Plasma ignition system for oil free power plant Zetes in Turkey and its advantages for the changed circumstance of energy market

Zhang Ke, Liu Lin, Hans-Christian Schröder and Feng Guoqing

Kurzfassung

Plasmazündsysteme für das Kraftwerke Zetes in der Türkei und ihre Vorteile im veränderten Energiemarkt

Nach 168 Betriebsstunden wurden die zwei 600-MW-Kohleblöcke des Kraftwerks Zetes in der Türkei in den kommerziellen Betrieb übernommen. Bereits im Planungsstadium wurde der Einbau eines Plasmazündsystems integriert. Auf die Zündfeuerung mit einem Ölsystem wurde verzichtet. Dies vermeidet den Einsatz von Öl als zusätzlichen Brennstoff und bietet zudem erhebliche ökonomische Vorteile im Betrieb. Das installierte Plasmazündsystem bietet zudem weitere Vorteile für den flexiblen Betrieb von Kohlekraftwerken.

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After having passed 168 hours of trial operation, the 2 x 600 MW coal-fired units in power plant Zetes in Turkey were put into commercial operation on July 19th, 2016 and August 27th, 2016 respectively. Already during their construction, the units integrated the plasma ignition system delivered by the China Yantai Longyuan Power Technology Co., Ltd (YTLY). The whole fuel-oil system has been renounced. The power plant realised oil-free start-ups during the boiler commissioning, which helped to save abundant oil, prevented the by non-application of ESP while burning oil at the ignition stage, and brought tremendous economic and environmental benefits for the power plant.

Along with a dozen years of development and practice, the plasma ignition system of YTLY; being installed at about 800 power plants, has reliable performance and matured application. The plasma ignition system is ready to replace oil-systems in coal-fired power plants for realising oil-free power plant operation, which is regarded as the inevitable element of future coal-fired power industry development. Meanwhile, this system has also established a solid foundation for flexible operation of retrofit projects of some coal-fired units. It belongs to the best available technologies (BAT) in accordance with European standards and will play an important role in energy-saving, emission reduction and the construction of green power coal-fired plants.

Introduction

In 1990s, based on the research in China and abroad, Yantai Longyuan Power Technology Co., Ltd. (YTLY) developed the plasma ignition and combustion stabilising system (PICS) with its own intellectual property right through independent R&D and continuous settlement of key technical issues. By the end of October, 2016, the system is successfully integrated in nearly 800 coal-fired units with a total installed capacity of 350 GW. In China, 52 coal-fired power plants have completely cancelled fuel-oil systems, meanwhile, two overseas fuel-oil free power plants are built and in operation, namely Zetes in Turkey and Dushanbe in Tajikistan.

Fig. 1. View of the Zetes power plant in Turkey.

The 2 x 660 MW units in Zetes in Turkey utilise once-through, single furnace, fire bituminous coal, in both units tangential-fired with super-critical, variable-pressure operation. The pulverising system is direct-fired, bowl-type with medium speed, five mills in operation and one as standby with hot primary air as the drying source, each mill supplies four coal burners on the some layer. The Zetes power plant (Figure 1) adopted PICS during its initial construction. Eight coal burners related to mill A and B were retrofitted with plasma burners, along with the installation of fitting carrier air system, cooling water system, power system, flame-image monitor system as well as cold furnace pulverising system. By using PICS, the power plant realised fuel-oil free start-up and stop in cold-state, guaranteed low-load stable combustion. As a result, Zetes cancelled the regular fuel-oil system and became a single-fuel coal-fired power plant with the help of PICS.

For a tangential-fired boiler, the coal flame from the plasma burner outlet of the lower layer could directly ignite the coal power coming out of the adjacent burner, so only one layer of plasma burner can achieve boiler ignition initiation and stable combustion. Two layers of plasma burners are applied in Zetes, Turkey in order to ensure that the boiler can be ignited by the other layer of plasma burners, once one layer had any malfunction on plasma burners or the corresponding mill.

The two units in Zetes, Turkey successfully passed 168 hours of trial operation in July 19th and August 27th, 2016 respectively and were put into commercial operation afterwards.

