Better Combustion Control Reduces Pollutants and Saves Fuel

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The quality of the combustion process has a fundamental effect on pollutant formation and operating economy in fossil-fueled power plants. The new Siemens combustion diagnostics system measures important combustion parameters quickly, quantitatively and with high spatial resolution. Using these data the combustion process can be reliably analyzed and adjusted as necessary.

The combustion process in fossil-fueled power plants has been regulated to date by controlling the flow of main steam or, in the case of gas turbines, by regulating the required electrical output. The combustion behavior and the pollutant formation of individual burners are not recorded and analyzed for control purposes. Faults and malfunctions in individual burners thus cannot be localized, and can be remedied only after a lengthy time delay.

Advanced Concepts in Combustion Process Control

Ultrasonic and spectroscopic techniques make it possible to qualitatively determine the flame intensity at various levels within the combustion chamber. The flame intensity, in turn, provides information on characteristic combustion parameters, which can then be used for combustion control.

To keep control system implementation costs low, neural networks and fuzzy logic are sometimes used today for control-related tasks. For controlling combustion processes, however, such systems must be trained individually for each burner and each fuel. Only then can the measured intensity distributions be correlated with previously defined operating states. Moreover, the stability of such control systems can be verified only to a limited degree, and they cannot be guaranteed to be effective under all operating conditions. Using fuels with different properties, for example, can result in operating conditions for which the system was not trained, and can thus produce unanticipated control states.

The new combustion diagnostics system (Fig. 1) developed by Siemens therefore relies on standard measurement and control concepts, and remains unaffected by specific operating conditions and fuels. This is made possible by an optical measurement system which acquires the pertinent data, which are also fed to the conventional control system in the form of parameter setpoints, and made available to the operating staff, who can optimize the combustion process if required (Fig. 2). If the optical measurement system fails, the existing control system still remains in operation.

Configuration and Operation of the New Combustion Diagnostics System

The combustion diagnostics system features a combustion analysis camera, a software-based data processing and analysis unit and a software package for visualization and data storage. At a typical distance of 3 meters between the camera and the measurement target, the system covers an area of approximately 3 m × 3 m, about a quarter of which is analyzed.

Measuring Principle

Due to the high temperature, dust and soot particles produced by the combustion process emit thermal radiation (Planck radiation). In the visible range of the spectrum in which the measurements are made, this radiation appears as a background whose intensity slowly increases with increasing wavelength. Spectral lines are superimposed on this background (Fig. 3). These lines are produced by chemical compounds—molecules and radicals—which were excited by chemical reactions and emit at their characteristic wavelengths.

Flame temperature can be evaluated by measuring the intensity of the thermal radiation. The concentrations of characteristic combustion products or intermediate products of combustion are determined using the measured spectral lines.

Combustion Analysis Camera

The flames in the combustion chamber are examined by means of spectral analysis. The camera incorporates an optical preprocessor as well as signal condi-

