

Optimisation of maintenance of power plant production assets equipped with carbon units in the last phase of operation

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1 Power system stability (KSE) as the greatest challenge for the operator

Analyses and forecasts accompanying the transformation of the Polish power sector indicate the possibility of a so-called capacity gap in the National Power System (NPS), which could mean a capacity deficit around 2032, preventing the continuity of electricity supply in certain periods. The capacity gap could reach as much as 7.4 GW by 2040. Despite the high probability of such threats, there are emerging opinions suggesting the need to accelerate the decommissioning of

coal-fired units, even within the next 10 years.

The costs of the ETS system and deteriorating energy market conditions for coal-fired sources are leading to a loss of economic justification for their continued operation. Therefore, a natural consequence is a reduction in expenditures on maintaining generating assets in coal-fired power plants and on retaining essential operating and maintenance personnel with appropriate professional competencies. This process is also occurring in companies providing repair services and diagnostic testing. At the same time, views are being expressed on the need to continue maintaining controllable coal-fired sources as a guarantee of power balance and the supply of system and quality services for the safe operation of the system, despite the significantly declining energy production from these sources. Analysis of the current energy production structure and load charts for individual generation sources indicates that coal-fired units remain the foundation. Currently, the National Power System has approximately 6,000 MW of installed capacity in highly efficient units with supercritical parameters, which, however, usually operate in regulation mode, often at lower parameters and sometimes at minimum, which means that their efficiency is at a level similar to that of still operating 200 MW class units built approximately 50 years ago.

2 Maintenance as the greatest challenge for the users of coal-fired units

Coal-fired units have entered their final phase of operation. During this time, they will increasingly stabilize the power system, meaning their availability will be a key feature. At the same time, maintenance costs should ensure their cost-effective operation.

Operating conditions similar to flexible operation will pose a challenge in ensuring proper technical condition. The high number and frequency of startups and longer, often unplanned, shutdowns will constitute a significant source of both typical damage and new, previously unheard-of or rare, damage. In addition to classic creep damage, which may not be dominant due to increasingly shorter operating times, thermal fatigue, erosion, and corrosion damage will become increasingly significant, stemming from the reduced stability of the physico-chemical parameters of circulating media (steam, water) and standstill corrosion.

The new operating regimes that power plants have been experiencing for some time now pose an increasing challenge to production assets. As illustrated in Figure 1, the intensity of creep damage is decreasing, while the number of damages caused by thermal fatigue and physical and chemical factors is increasing. Changing the unit's operating mode affects the location and nature of damage, requiring appropriate diagnostics, including equipment for detecting damage in unusual and difficult-to-access locations. This process can be objectively assessed, for example, using the Index of Flexible Operation (IFO).

3 Diagnostics in the final operational phase of coal-fired units

Diagnostics in the final operation phase of power units faces many challenges if the units are to be available during this phase, even while remaining in operational or strategic reserve [1-3,8]. Figure 2 illustrates, for example, the final operation phase of a 200 MW unit. This unit was taken out of service (due to the end of the derogation period). The increasing number of physico-chemical damages should be considered a

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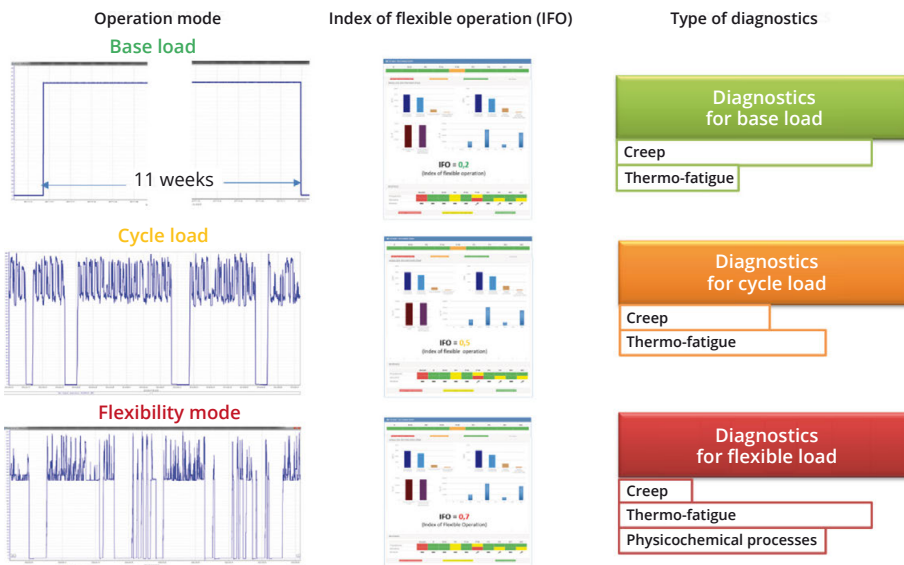