Plasma ignition and combustion stabilising system

The PICS (Plasma ignition and combustion stabilising system, Figure 2) used in Zetes power plant in Turkey consists of plasma generator, burner, power system, flame-image monitor as well as air heater, water pump and air fan. The system has been successfully certified by CE.

Plasma ignition system

As shown in Figure 3, each plasma ignition system comprises a plasma generator and a plasma burner. By utilising DC current, the plasma generator is able to ionise a gas medium at certain pressure to obtain the plasma with stable power, and the temperature of plasma is over 5,000 K.

The plasma generator is inserted into the plasma burner in axial direction, then a local high temperature section with a sharp temperature gradient is formed inside the plasma burner. When passing through this section, the coal powder particles rapidly release the volatiles and break down, thus enables rapid combustion. Since the reaction is carried out in a gas phase, when the fractions and compositions of the mixture changes, the coal combustion would speed up, as a result, the ignition energy needed by coal is greatly reduced. So that partial coal powders are ignited with lower energy, then, all pulverised coal inside the burner would be ignition by the way of internal combustion and gradual enlargement. In order to guarantee the safe operation of plasma burner, thermocouples are installed at corresponding positions to monitor the wall temperature which is also displayed in the control system.

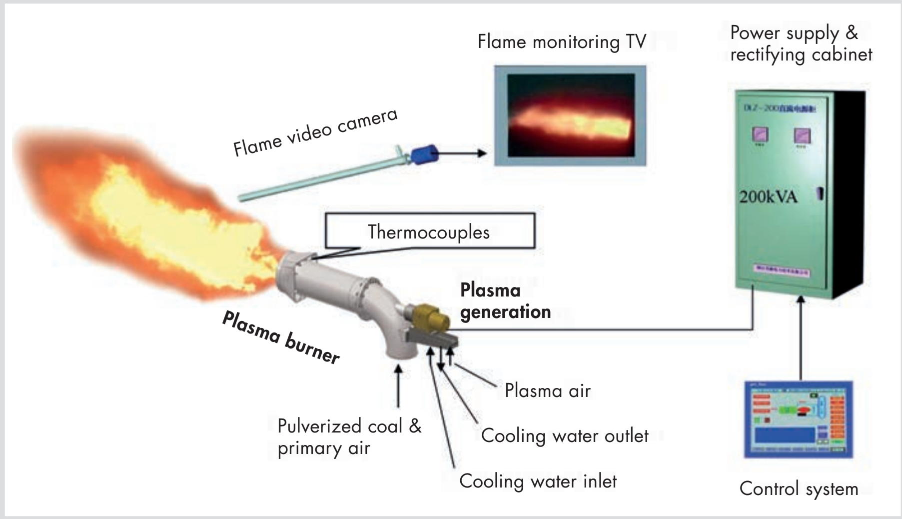

Fig. 2. Plasma ignition and combustion stabilising system.

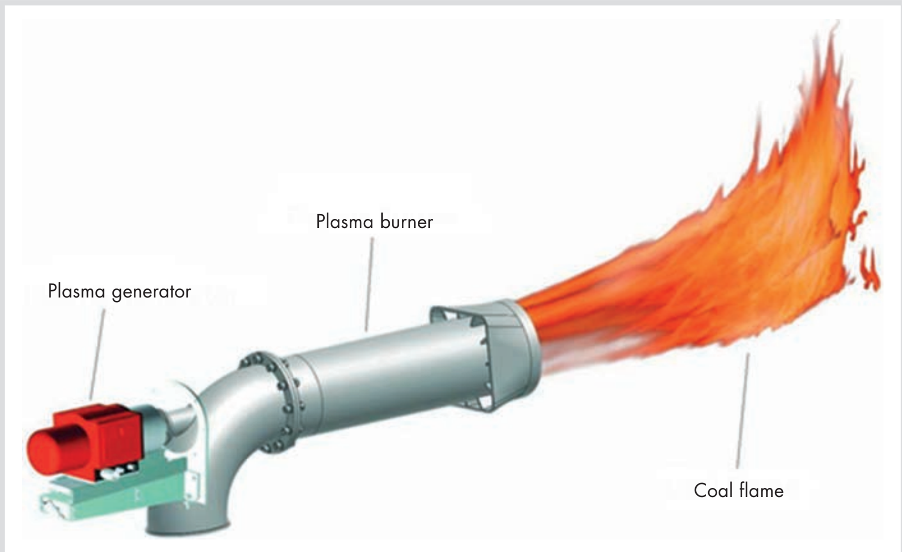

Fig. 3. Plasma ignition system.