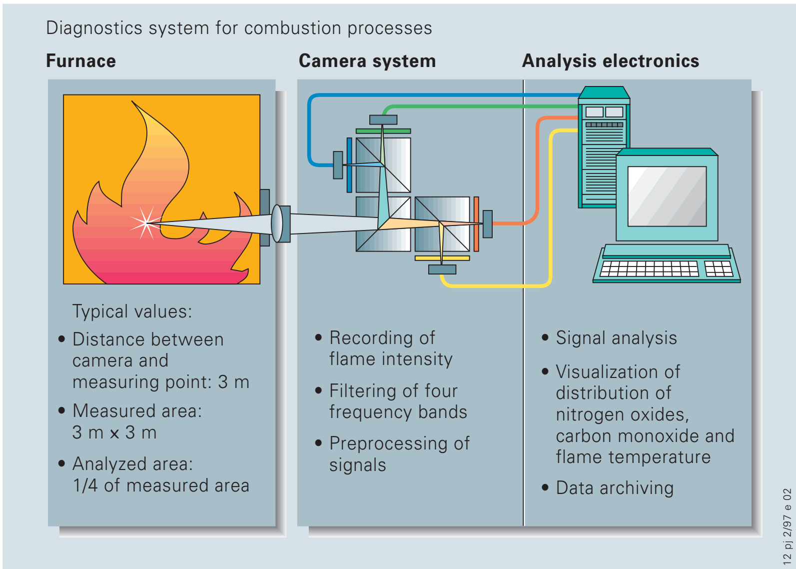


Fig. 1
The camera system filters four frequency ranges out of the combustion's emission spectrum, which are then analyzed and visualized on a PC.

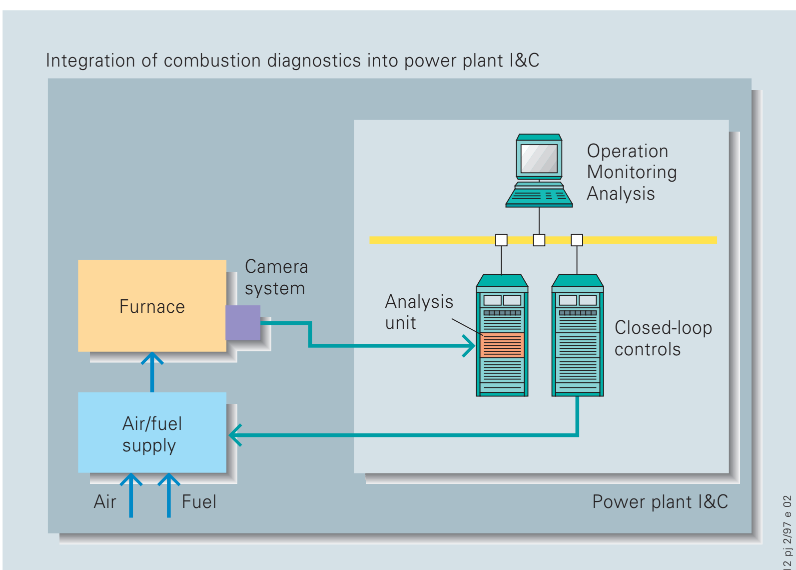


Fig. 2
Results of the combustion process analysis are fed to the power plant I&C and then used to optimize the combustion process, or are made available to the operating personnel.

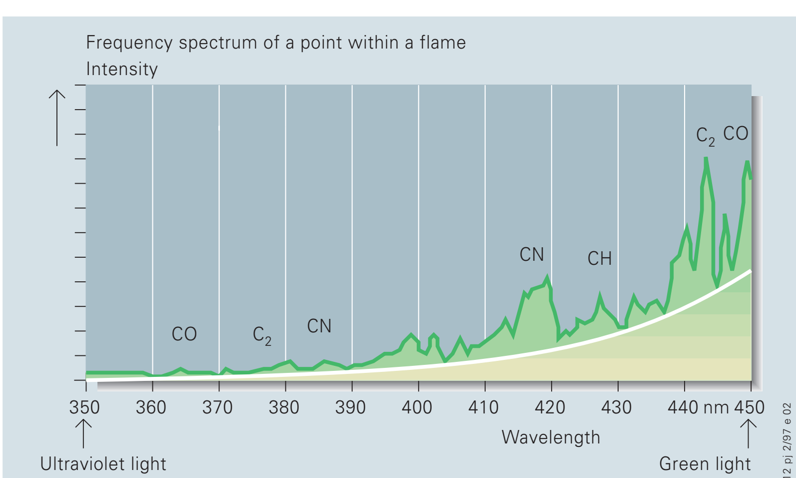
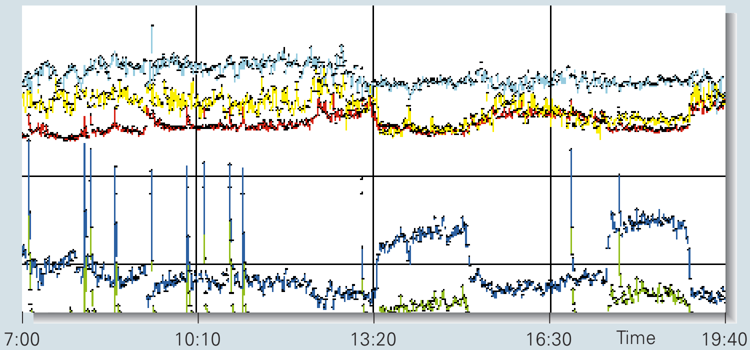