Fig. 1: The relationship between the unit's operating mode, the nature of the damage and the type of diagnostics.

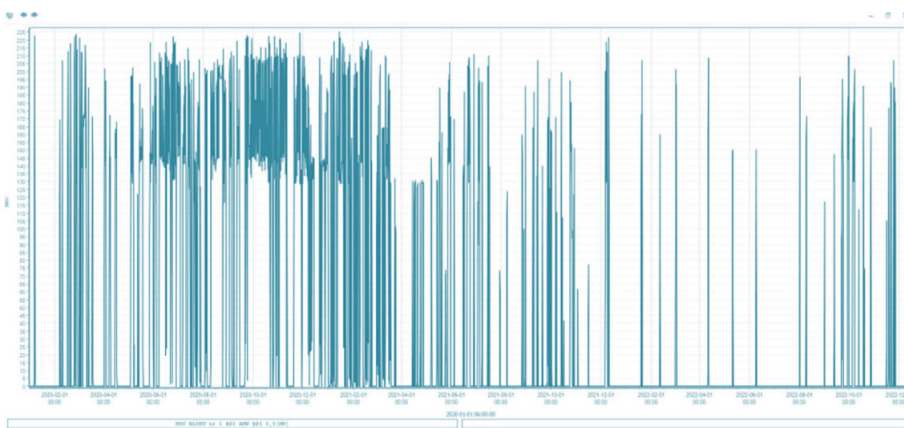


Fig. 2: Operation of the unit before decommissioning.

significant challenge to the availability of coal-fired units.

During emergency and/or accidental operation, corrosion damages are detected in less obvious locations, based on previous experience. Damage and irregularities are caused by all types of corrosion and erosion. Particular attention should be paid to stress corrosion cracking. Damage of this nature is also initiated and develops during equipment shutdowns, especially if they are not adequately protected and chemically prepared for intensive regulation [1-3]. The severity of this type of damage should also be expected due to the increasingly common co-firing of biomass and alternative fuels [1-2].

Their operational duration will depend on both profitability and the needs of the power system operator. Because the operator's needs may be redefined during the operation of individual power units, some may remain in operating reserve. Without a systematic approach to their continued operation, it will be difficult to meet the operator's expectations.

Depending on their location in the power grid, technical condition, suitability for control operation, access to coal deposits (lig-

nite-fired units), and operating costs, coal-fired units in commercial power plants and combined heat and power plants will be gradually decommissioned by approximately 2040. There will also be a risk associated with a weakening of technical maintenance competencies. The best solution seems to be the LTDSA formula for overhauls in the period between the last major overhaul and the end of a power unit's operation, Figure 3.