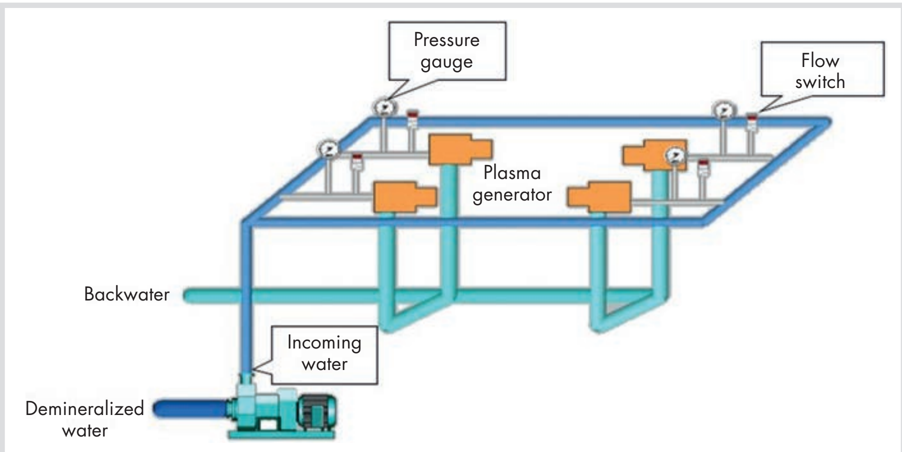

Fig. 4. Cooling water system for the plasma ignition system.

Cooling water system

When the plasma arc is formed, the temperature of arc column would exceed 5,000 K. Therefore, water is applied to cool down the cathode, anode and coils in the plasma generator. Considering the possible corrosion on anode and cathode, desalted chemical water is preferred. In order to ensure the effect, the water flow is running at high rate with a temperature not beyond 40 °C, otherwise, it would affect the life of anode and cathode. The pressure difference of cooling water between the inlet and outlet ends on plasma generator must satisfy the design requirements. For example, the cooling water pressure difference for DLZ-200 series plasma generator is above 0.4 MPa. (Figure 4)

Carrier air system

Carrier air is the medium of the plasma arc, with a certain flow rate, it helps to make the plasma arc available. Therefore, PICS is equipped with the carrier air system. In order to ensure a stable operation of plasma generator, the carrier air should be clean, oil-free, and pressure-persistent. In the Zetes power plant, Turkey, the DLZ-200 series plasma generator utilises instrumental compressed air as the carrier air source. The pressure of the assembly at the inlet of plasma generator is 5-10kPa and the flow rate is about 60 Nm^3 / hr. (Figure 5)

