 6. Measurements for Combustion Optimisation.

Calibration Module for Pressure- and Temperature Instruments

As a rule, measuring devices (temperature measuring instruments, pressure measuring devices) have inaccuracies, given by the manufacturer. In general, these inaccuracies refer to the measuring range end value and the manufacturer guarantees the keeping of these inaccuracies. If a better accuracy will be achieved, the measuring transducer has to be calibrated; i. e. the systematic error of these devices has to be determined. The comparing calibration is the most common procedure. Here, the measuring device to be tested will be compared with a reference measuring device. The inaccuracy of the reference measuring device is known. A test certificate or a calibration certificate belongs to the reference measuring device. These documents indicate the inaccuracy precisely. In Germany, this certificate will usually be issued by a test laboratory of the Deutscher Kalibrierdienst (DKD, German calibration services). The measuring devices of the calibration laboratories will be checked by a national authority. This is the Physikalisch Technische Bundesanstalt (PTB, German physical technical authority).

The production of the special measuring systems and the implementation of the measuring vehicles have been carried out in the test departments of EEN and STEAG. Also the technical services had been handled here in connection with this project. Technical details and special customer demands had been stipulated in detail after conclusion of the contract during the "Design Liaison Meeting" with representatives of all customers.

Before shipping of the measuring vehicles and systems to China, the equipment had been inspected by the customers regarding function and completeness. Altogether 26 Chinese experts from the Research Institutes attended several training measures in Germany for more than three months, in order to get familiar with the operation and the maintenance of the measuring systems and measuring vehicles.

After arrival of the equipment at each destination port in China and after finishing the custom clearance, whereas GTZ gave a helping hand, the commissioning and the acceptance tests for the measuring systems had been carried out by EEN and STEAG employees in seven different provinces in China.

Process Engineering for Process Optimisation

In line with this project concrete optimisation measures will be carried out in Chinese power plants. On the one hand, this serves to train the staff of the Research Institutes and on the other to convince the power plant management about the advantages of a process optimisation based on measuring results. As the combustion process offers sufficient optimisation potential, often without additional investments and modifications, in the first instance exemplary combustion optimisations by using the combustion-technology modules of the MPO Systems will be carried out.

On the basis of the training measures carried out on behalf of the GTZ in the Xutang power plant, the process engineering i. e. the procedure for a combustion optimisation should be demonstrated. The two-week lasting training had been carried out by two EEN employees and by using the MPO System of the Jiangsu Provincial Electric Power Research Institute.

The Xutang power plant consists of two identical coal-fired units, each of 300 MW output. Two additional 300 MW units of the same design are presently under construction. The coal-fired once-through forced-circulation type boiler with a reheater consists of a dry-bottom furnace with a tangential firing system. The multi-jet burners, arranged in the corners of the steam-generator, are fed by five bowl-mills, type MPS, with baffled-typed-classifiers. The coal dust leaves the classifier in a single outlet line and will be distributed on four burner pipes by a riffle type distributor. The steam generator is constructed both, on the air- and flue-gas side, in two lines and equipped with an electrostatic precipitator (ESP).

The measurements for optimising combustion could be classified in three duties as indicated in Figure 6.

During the training measure in the Xutang power plant at unit 5 the following measurements have been carried out and results have been achieved:

Pulverised Coal Measurements

For the determination of the actual condition, isokinetic coal dust measurements by using the AKOMA measuring systems had been carried out in the four dust lines behind the pulveriser. During the pulverised coal measurements the coal mass flow, the distribution and the pulverised coal fineness had been determined. Furthermore the velocities in the dust pipes were measured. To assess the efficiency of the mills, the fineness of grinding, the power consumption and the pressure loss, dependent on the classifier position (classifier characteristic curve, see Figure 7), had also been determined.