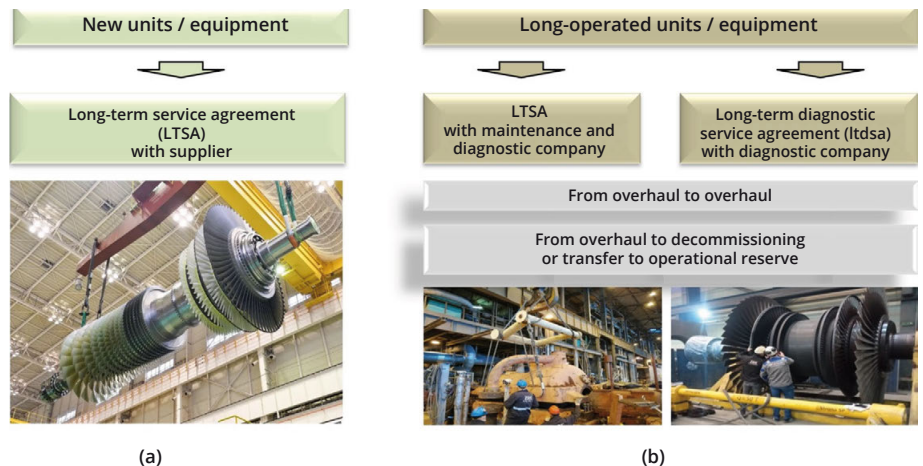


Fig. 3: Long-term supplier services (a) and LTDSA services (b) of a diagnostic company with the participation of a repair company.

This formula should also cover the period when the unit remains in operating reserve.

4 Pro Novum solutions supporting KSE stability

4.1 Service supporting the availability of coal-fired units in the final stage of operation

LTDSA plays a crucial role in resolving emergency problems, enabling faster identification of failure causes and more effective repair actions. It's difficult to imagine ensuring the high competence of service companies, including diagnostics, during the operation of new units without long-term contracts, especially since they are generally purchased without technological offset. Significant knowledge and competence are not gained by periodically performing ad hoc work. Combining LTSA and LTDSA allows for a compromise between operational safety, the supplier's interests, and the user's need for knowledge and control over the technical condition of equipment.

To meet the aforementioned requirements, we have developed a systematic approach to maintaining the technical condition of coal-fired power units in the final phase of their operation. This approach identifies the risks and potential consequences associated with modified/flexible power unit operation. The system utilizes stress criteria to analyze the stress of critical components and advanced algorithms to identify various degradation mechanisms, including corrosion and erosion. This will optimize maintenance costs and, if necessary, enable the power system operator to extend operating time and/or maintain units in operational reserve at a low cost.

4.2 System identifying risks associated with flexible operation of coal-fired units

Critical components of the boiler and turbine set, as well as equipment (pipelines, condenser, generator), were modeled as