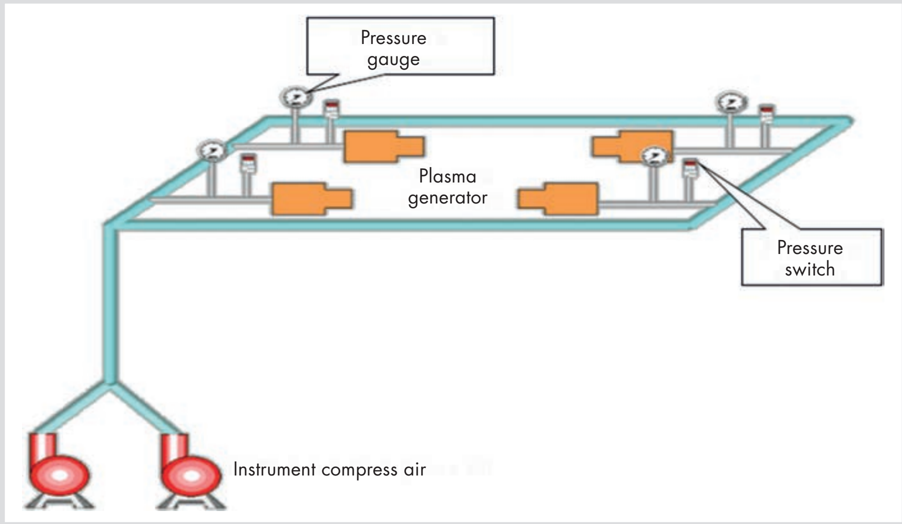

Fig. 5. Carrier air system for the plasma ignition system.

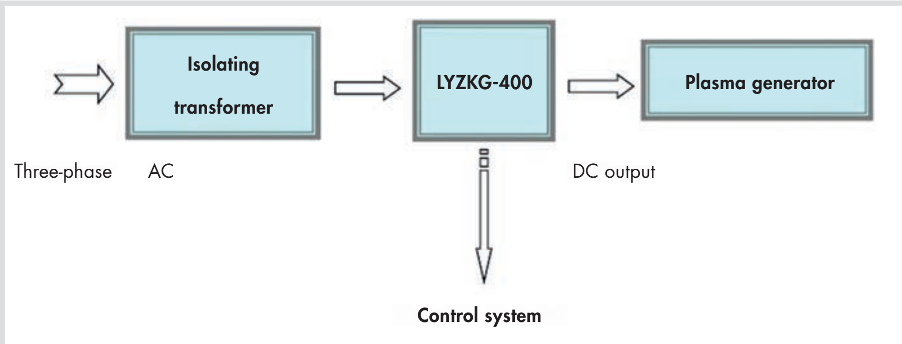

Fig. 6. Power system for the plasma ignition system.

Power system

The plasma generator uses DC power. The power system consists of AC-DC converter device and others, it can produce DC power to maintain stable plasma arc. There are two types of the AC-DC converter, LYZKG and LYKG. LYZKG-400type power system is used in the Zetes project with supporting isolation transformers. (Figure 6)

Cold-furnace pulverising system

The cold-furnace pulverising system is integrated in Zetes project in order to satisfy the pulverising conditions when the boiler is at cold-state. One set of Air heater is added at the inlet of the mill to warm up the primary air by utilising boiler's auxiliary steam, therefore the mill is initiated from cold-state directly to provide necessary pulverised coal for plasma ignition.

Flame-image monitor system

The flame-image monitor system consists of flame monitor probe, multiplexer, TV & etc. It monitors inner furnace combustion conditions from observing flame image. The flame monitor probe directly captures flame image of burner by the wide angle, telephoto lens and the colour CCD camera (view angle is 85 ° to 90 °), which will provide the operator with visualised real-time burning image information. As a result, the operator could adjust the ratio of primary air and secondary air based on such information to increase the burnout of the pulverised coal and the combustion efficiency of the boiler, meanwhile, reduce the flue gas pollution. In a word, the flame-image monitor system helps to supervise inner furnace combustion, guide relevant adjustment and optimise the boiler operation therefore to realise a stable, economical and clean combustion.

Advantages of the oil-free power plant with PICS

Economic efficiency analysis

Coal-fired power stations normally have complex and expensive fuel oil systems. The investment of the fuel oil system for a newly built coal-fired power plant with 1 x 600 MW units will exceed about 10 million RMB, including fuel oil transportation, storage, conveyor, combustion devices and so on. Comprehensive safety facilities are needed because of the flammable and explosive characteristics of fuel oil, such as fire dike around oil tank area, lightning protection system, anti-static system, firefighter system & etc., which will not only increase the construction cost of the power plant, take up additional space, but will also raise operation and maintenance expenses. Therefore, after the replacement of oil system with PICS, the power plant could realise oil-free operation by burning single fuel as coal, bringing huge economic benefits along with enhanced safe operation. (Figure 7)

The use of PICS in oil-free power plant construction will bring huge economic benefits and enhance safety operation. Taking a single 600 MW, tangential-fired boiler as an example,, the conventional oil system investment is nearly 10 million RMB, oil consumption during commissioning is over 3,000 to 4,000 t, being replaced with PICS system, in accordance with oil-free power plant design, equipment investment would be recovered before the unit is put into commercial operation, meanwhile, a large amount of oil will be saved. The economic analysis during construction is as listed in Table 1. The situation in Zetes power plant in Turkey is similar as the power plant in China.