Fig. 3
Section of the emission spectrum of one flame. The thermal radiation appears as a background which slowly increases with increasing wavelength. Spectral lines of specific chemical compounds are superimposed on this background.

Fig. 4
The new combustion diagnostics system measures important combustion parameters quickly, quantitatively and with high spatial resolution.

Measurements taken in the Völklingen prototype power plant on June 5, 1997



Center of flame in y direction
Center of flame in x direction
Average combustion temperature
Nitrogen oxide formation
Carbon monoxide formation

The increased CO and NO_x levels after 1:20 and 5:20 p.m. were caused by the firing of coke oven gas in addition to coal.

The frequently occurring peaks between 7:00 and 11:00 a.m., the slight temperature rise and pronounced CO und NO_x formation can be attributed to the ejection of the coal retained in the coal mill.

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tioning electronics (Fig. 1) which provide this information.

The optical preprocessor filters four frequency ranges out of the emission spectrum, which are then fed to the processing and analysis software. The flame geometry and the ignition point, temperature distribution and carbon dioxide and nitrogen oxide formation by the burners are calculated, and displayed and documented using visualization and data storage software. These data are also made available for control intervention (Fig. 4).

Openings with a diameter of 10 mm must be made for the cameras at suitable monitoring locations on the boiler or combustion chamber; in most cases, it is not necessary to bend the tubing out of the way. An appropriate recess must be made in the insulation on the boiler wall to accommodate the camera housing, which is rigidly mounted on the boiler.

Highly Modular Design Enables Three Different Configurations

Thanks to its modular design, the combustion diagnostics system can be operated as a mobile (local) measurement system, as a compact system with software communication via a bus, and as a distributed system using the TELEPERM XP terminal bus and plant bus structure (Fig. 5). The system can be easily integrated into existing process control systems, and can be expanded step by step from the smallest system for monitoring one burner up to a large-scale system for monitoring an entire boiler.

Reduced Pollutant Formation and Fuel Consumption

The new combustion diagnostics system provides better information on the combustion process since it allows the determination of parameters such as flame geometry and size of the turbulence cells. Visualization of the combustion process allows problems such as coal flow stratification and red-hot baffle plates at the mouth of the burner to be clearly identified. The appropriate response and/or control action can then be implemented, thereby shortening or eliminating downtimes. Improved combustion control thus contributes to boiler operation modes which minimize life-limiting effects, and it optimizes the flame, reduces pollutant formation and lowers fuel consumption by about one percent.

Increasing Plant Efficiency by Up to One Percent

The combustion diagnostics system continually adjusts the supply of fuel and air to each burner to maintain an optimized level in accordance with overall combustion criteria. The system can respond to changes in the calorific value of the coal, for example, ten times more quickly than control concepts used to date.