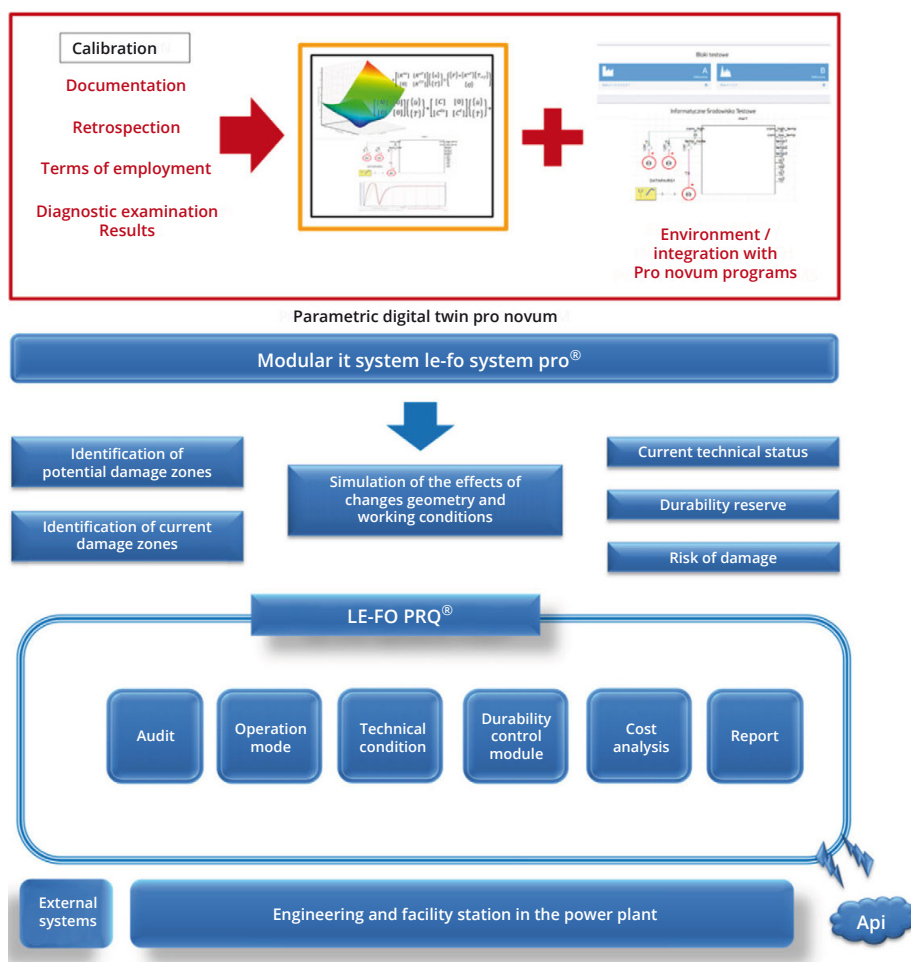


Fig. 4: LE-FO System PRO® performing diagnostic supervision, especially in terms of availability in the period before the decommissioning of coal-fired units.

parametric digital twins based on documentation and test and measurement results of actual components and installations. The digital twins were integrated with modules containing information from operational history and retrospectives on the LE-FO System PRO® IT platform [8] (Figure 4). Based on the analysis of operational history, measurement system audits, and maintenance shutdown schedules, so-called representative units were identified in individual power plants, for which diagnostic system modules are manufactured, tested, and installed after prior verification in the Pro Novum diagnostic test environment.

The technical condition of critical components of devices subject to the Office of

Technical Inspection is assessed in accordance with applicable regulations and, in parallel, in accordance with the methodology described above, which uses modeling of geometry, stress states, and temperatures in components, structural nodes, and devices. As a result, one of the System's modules allows for diagnostic supervision of the conditional safety of damaged components [5].

The transformation of the Polish energy sector contains many unknowns. The manner and pace of its transformation should take this into account. Some of the currently existing coal-fired power units can still operate for approximately 10 to 15 years. Their increasingly regulated and flexible opera-

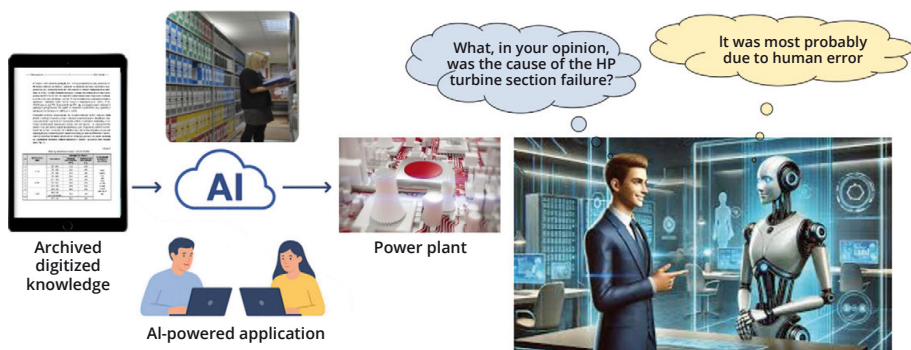


Fig. 5: An application designed to support the skills of specialists responsible for the maintenance of power plant production assets.

tion will accelerate the decline in equipment durability. This will require increasingly greater engineering skills, which may be lacking. Therefore, we have begun work on an application utilizing AI technologies, providing access to Pro Novum's knowledge and experience database (Figure 5).

In the foreseeable future, energy security in many European countries cannot be ensured without the continued operation of coal-fired power plants. This also applies to Poland, where lignite and hard coal account for approximately 50% of electricity generation. The final phase of coal-fired power plant operation contains many uncertainties [1,6,7]. While their operating conditions will increasingly differ from those for which they were designed, the economic impact of their operation may make it difficult to maintain their technical condition according to standards ensuring their availability required for sources stabilizing the energy system. Technical maintenance competencies will be crucial to meeting these expectations. Diagnostics, as a source of knowledge about the current technical condition, is an important part of maintenance. Modern analytical, digital, and IT technologies significantly improve its capabilities. Skillfully applied algorithms can replace specialists, whose shortage is becoming increasingly apparent. A tailored maintenance organization, including diagnostic services, can significantly reduce the risks associated with the longer, increasingly flexible operation of coal-fired power plants and entire power plants.