The above table indicates that the unit with PICS in oil-free power plant is far beyond the one with regular oil system regarding economic efficiency. During commissioning of new unit there is a saving of approx. 3,000,000 USDwhich is 2~3 of the total capital investment of PICS

Installation (4 sets). Besides, the initial oil system investment of nearly 10 million RMB can be saved, by abandoning oil system from the beginning of construction design.

Fig. 7. Benefits from the plasma ignition system, installation and buildings not necessary, due to the renunciation of the infrastructure for the oil fired system.

Tab. 1. Economic analysis during construction in China (1 x 600 MW with 4 burners).

No	Item	Boiler with oil ignition	Boiler with plasma ignition
1	Oil consumption 4,000 MT Equivalent Coal consumption 10,000 MT	4,000 MT @ USD 1000 / MT = USD 4,000,000/	10,000MT @ USD 100 / MT = USD 1,000,000
2	Power consumption for pulverising system & plasma ignition system		USD 15,000/
3	Costs for PICS Anode & Cathode		USD 2,000/
	Total operating cost during commissioning	USD 4,000,000/-	USD 1,017,000/
Saving cost during commissioning = 4,000,000 - 1,017,000 = USD 2,983,000			

Tab. 2. Economic analysis during commercial operation in Germany for a power plant 480 MW.

Start type	Cost for each cold start	Cold start frequency Eeach year	Warm start	Warm start frequency each year	Total Amount EUR
With regular oil gun	31,000EUR	20	22,000 EUR	30	128,0000
With PICS	16,000EUR	20	6,000 EUR	30	500,000
Total cost Save					780,000

We take the unit 3 and 4 of the Yonghung Power Plant (Korea South East Power Co., Ltd) as another example. There are T-fired boilers with 870 MW each, which are built by Doosan with Alstom license for bituminous coal, where four coal burners at the bottom elevation of unit 4 were substituted with plasma burners. PICS have been in service from first fire through initial plant start-up. The financial benefits during commissioning is significant. Compared to unit 3 there are 2.7 Million litres diesel fuel (~710,000 gallons) with value of 7,508 million kWh (~US$ 6.6 million) saved.

During commercial operation, for the units which have frequent start-ups and especially those have to run at low load in the long-term, the economic efficiency with PICS is still far beyond the units with regular oil system, because the PICS system can work promptly to stabilise the consumption without any support from oil, only some consumables such as cathodes and anodes are needed.

Taking 1 x 600 MW, tangential-fired unit in China as an example, there are savings of 750,000 USD each year in operating cost due to PICS. For the Yonghung Power Plant in south Korea there is the saving of 50 million kWh (approx. USD 44,000) in each cold start.

Because of different prices conditions of the diesel fuel in Europe, the saving potential will be much higher as in China. The Table 2 describes the cost submit for a power plant of 600 MW in Germany. The Saving in operation cost in one year will be about 780,000 EUR. The pay back period for capital cost of PICS with 4 burners is approx. 15 months.

Besides, considering the investment and operation cost of firefighting, when realised single fuel operation, the fire pump will be greatly simplified and much less operation time is needed. Some power plant has the statistic that the annual power cost saved from reduced fire pump operation could be as much as over a million RMB.

Environmental analysis and safety assurance

Traditionally, during ignition or low load operation, since the unit uses oil or oil-coal mixture, the ESP is unable to work in order to avoid the contamination on electrode caused by unburned oil droplets, as a result, lots of smoke is directly discharged into the air, which brings serious pollution to the environment, moreover, the dust in the smoke will give rise to blade abrasion on the induced-draft fan, power plants have to bear the relevant environmental and economic losses. When applying PICS instead, the ESP can be put into use during ignition and low load operation, therefore, the dust emission will be much less.

