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Construction and Engineering Application of an Anti-Disturbance Control Power Supply System for Key Auxiliary Equipment in Coal-Fired Power Plants Under Weak Grid Conditions

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Abstract

In response to the frequent occurrence of grid disturbances such as voltage sags caused by the weak grid structure in the area where the Datang Jinguang Kalteng Power Plant in Indonesia is located, which have led to power-loss trips of key auxiliary equipment including the coal feeder control system and motor-operated valves (MOVs), posing a serious threat to the safe and stable operation of the generating units, this study carries out applied research and engineering retrofitting of an anti-grid-disturbance control power supply system. Through systematic analysis of historical grid disturbance characteristics and the tolerance capabilities of coal feeder control equipment, a high-reliability control power upgrade solution based on online double-conversion UPS and an intelligent power distribution system is designed and implemented, establishing a "secure power supply zone" effectively isolated from grid disturbances. The project completed system design, equipment selection, engineering implementation, and commissioning verification on schedule. Operational results demonstrate that the new system significantly improves the power supply reliability of the coal feeder system under grid disturbance conditions, providing a replicable and scalable technical approach for ensuring reliable power supply to key auxiliary equipment in coal-fired power plants located in weak grid regions.

INTRODUCTION

Reliable electric power supply to key auxiliary equipment is a fundamental prerequisite for the safe, continuous, and efficient operation of coal-fired power plants (Wei et al., 2024). Auxiliary systems such as coal feeders, motor-operated valves (MOVs), and pulverizing mills depend on uninterrupted control power to maintain accurate positioning, sequencing, and protection logic; any momentary loss of control power can trigger unplanned trips that cascade into load reduction, boiler-turbine mismatch, or even unit shutdown (Utomo et al., 2023; Sun et al., 2026; Jin et al., 2023; Komala et al., 2022). As power systems in many developing regions continue to expand alongside industrial and economic growth, the reliability of the transmission and distribution networks that supply these plants has become an increasingly critical engineering concern, particularly where grid infrastructure has not kept pace with the growth of connected generation and load (Amega et al., 2024; International Energy Agency, 2023).

In Indonesia, several regional power grids, particularly those serving remote or newly developed industrial areas, exhibit the characteristics commonly associated with a weak grid: dispersed and comparatively small generation sources, long overhead transmission corridors, limited network meshing, and high exposure to lightning strikes, vegetation contact, and other environmental disturbances. These conditions make voltage sags and short-duration interruptions considerably more frequent than in mature, well-interconnected systems (Tang et al., 2022). Because such disturbances typically last from a few cycles to a few seconds, they rarely cause structural or thermal damage to plant equipment; however, they are long enough to disrupt the operation of voltage-sensitive control components, and their recurring nature erodes the operational stability that coal-fired units are expected to provide as base-load or semi-base-load resources (Bauhus et al., 2017; Casal, 2017; Fahmi et al., 2022; Liu et al., 2016; Papaelias et al., 2016).

This situation is clearly reflected in the operating experience of the Datang Jinguang Kalteng Power Plant, located in an area served by a comparatively weak regional grid in Central Kalimantan, Indonesia. Over an extended period of commercial operation, the plant's key auxiliary equipment, most notably the coal feeder control system and its associated motor-operated dampers, has repeatedly tripped following momentary voltage sags originating from the external grid. Although none of these events resulted in physical damage to equipment, each trip forced a rapid reduction in fuel feed, disturbed the combustion and steam-generation balance, and required manual intervention to restart the feeder and restore stable load. The cumulative effect of these repeated disturbances has been a measurable erosion of unit availability and an elevated operational risk profile, underscoring the urgency of a dedicated engineering solution rather than a purely procedural or operational workaround (Çolak, 2026; Meyer & Reniers, 2025; Ovi & Shova, 2026; Ray, 2026; Singh, 2025).

