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ПОВЫШЕНИЕ НАДЕЖНОСТИ ЭЛЕКТРОСНАБЖЕНИЯ ЦЕХОВ ЧЕРЕЗ АВР С МИКРОПРОЦЕССОРНОЙ ЗАЩИТОЙ

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Аннотация

В статье рассматриваются проблемы обеспечения бесперебойного электроснабжения промышленных цехов в условиях повышения требований к технологической непрерывности. Проанализированы недостатки традиционных релейных схем автоматического ввода резерва (АВР), в частности ложные срабатывания при провалах напряжения и отсутствие селективности. Обсуждены преимущества современных микропроцессорных терминалов АВР, включая логику сравнения фаз, контроль отсутствия напряжения на шинах и интеграцию с протоколами цифровой подстанции. Приведен сравнительный анализ алгоритмов электромеханической и микропроцессорной защиты. Сделан вывод о том, что переход на интеллектуальные системы АВР является критическим фактором минимизации производственных рисков и обеспечения энергетической устойчивости.

Ключевые слова: автоматический ввод резерва (АВР), микропроцессорная защита, надежность электроснабжения, электроснабжение цехов, провал напряжения, селективность, промышленная автоматизация, аварийный резерв.

IMPROVING THE RELIABILITY OF WORKSHOP POWER SUPPLY THROUGH AUTOMATIC TRANSFER SWITCHES WITH MICROPROCESSOR PROTECTION

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ABSTRACT

The article examines the problems of ensuring uninterrupted power supply to industrial workshops in the context of increasing requirements for technological continuity. The limitations of traditional relay-based Automatic Transfer Switches (ATS) are analyzed, specifically false

triggering due to voltage sags and lack of selectivity. The advantages of modern microprocessor-based ATS terminals are discussed, including phase comparison logic, dead bus transfer control, and integration with digital substation protocols. A comparative analysis of electromechanical and microprocessor protection algorithms is presented. The article concludes that the transition to intelligent ATS systems is a critical factor in minimizing production risks and ensuring energy resilience.

Keywords: automatic transfer switch (ATS), microprocessor protection, power supply reliability, workshop electrification, voltage sag, selectivity, industrial automation, emergency reserve.

Ensuring reliable and uninterrupted power supply to industrial workshops remains one of the key tasks in the operation of electrical facilities, especially for enterprises with continuous or cyclical production processes. In modern industry, where technological lines are characterized by high inertia and sensitivity to power quality, even a short-term power disruption can lead to catastrophic consequences: product defects, damage to expensive equipment, violation of technological regulations, and significant financial losses. The traditional power supply scheme, based on two independent power sources and an Automatic Transfer Switch (ATS) system, has proven its effectiveness over decades of operation. However, as production processes become more complex and the share of non-linear loads increases, classical electromechanical solutions no longer meet modern requirements for speed, selectivity, and informativeness [1].

The main problem with traditional ATS systems based on intermediate relays and contactors lies in their fundamental "blindness" to the nature of the disturbance in the network. Electromechanical logic reacts exclusively to the fact of voltage dropping below a set threshold, without analyzing the cause of this phenomenon. In real industrial networks, short-term voltage sags lasting 50–200 ms are frequent, caused by the starting of powerful motors, short circuits in external networks, or switching overvoltages. For many types of technological equipment, such sags are not critical and are successfully compensated by the inherent inertia of the drives or built-in capacitor banks. However, a relay-based ATS perceives any sag as an accident and initiates a switch to the backup source. This leads to so-called "false trips," which themselves create current surges, mechanical shocks to contactors, and unnecessary wear on equipment, and can also destabilize the operation of sensitive electronics in the workshop. Moreover, the lack of feedback on the status of the backup source at the moment of switching creates a risk of closing onto a faulty busbar or unsynchronized closing, which can lead to an accident on the backup side itself [2].

The transition to microprocessor-based ATS terminals radically changes the paradigm of reserve management. A modern intelligent terminal is not just a replacement of relays with a circuit board, but a full-fledged computing system capable of analyzing vector diagrams of voltages and currents in real time. The key advantage of such a system is the ability to implement complex blocking and switching permission algorithms. The terminal can distinguish between a true accident of the main input (persistent voltage loss, single-phase short circuit) and a temporary disturbance, ignoring the latter thanks to programmable time delays and filters. In addition, microprocessor protection ensures phase synchronization control before closing the sectional circuit breaker: if both inputs are energized (for example, after the main source is restored), the terminal will check the coincidence of the phase shift angle, amplitude, and frequency, preventing unacceptable equalizing currents. This function, unavailable in relay circuitry, is the foundation for safe operation of bus sections in workshop transformer substations [3].

For a clear demonstration of the evolution of approaches to organizing redundancy, it is advisable to refer to the comparative analysis presented in Table 1.