5 Summary

In the final phase of coal-fired power units' operation, flexibility and availability will be their most desirable features, while maintenance costs will determine their suitability for users. To create the conditions for meeting both requirements, we have developed a methodology for improving the flexibility of 200 MW power units and implemented remote systems for online diagnostic monitoring, including LTDSA. Systems are currently being implemented to identify risks associated with flexible operation and share Pro Novum's knowledge and experience.

We are prepared for various scenarios for the continued transformation of the Polish power system, including some that are less optimistic than those commonly reported.

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Kurzfassung

IT-gestützte Instandhaltungs-optimierung bei Kohlekraftwerken in ihrer letzten Betriebsphase

Der Betrieb von Kohlekraftwerken nach langer Laufzeitdauer ist hinsichtlich der Wirtschaftlichkeit der Anlage eine unternehmerische Herausforderung: Flexibilität und Verfügbarkeit am Strommarkt müssen weiterhin und bestmöglich gewährleistet werden, während Instandhaltungskosten eine besondere Belastung darstellen können. Die sich verschlechternden polnischen Marktbedingungen für Kohleerzeugung führen zur Reduzierung der Ausgaben für die Instandhaltung und zu weniger Beschäftigung von Betriebs- und Wartungspersonal mit entsprechenden fachlichen Kompetenzen. Gleichzeitig werden Stimmen laut, die die Notwendigkeit be-

währter und kontrollierbar Kohlekraftwerke betonen. Der vorliegende Fachbeitrag stellt deshalb eine Methodik zur Instandhaltungs-optimierung vor, welche auf Fernüberwachungssystemen zur Onlinediagnose basiert und zur höheren Flexibilität von 200-MW-Blöcken beitragen kann. Das neu entwickelte System nutzt Belastungskriterien zur Analyse der Belastung kritischer Anlagenkomponenten und setzt auf fortschrittliche Algorithmen zur Identifizierung verschiedener Verschleißmechanismen, einschließlich Korrosion und Erosion. Auf Grundlage der Analyse der Betriebshistorie, der Audits der Messsysteme und der Wartungs- und Stillstandspläne wurden in einzelnen Kraftwerken sogenannte repräsentative Einheiten identifiziert. Für diese Einheiten wurden Systemmodule hergestellt, getestet und nach vorheriger Verifizierung erfolgreich in die Pro-Novum-Testumgebung installiert.



vgbe-Standard VGBE-S-517-00-2024-11-EN

Rating charts for rating the microstructural composition and creep rupture damage of creep-resistant steel for high pressure pipelines and boiler components and their weld connections

(4th Edition, replaces VGB-S-517-00-2014-11-DE-EN)

VGBE-S-517-00-2024-11-EN. 194 p., 141 fig., 5 tab. (2025), DIN A4, print/e-book
 ISBN 978-3-96284-384-7 (print, English), ISBN 978-3-96284-385-4 (e-book, English)
 Price for vgbe-members* 280,- €, non-members 420,- €, + packaging and shipping and VAT.
 This vgbe-Standard is available in German and English.

To determine the microstructural condition and assess material fatigue, metallographic microstructural analyses are performed on power plant components that have been operated in the creep range for long periods of time. Real microstructural images, which are part of this vgbe-Standard, assist in the determination and evaluation. This vgbe-Standard summarises existing documentation, information and findings.

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In this fourth edition, the optional assessment of creep damage based on porosity determination for martensitic 9%–12% Cr steels has been added.

The assessment classes for base materials have been adapted to the latest findings in damage assessment, and the illustration appendix has been supplemented and updated with current high-quality illustrations.

Helpful additions for users, such as a correlation table of relative creep life consumption as a function of porosity, including reference values and typically used etching agents, have been included.

Furthermore, examples of the interaction and differentiation between creep damage and relaxation crack formation have been added.

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