The underlying technical cause of this vulnerability lies in the conventional configuration of control power supply systems, in which control and instrumentation circuits are fed directly, or through only a simple transformer and rectifier stage, from the plant's auxiliary power system. Such an arrangement offers little independence from the behavior of the upstream grid: once a sag propagates into the auxiliary bus, control power drops accordingly, causing controller resets, communication interruptions, and loss of actuator position feedback. Previous studies have approached this vulnerability from different angles. Investigations into the impact of voltage sags on thermal power plant control systems have documented similar trip mechanisms and proposed mitigation measures at the protection and control-logic level (Automation of Electric Power Systems, 2019), while control-theoretic approaches such as gearless coal mill anti-disturbance sliding mode control (Wang et al., 2025) and anti-blocking control strategies for coal feeders in Indonesian power plants (Dermawan et al., 2024) improve the robustness of the control algorithm itself but do not remove the root cause of power interruption at the supply level. Meanwhile, general applications of online UPS technology in power plant control power systems have been reported (Power Equipment Management, 2020; Electric Power Safety Technology, 2021), and relevant technical standards for UPS systems and voltage-dip immunity are well established (GB/T 7260-2016; IEC 62040-1:2017; IEC 61000-4-11:2020; DL/T 774-2015); yet these references remain largely generic and do not offer a site-specific engineering methodology that links historical disturbance statistics, equipment tolerance characteristics, and an integrated power-supply-and-monitoring architecture for a plant operating under the particular weak-grid conditions found in overseas, Belt and Road-associated projects such as Kalteng.

This gap between generic UPS and standards guidance on one hand, and the specific reliability requirements of a weak-grid, overseas coal-fired plant on the other, motivates the present study. Rather than treating the coal feeder trip problem solely as a control-logic issue, this research addresses it at its source, the control power supply itself, by combining a statistical characterization of the plant's historical grid disturbance profile with the tolerance limits of the coal feeder control equipment, and then translating these findings into a concrete engineering design based on an online double-conversion UPS integrated with an intelligent power distribution and monitoring system. The objective of this study is therefore to design, implement, and evaluate an anti-disturbance control power supply system capable of isolating key auxiliary equipment from external grid disturbances, and to verify its effectiveness through actual engineering application at the Kalteng Power Plant. This research contributes a systematic methodology integrating historical disturbance analysis, equipment tolerance characterization, and UPS-based power supply design for weak-grid conditions, extending online double-conversion UPS application to coal-fired plant auxiliary systems in developing regions with empirical operational validation. Practically, it provides a replicable, scalable technical solution for coal-fired power plants in weak-grid regions, particularly Belt and Road partner countries facing similar challenges.

METHOD

Technical Approach and Overall Plan

The project was implemented following a technical route of "problem diagnosis, solution design, equipment customization, engineering implementation, verification and optimization." First, historical grid disturbance data were statistically analyzed to identify the characteristics of voltage sag magnitude, duration, and occurrence frequency. Based on this analysis and in combination with the tolerance capabilities of coal feeder control equipment, the reliability design objectives of the control power supply system were determined.

On this basis, a control power supply system solution based on an online double-conversion UPS was studied and designed. By establishing an independent control power supply circuit, the coal feeder control system was effectively isolated from external grid disturbances. In parallel, an intelligent power distribution system was implemented to enable centralized monitoring and refined management of power supply status. At the overall design stage, full consideration was given to interface compatibility and logical coordination with the existing DCS system, laying a solid foundation for subsequent deep integration.

RESULT AND DISCUSSION

Key Technologies and System Design

Considering the actual on-site operating conditions and the findings of the historical disturbance analysis described in the Method section, the project team selected a 40 kVA online double-conversion UPS as the core power supply equipment for the anti-disturbance control power system. The double-conversion topology was chosen deliberately over line-interactive or offline alternatives, because it continuously rectifies incoming AC power to DC and then reinverts it into a regulated AC output, so that the load is permanently decoupled from the raw behavior of the incoming grid rather than being switched over only after a disturbance has already been detected. This near-zero transfer-time behavior is particularly important for coal feeder control circuits, whose microprocessor-based controllers and actuator drives can lose their operating state within a few tens of milliseconds of a supply dip, a timeframe well within the switching delay of conventional standby or line-interactive UPS designs. In this respect, the selected architecture directly targets the failure mechanism identified during the diagnostic stage, rather than merely reacting to it after the fact.

The UPS was sized to supply the combined control, instrumentation, and low-power actuator load of the coal feeder system with a reasonable margin for future expansion, while remaining compact enough for retrofit installation within the existing electrical room without requiring major civil modification. The unit was equipped with a high-reliability battery bank capable of providing a backup time of no less than thirty minutes at 55% load. This duration was selected to cover not only momentary sags of a few cycles, but also short-duration outages lasting up to several minutes, during which operators may need to execute manual switching, fault isolation, or restoration procedures; the design is broadly consistent with the guidance on UPS sizing and backup-time selection given in GB/T 7260-2016 and DL/T 549-2014, and with the voltage-dip immunity classifications defined in IEC 61000-4-11:2020 and DL/T 774-2015, which the study used as reference benchmarks when defining acceptable ride-through performance for the control power system.