Table 1. Comparative characteristics of traditional and microprocessor ATS systems

Comparison Parameter	Traditional ATS (Relay-Contactor)	Microprocessor ATS (Protection Terminal)
Decision Logic	Binary (voltage present/absent)	Vector (analysis of phases, frequency, harmonics)
Response to Voltage Sags	False tripping on any sag > setting	Intelligent filtering, ignoring temporary disturbances
Backup Status Control	Absent or limited	Full monitoring of backup line readiness
Synchronization during Closing	Not controlled (risk of unsynchronized closing)	Automatic check of phase alignment and slip
Protection Selectivity	Low, depends on relay operating time	High, digital masking of action zones
Integration with ACS TP	Only discrete signals "alarm" / "reserve"	Modbus TCP, IEC 61850 protocols, oscillogram transmission
Diagnostics and Archiving	Impossible	Event log, recording of emergency processes, self-diagnostics
Configuration Flexibility	Physical replacement of relays/jumpers	Software configuration without changing the scheme
Switching Time	Fixed, depends on device type	Adaptive, optimized for the current mode

The data in the table confirms that the introduction of microprocessor terminals transforms the ATS from a passive executive mechanism into an active element of the reliability management system. The ability to integrate with the upper level of the Automated Process Control System (ACS TP) via open protocols (briefly touching on the topic of automation) allows the workshop dispatcher to see not only the fact of switching but also its causes, network parameters at the time of the accident, and the forecast of the remaining resource of switching devices. This forms the basis for predictive maintenance and prevention of secondary accidents.

The architecture of a modern ATS cabinet with microprocessor control is built on the principle of functional redundancy and modularity. The power part is performed on vacuum circuit breakers or contactors with an electromagnetic drive, controlled directly by the terminal outputs. The information part includes a block of measuring transformers, a communication interface with the SCADA system, and a local HMI panel for operational personnel. An important element is the organization of DC operational circuits: the microprocessor terminal must remain operational and retain event memory even when the AC operational voltage completely disappears, which is ensured by built-in buffer batteries or connection to a separate DC panel group. The connection diagram of such a complex is shown in Figure 1.

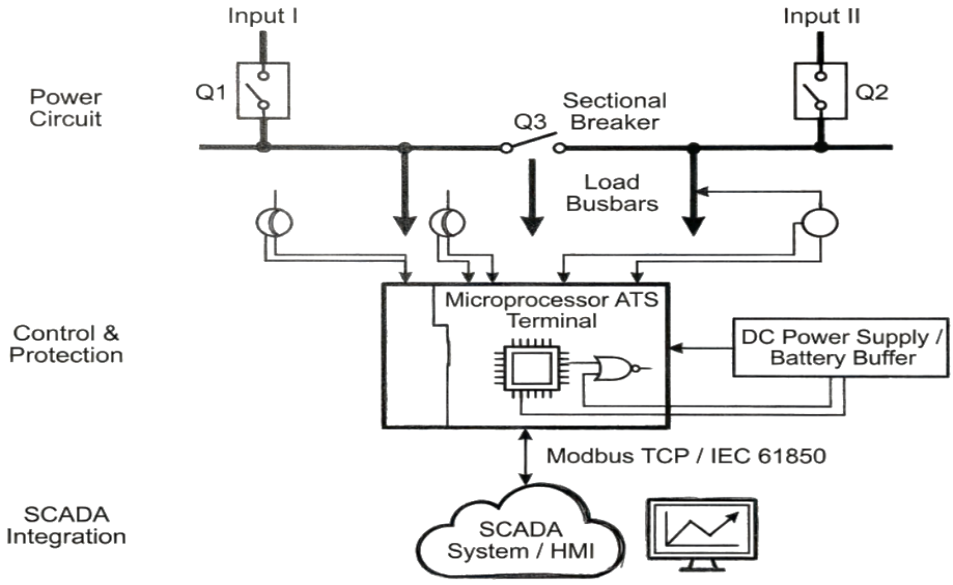


Figure 1. Structural diagram of an ATS cabinet with a microprocessor terminal and integration into ACS TP

The scheme presented in Figure 1 illustrates a three-level interaction structure: the power level (circuit breakers Q1, Q2, Q3), the control level (ATS terminal with power supply and I/O block), and the dispatching level (SCADA server). It is evident that the terminal acts as the central node, collecting analog and discrete signals from all sides and issuing control actions taking into account the embedded safety algorithms. The presence of bidirectional communication with the ACS TP allows for remote testing of the ATS logic without taking the equipment out of service, which is critically important for enterprises with a 24/7 operating cycle. This architecture ensures not only the reliability of the switching itself but also process transparency for operational personnel, eliminating human error in the analysis of emergency situations.