PICS technology is a very good solution to the problems caused by the oil-coal mixture to the SCR, FGD and GGH equipment, especially when the Chinese government is implementing regulations relating elimination of desulfurisation bypass.

The PISC increases the safety assurance and eliminates hidden danger of personal casualty and equipment failure to be caused by fuel oil burning.

This is very important especially for certain power plants in Germany and Europe which are located near the big cities with million people.

ZETES Phase III (2×660MW) Plant are supercritical units of the largest single unit capacity in Turkey and they are equipped with modern FGD device, SCR devises and combined filters of E-filter and bag filter. The operation since summer 2016 has proven that the PICS work impeccable with those devises according to the standards similar as Europeans.

Load change flexibility: More often, lower and faster

Along with the social development and environmental protection tendency in recent years, clean energy is steadily increasing in power industry, coal-fired units are inclined to shift the major role into peak-load regulating. The flexibility retrofit for coal-fired is also put on the agenda, for example, Germany and Europe have implemented the energy conversion policy of prior grid connection for renewable power. (Figure 8)

Under this background, many coal power plants, which are designed as base load plants, will be used as the puffer-load units. Those Plants have more start-ups, stops and longer low load combustion, which requires highly reliable ignition system to

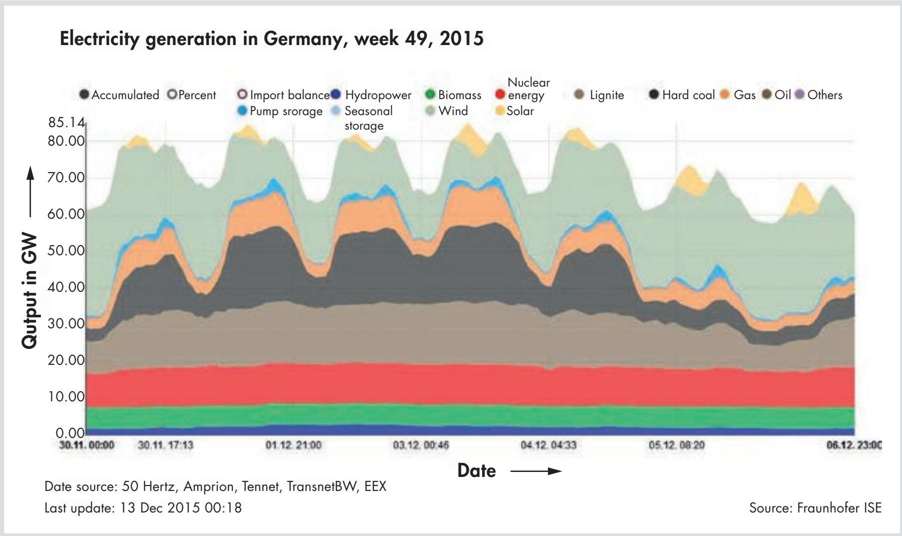

Fig. 8. Electricity generation in Germany with operational need for flexibility.

ensure timely input. We take a power plant with 800 MW in German as an example, the numbers of warm start and cold start must be increased to 30 and 20 each year compared to the original design of 2 and 5.

The second goal for increasing the flexibility is reducing minimum of technical load of currently 50 % to 30 % or more part load in future. When regulating the low-load for coal-fired units, the main problem is to guarantee boiler's stable combustion under low-load conditions. PICS technology offer exactly the perfect solution, with its help, the unit can realise cold-state start-up, moreover, it can be used as the ignition source to achieve stable combustion under extreme low load (0 to 30 % BMCR). (Figure 9)

Another important aspect is Increasing movable load gradient Increase of load rates speed within the load range and flexible response to volatile supply of renewable energy such as Improving contribution to system stability. (Figure 10)

After nearly 20 years of development gradual solution on technical matters, now there is a complete R&D system for PICS, the operation of cathode and anode is stable, electric arc is persistent, and maintenance is easy. As an internal combustion type burner, the plasma burner has the merits of fast fire rate, high initial burnout rate, wide adaptability of coal-gas flow, controllable temperature and stable combustion, moreover, it has excellent anti-coking and anti-burning features. The PICS system can work promptly to stabilise the consumption without regular oil system.