At the power distribution level, a dedicated intelligent distribution cabinet was designed to supply the coal feeder control circuits, actuators, and related auxiliary equipment in separate zones with graded protection. Rather than feeding all downstream loads from a single protective device, the distribution architecture was segmented so that a fault occurring in one branch, for example an actuator circuit, could be isolated by its own protective device without de-energizing the control circuits of the remaining branches. This graded arrangement improves the fault tolerance of the overall system and reduces the consequence of any single-point failure within the retrofit scope. By optimizing the selection and coordination of the UPS, the battery bank, and the distribution equipment as an integrated set rather than as independently procured components, the project sought to improve both overall system availability and expected service life, an approach consistent with reliability-improvement practices reported for control power supplies of key auxiliary equipment in thermal power plants (Electric Power Safety Technology, 2021).

In parallel with the power-supply design, deep integration between the UPS system and the plant's existing DCS was achieved. Operating status signals, key electrical parameters such as output voltage, load current, and battery state of charge, and fault or pre-alarm conditions were mapped into the DCS, enabling remote monitoring and centralized management from the main control room rather than requiring local inspection of the UPS panel. This integration extends the visibility of the control power system into the same operator interface already used for the rest of the unit, thereby improving situational awareness and shortening the time needed to recognize and respond to abnormal conditions before they can affect coal feeder operation.

Project Implementation and System Integration

During project implementation, the installation, wiring, and commissioning of the UPS system and intelligent distribution cabinets were carried out in strict accordance with the approved technical design and applicable construction specifications. Site preparation included verification of cable routing, cabinet foundations, and earthing arrangements, followed by installation of the UPS module, battery bank, and distribution cabinet within the designated electrical room. Because the coal feeder control system could not be taken out of service for an extended period without affecting unit operation, particular attention was given to the parallel-operation characteristics of the new control power supply system relative to the existing arrangement. Detailed switchover and commissioning plans were developed in advance, including step-by-step sequencing of circuit transfers, temporary bypass arrangements, and clearly defined rollback procedures, so that the retrofit could proceed with minimal risk and negligible impact on unit operation.

At the system integration stage, emphasis was placed on the logical interfacing of UPS operating signals and alarm information with the DCS, so that key operating parameters could be monitored in real time and early warning could be given for abnormal conditions such as battery degradation, overload, or loss of the incoming supply. Once the physical installation and signal mapping were completed, a series of multi-condition simulated grid disturbance tests were conducted to verify the anti-disturbance capability of the new system. These tests reproduced representative sag magnitudes and durations drawn from the historical disturbance analysis, applied under controlled conditions so that the response of the UPS, the distribution cabinet, and the downstream coal feeder control circuits could be observed without exposing the operating unit to unnecessary risk. Based on the results of these tests, protection settings, alarm thresholds, and elements of the control logic were further optimized, including refinement of the coordination between upstream and downstream protective devices and adjustment of communication mapping to the DCS, to ensure stable and predictable behavior under actual site operating conditions rather than only under idealized test conditions.

This staged approach to implementation and integration, moving from detailed planning, to careful physical installation, to structured functional verification, and finally to parameter optimization based on test evidence, reflects established practice for retrofit projects on operating thermal power units, where the cost of an unplanned trip during commissioning can be significant. It also created a documented basis for the technical scheme subsequently developed from the project, since each design decision could be traced back to a specific diagnostic finding or test result rather than to assumption alone.

Analysis of Operational Effects and Results

After the system was put into operation as scheduled in December 2025, it has been running in a stable and reliable manner. Under grid disturbance conditions that, prior to the retrofit, would routinely have caused the coal feeder control system to trip on loss of control power, the system has continued to operate without interruption, and the associated power-outage failure rate attributable to grid disturbances has been reduced to zero over the observed operating period. The UPS system has maintained a stable output voltage within the range of 400 Vac ± 1% regardless of fluctuations on the incoming grid, and the overall availability of the control power system has exceeded 99.9%, with the mean time between failures meeting the design requirements established during the diagnostic and design stages. Table 1 summarizes the qualitative comparison of key performance indicators before and after the retrofit, based on plant operating records and post-commissioning observation.