Through the results of the pulverised coal measurements the operational parameters were optimised as follows:

By setting the classifier to a higher degree of fineness (from 63 to 55 degree classifier position), the coal fineness was adjusted according the used coal quality. For the further optimisation of the pulveriser performance the primary air mass flow had been reduced with regard to the velocities in the coal pipes by 10 %, and the classifier temperature had been increased from 80 to 88 °C. Compared with the actual condition, the pressure drop and the power consumption of

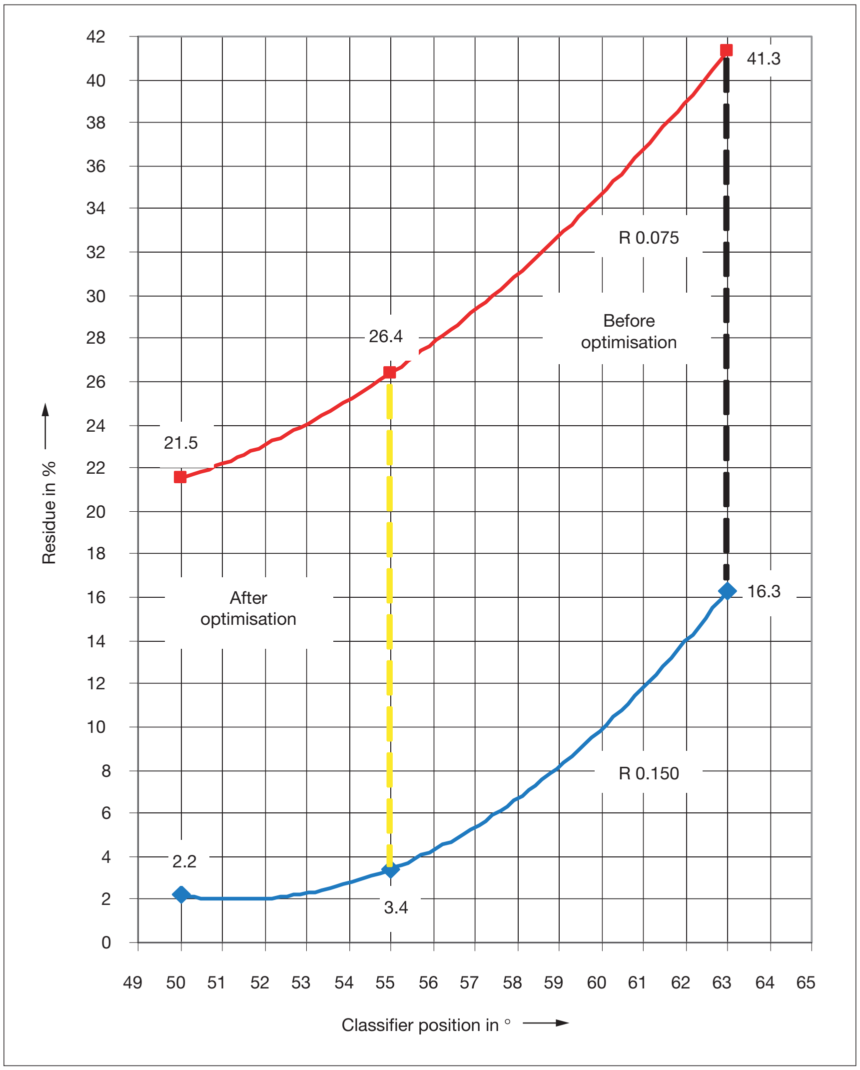


Figure 7. Classifier Characteristic Curve.

the pulverisers had been reduced in spite of a better fineness.

Combustion Air Measurements

Before the beginning of the training measure the experts of the Jiangsu Provincial Electric Power Research Institute checked the combustion air adjustment already. Therefore, no further combustion air measurements and optimisations had been carried out during the training.

Flue Gas Measurements

After adjusting the pulveriser parameters, flue gas measurements for optimisation of the excess air in the furnace have been carried out. The excess air was reduced step by step from n = 1.22 to n = 1.18. However, the flue gas measurements showed that at an excess air of n = 1.15 the CO, O_2 concentrations were in an inadmissible range. Therefore, the excess air in the furnace had been adjusted to n = 1.18. Here, the atmospheres at the furnace walls were at an aimed range. Having residual oxygen contents of > 1 % as well as CO concentrations of < 0.5 % damage to the furnace walls is not being expected.

In the scope of combustion tests for the optimisation of the combustion process, possibilities to reduce the primary NO_x content were demonstrated. For reducing the primary NO_x values a coal-air-staging in the furnace at an optimised excess air level had been carried out in short time tests. By this means a NO_x reduction of 245 mg/m^3 could be reached. Also at a reduced excess air and at a low NO_x operation mode the loss on ignition was lower than 1.5 %.