The Table 3 describes that the unit continuous loading/unloading rate in the power plant Zetes Turkey can reach to 5 % per minutes of the Rated Power Output, while the normal power plants are designed per 2 %. Minimum Continuous Rated Power Output with plasma ignition can reach 15 % BMCR?

Tab. 3. Ignition properties of Zetes Power Plant Phase III.

No	Performance	Unit	Value
1	Turbine and boiler continuous loading / Unloading rate	MW/min	33 MW/min at btw 50 % - 100 % 19,8 MW/min at btw 30 % - 50 % 13,2 MW/min at btw 0 % - 30 % (with Plasma ignation?)
2	Minimum continuous rated power output without plasma ignition (CCS mode of operation)	%	≤30
3	Minimum continuous rated power output with plasma ignition	%	0-30

Summary

With advanced PICS system applied on the 2 x 600 MW units, the Zetes oil-free power plant in Turkey is successfully built up. Tremendous oil was saved, besides, the ESP could work from the ignition stage, so environment pollution was greatly restrained, moreover, since the oil system was canceled, the power plant had safer operation.

Along with continuous development of relevant technologies, PICS has reliable performance, matured application, it has the unparalleled advantages than traditional oil system on the economic efficiency, safety as well as environmental protection and flexibility of load regulation. Therefore, the construction of energy-saving, safe, oil-free power plant with coal as the single fuel is the inevitable direction of coal-fired power industry development. All these PICS advantages will make PICS to the best available technologies (BAT) in accordance with the European Industrial Emissions Directive (2010/75/EC) and will provide a solid foundation for flexible coal-fired units retrofit in the changed circumstance of energy market in Europe too.

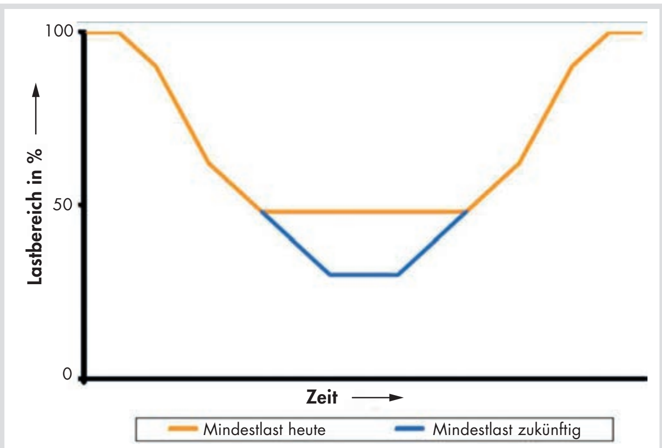

Fig. 9. Minimum load today and in the future.

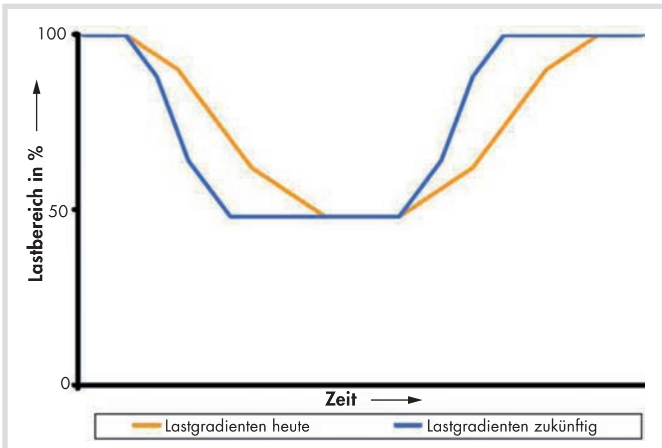

Fig. 10. Load gradients today and in the future.

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98,- Euro (für Abonnenten der Printausgabe), 198,- Euro (ohne Abonnement), incl. 19 % MWSt. + 5,90 Euro Versand (Deutschland) / 19,90 Euro (Europa)