In new power plants the system can increase plant efficiency by up to one percent. A major contribution is the improvement in boiler efficiency of about one percent, which alone already raises

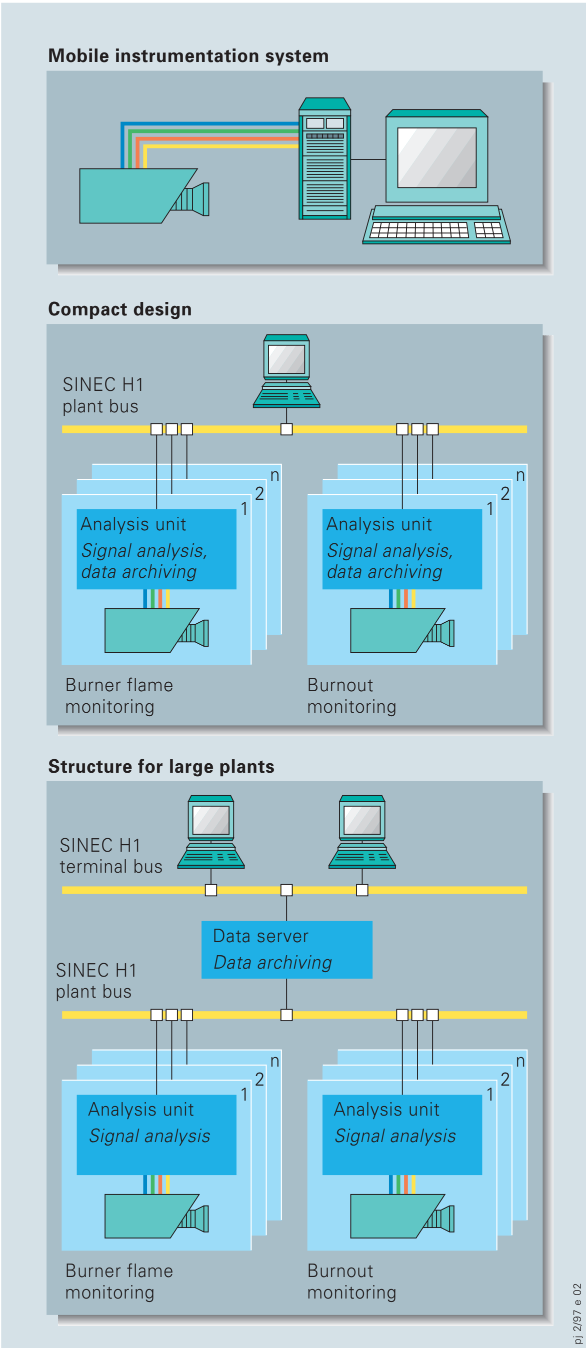

Fig. 5
Thanks to its highly modular design, the combustion diagnostics system has a wide range of applications from the smallest system for monitoring one burner up to a large-scale system for monitoring an entire boiler, and can be easily integrated into existing process control systems.

plant efficiency by about 0.45 percent. In a coal-fired power plant with a thermal output of 1800 MW, a more uniform burner adjustment can reduce the excess of air by 0.1, which in turn can reduce coal demand by 6.75 metric tons per hour—a saving in fuel costs of about $US800,000 per year.

More uniform operation also has a favorable effect on the service life of the combustion-related subassemblies. The intervals between maintenance, for example, can therefore be increased.

Due to its ease of installation and removal, the combustion diagnostics system can be used in new plants and integrated into older boiler systems. The amortization time is one to two years for lignite-fired and anthracite-fired power plants.

Initial Installations

Since March 1997, the combustion diagnostics system has been used successfully in various plants:

• Franken II power plant (hard-coal slag-tap furnace)

• Erlangen municipal utility (hard-coal dry-ash furnace and oil-fired furnace)

• Schwarze Pumpe power plant (lignite-fired furnace)

• Völklingen prototype power plant (hybrid burners for coal, oil and coke oven gas).

With gas turbines in gas premix mode, only a few soot particles are formed. Since the intensity of the background is low in these cases, temperature measurement is not possible. The other parameters are not affected, and can be determined.

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is responsible for optical combustion analysis R&D for boiler control in fossil-fueled power plants. Previously he assisted in the elaboration of instrumentation & control concepts for a modern process control system. His university studies concentrated on optics.