Furthermore the boiler efficiency was determined according to DIN 1942. By reducing the excess air from n = 1.22 to n = 1.18 an increase of the boiler efficiency of 0.15 %-points had been achieved. Additionally a total power consumption of 310 kW for the primary air fan, forced-draught fan and the induced-draught fan will be saved.

Resume

In a first project in 1991, E.ON Engineering GmbH supplied a MPO System to a Research Institute on behalf of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. From 1991 until 1995, 18 Chinese power plant units with an installed capacity of 6,000 MW in total were examined. Optimisation of the combustion processes led to an average increase of the boiler efficiency by 1.06 %-points, thus saving about 140,000 tons of coal per year and reducing CO_2-emissions by about 300,000 tons per year in these power plants. Based on current fuel costs of 40 US-$/ton, the achievable financial benefit for the power plant operators due to the increased efficiency adds up to more than 5.5 million US-$ per year.

For selected power plants with a capacity of 300, 350 and 600 MW the achieved average efficiency increase and fuel cost savings are shown in Figure 8.

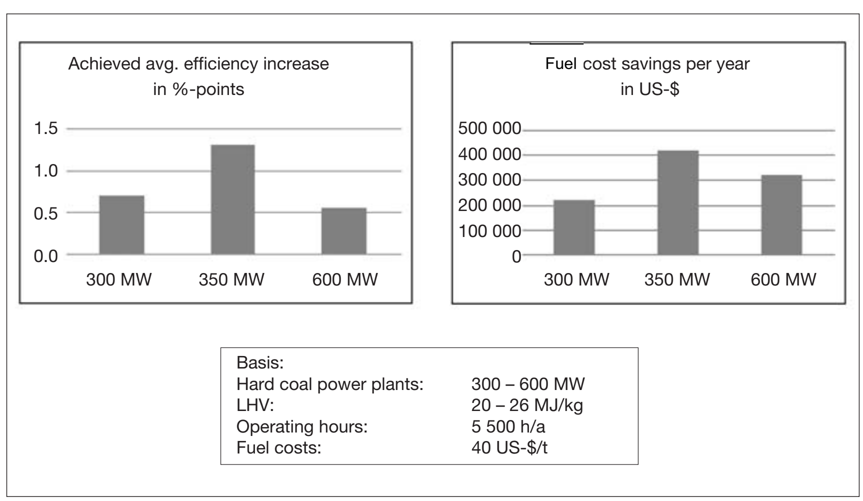


Figure 8. Economical Benefit for Selected Capacities.

The 11 MPO Systems, delivered in 2001 and 2002 to China, will be used by the Research Institutes with the advice of the GTZ for the examination and the optimisation of numerous power plants. The activity area of the 11 Research Institutes comprises 14 provinces of China with a capacity of more than 140,000 MW coal-fired power plants in total. With increasing know-how and the establishment of the offered energy services, this project contributes to a sustainable reduction of pollutant emissions, the efficient use of natural coal resources as well as to the increase of the availability and economic viability of Chinese coal-fired power plants in an energy sector which is more and more characterised by market-economy structures.

More than that, the application of the mobile measuring technology in combination with the extensive training of the Chinese experts contributes to a vast transfer of technology and know-how between Germany and China.

The consortium E.ON Engineering and STEAG is also aiming together to market MPO Systems worldwide and so make use of its experiences gained from the project in China implemented by GTZ. The consortium already delivered a further measuring vehicle with mobile measuring systems for analysing furnace and machinery systems to Serbia. After completion of the training measures in Germany and in Serbia the MPO System is also used for acceptance and optimisation measures in lignite-fired power plants in Serbia.

Apart from its economical aspect, the process optimisation by using mobile measuring technology also is a positive contribution to the reduction of CO_2 emissions. Further MPO projects should be realised, for example on the basis of the Clean Development Mechanism (CDM) provided by the Kyoto Protocol and the European emissions trading scheme. Under consideration of the respective basic conditions in the developing countries, actually CDM project drafts are developed and discussed at the political and intracorporate level. □