To confirm the theoretical provisions, it is advisable to consider a real case of implementing a microprocessor ATS terminal at one of the chemical industry enterprises in St. Petersburg, specializing in polymer production. Before the modernization, the power reserve system for the polymerization workshop was built on the basis of RVP72-3121 time relays and KMI intermediate contactors. During 2022–2023, the operational personnel recorded 14 cases of false ATS triggering caused by short-term voltage sags lasting from 80 to 150 ms during the start-up of powerful 400 kW extruders. Each false switching was accompanied by a current surge up to 6 times the nominal value, mechanical wear of the main contacts of the contactors, and, most critically, the stoppage of the polymerization line for the time required to restart the technological cycle (from 40 to 90 minutes). The cumulative damage from downtime and defective products for the specified period amounted to more than 12 million rubles.

As part of the power supply reliability improvement program, in the first quarter of 2024, the outdated relay logic was dismantled and a BMRS-ATS-03 microprocessor terminal manufactured by NPP "EKRA" was installed. When configuring the device, the following key algorithms were implemented: a programmable time delay for reacting to the disappearance of voltage on the main input was set to 300 ms, which allowed ignoring all previously recorded short-term sags; phase synchronization control was enabled with an allowable mismatch angle of no more than 10° and a frequency difference of no more than 0.5 Hz; the ATS blocking function was activated upon receiving an "alarm" signal from downstream protections of the sectional circuit breaker. In addition, the terminal was integrated into the existing workshop SCADA system via the Modbus TCP protocol, which ensured the transmission of oscillograms of emergency processes and the event log in real time.

The results of operating the modernized system from April 2024 to September 2026 demonstrated the high efficiency of the adopted solutions. Over 30 months of operation, not a single case of false ATS triggering was recorded, despite the preservation of the previous electrical load profile and regular starts of powerful drives. Three times the device correctly handled true accidents of the main input (long-term external network disconnections exceeding 2 seconds), ensuring a seamless transition to the backup line with a power restoration time of less than 1.2 seconds, which fully complied with the requirements of the polymerization workshop's technological regulations. The presence of a detailed event log allowed operational personnel to twice identify hidden defects in the cable lines of the backup input (increased insulation resistance, loosening of bolted connections in the busway) at an early stage, before developing into a full-scale accident. Predictive analytics of the contact system resource of vacuum circuit breakers, implemented by the terminal based on counting the number of switching cycles and breaking currents, allowed scheduling preventive maintenance during a planned production shutdown, avoiding unplanned downtime. This practical experience confirms that replacing electromechanical logic with microprocessor logic is not a formal modernization, but a qualitative leap in reliability management, directly convertible into production and economic indicators of the enterprise.

Special attention deserves the issue of the economic efficiency of ATS system modernization. The cost of downtime for a modern industrial workshop can amount to hundreds of thousands of rubles per hour, not counting the damage from defects and possible environmental fines. The implementation of an intelligent ATS reduces the probability of false switching by 80–90%, which directly preserves the resource of power equipment and prevents technological failures. In addition, the presence of a detailed event log allows reducing the time to find the causes of emergency shutdowns from hours to minutes, accelerating the restoration of normal mode. In the long term, the ability to perform predictive maintenance of switching devices based on operation statistics accumulated by the terminal allows planning repairs during scheduled shutdowns, avoiding unplanned downtime. Thus, capital costs for the purchase and installation of a microprocessor terminal are recouped by preventing just one or two serious incidents during the device's service life [4].

No less important is the issue of ensuring protection selectivity in cascading power supply systems of workshops. When using traditional relays, setting the time settings of the ATS often conflicts with the selectivity requirements of downstream protections, leading either to excessive power restoration time or to mass consumer disconnection during a local accident. Microprocessor terminals solve this problem by using logical selectivity and exchanging blocking signals between devices via digital communication channels. This allows instant determination of the fault location and blocking of unnecessary ATS switching, isolating the accident to the smallest possible section of the network. Such precision is unattainable for analog systems and is a direct consequence of applying digital technologies in relay protection [5].

Cybersecurity issues when implementing networked ATS terminals also require elaboration at the design stage. Since the device is integrated into the enterprise's general network, it becomes a potential entry point for unauthorized access. Modern standards (including GOST R IEC 62351) prescribe the use of dedicated VLANs for relay protection networks, hardware encryption of communication channels, and strict access rights separation. New-generation microprocessor terminals support these requirements "out of the box," ensuring the protection of critical infrastructure without reducing functionality. Ignoring these aspects can negate all the benefits of digital modernization, turning the reliability management system into a vulnerability [6].

Thus, improving the reliability of industrial workshop power supply through the introduction of ATS with microprocessor protection is a justified and economically effective technical solution. The transition from reactive logic "voltage lost – switch on reserve" to a

proactive strategy of network state analysis allows eliminating false trips, ensuring safe synchronization, and increasing the overall stability of the enterprise's power system. Automation in this context acts not as an end in itself, but as a necessary tool for implementing complex protection algorithms unavailable to classical circuitry. Further development of the direction is associated with integrating ATS functions into unified energy efficiency management systems, adapting algorithms to the specifics of distributed generation, and improving methods for diagnosing the condition of switching devices based on data accumulated by intelligent terminals.

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