These results are consistent with the intended function of the double-conversion UPS topology described in the Method and Key Technologies sections: because the load is continuously supplied from the inverter output rather than being switched onto backup power only after a disturbance is detected, the coal feeder control circuits no longer experience the brief but disruptive voltage collapses that previously caused controller resets. The measured voltage regulation performance also falls comfortably within the voltage-dip immunity classifications referenced in IEC 61000-4-11:2020 and the power-quality criteria defined in DL/T 774-2015, indicating that the retrofit not only resolved the specific trips observed at Kalteng but did so in a manner aligned with recognized international and domestic technical benchmarks for control power reliability. Compared with the sliding-mode control-logic approach reported for coal mill anti-disturbance control (Wang et al., 2025) and the anti-blocking control strategy documented for a coal feeder application in Indonesia (Dermawan et al., 2024), the present solution addresses the disturbance problem upstream, at the level of the power supply itself, which has the practical advantage of protecting the entire control and instrumentation chain rather than only the specific control loop for which an algorithm has been tuned.

It should also be noted that the improvement achieved is not without engineering trade-offs. The double-conversion process inherent to online UPS technology introduces a continuous conversion loss, typically in the range reported for this topology in the wider UPS literature and reflected in the efficiency classifications of IEC 62040-1:2017, which represents a modest but permanent increase in the auxiliary power consumption of the coal feeder system compared with a direct-fed arrangement. In addition, the battery bank requires periodic inspection, capacity testing, and eventual replacement to preserve the thirty-minute backup capability at 55% load, introducing a recurring maintenance obligation that did not previously exist for this circuit. These trade-offs were considered acceptable in view of the frequency and operational consequence of the disturbances being addressed, but they are relevant considerations for any plant contemplating a similar retrofit, and they point toward battery health monitoring as a natural extension of the DCS integration already implemented in this project.

The project also produced a documented technical output beyond the physical retrofit itself. A complete technical solution titled "Technical Scheme for the Retrofit of Anti-Grid-Disturbance Control Power Supply Systems in Coal-Fired Power Plants" was developed, consolidating the disturbance-diagnosis methodology, the equipment selection criteria, and the commissioning and verification procedures used at Kalteng into a form that can be reviewed and adapted for other sites. A related technical paper was also prepared, providing a practical reference for power plants of similar type and operating environment, so that the lessons learned during this project, including both the successful outcomes and the trade-offs discussed above, can inform future retrofit decisions elsewhere.

Benefit Analysis and Promotion Prospects

In terms of economic benefits, the project effectively reduced unplanned outages of the coal feeder system caused by grid voltage sags, which in turn supports a more stable equivalent availability factor for the generating units. Because coal feeder trips of the kind previously experienced at Kalteng typically require a rapid reduction in unit load followed by a manual restart and load recovery sequence, eliminating these events removes both the direct loss of generation during the trip and the indirect operational burden of repeated recovery operations on plant personnel. Over an extended period of operation, this contributes positively to the stabilization of power generation output and, by extension, to the reliability of electricity revenue for the plant.

In terms of social benefits, the project enhanced the stability and reliability of power supply available to the Kalteng area, an outcome that extends beyond the plant itself to the broader regional system that depends on it as a generation source. The project also established a representative overseas case of anti-grid-disturbance technical retrofitting for power plants, demonstrating that a systematic, standards-informed engineering approach can resolve a recurring operational problem in a weak-grid environment without resorting to large-scale grid reinforcement, which would typically require far greater investment and a longer implementation timeline. In doing so, the project helped strengthen the technical image and market influence of China Datang Group in the overseas power sector, illustrating the value of applying rigorous domestic engineering practice to the specific conditions encountered in international projects.

From the perspective of promotion and application, the technical solution developed in this study is well suited to coal-fired power plants located in regions with weak power grids and frequent voltage sags, particularly those situated in Belt and Road partner countries, where similar combinations of dispersed generation, long transmission distances, and environmental exposure are common. Because the underlying methodology, statistical characterization of grid disturbances, equipment tolerance assessment, and an integrated online-UPS-based power supply design, is not tied to any single site, it can be replicated and promoted at other power plants in Indonesia and comparable regions with appropriate adaptation of equipment sizing and distribution architecture to local conditions. Full-process services, including technical consulting, solution design, equipment selection, and engineering implementation, can be offered on this basis, allowing the experience gained at Kalteng to be transferred efficiently to future projects while continuing to be refined as additional operating data becomes available.

CONCLUSION

By implementing an online UPS-based anti-grid-disturbance control power supply retrofit for the coal feeder system, the project successfully addressed the vulnerability of key auxiliary equipment in coal-fired power plants located in weak-grid regions to grid disturbances. Practical application of the project demonstrates that the proposed solution is technologically mature, operationally reliable, and highly suitable for wider deployment, making a positive contribution to enhancing the safe and stable operation of coal-fired generating units.

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