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Automatic Reserve Power Switching as a Means of Enhancing the Reliability of Industrial Power Supply

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Abstract. Industrial power systems face growing pressure to remain uninterrupted as production lines become more automated and more sensitive to even momentary outages. Automatic reserve power switching, widely known in engineering practice by its Russian-derived acronym ABP, remains one of the most cost-effective safeguards against supply interruption, transferring loads from a failed source to a healthy backup within a window ranging from milliseconds to a few seconds. This paper reviews the operating principles of conventional and fast-acting reserve switching schemes and places them within the broader evolution of substation automation, digital protection, and self-healing distribution networks. Drawing on twenty-two peer-reviewed sources published between 2018 and 2025, the study identifies a persistent gap between generic distribution-level reliability research and the specific switching-time requirements of industrial facilities such as metallurgical plants and continuous-process manufacturing sites. Building on this synthesis, the paper proposes a Criticality-Tiered Reserve Switching framework that matches load criticality categories to an appropriate class of switching technology, synchronization method, and communication protocol. The framework is intended as a decision-support tool for engineers selecting or upgrading reserve switching schemes. The proposed approach also enables engineers to balance switching speed, system complexity, and implementation cost according to the actual consequences of power interruption for each load category. By differentiating protection and redundancy requirements across criticality tiers, the framework can support more efficient allocation of technical resources while maintaining the required level of power-supply reliability. The paper concludes that the reliability benefits promised by digital substation technologies are only realized when switching logic is deliberately matched to process criticality rather than applied uniformly across a facility.

Keywords: automatic reserve switching; ABP; power supply reliability; industrial electrical networks; substation automation; self-healing distribution networks; IEC 61850

Introduction

Continuous electricity supply is a precondition for almost every modern industrial process, and its loss carries consequences that extend well beyond a simple stoppage of equipment. In continuous-process industries such as ferrous metallurgy, chemical synthesis, and semiconductor fabrication, even a supply interruption lasting a fraction of a second can spoil a batch, damage equipment through thermal shock, or create a safety hazard on the shop floor [14]. For this reason, the majority of industrial enterprises with significant reliability requirements are supplied from two or more independent feeders, with the switching mechanism between them acting as the last line of defense against a total loss of supply. That switching mechanism, automatic reserve power switching, or ABP, is deceptively simple in concept: detect the loss of the working source and connect the reserve source before the interruption becomes damaging. In practice, the engineering behind it has grown considerably more sophisticated over the last decade.

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Two forces are reshaping how ABP is designed and specified. The first is the changing composition of the source side of the network. Distributed generation, energy storage, and renewable infeed alter fault behaviour, voltage profiles, and the assumptions that switching logic was originally built on [1; 5; 7; 16]. The second is the parallel push toward self-healing distribution automation, in which switching decisions once made by a single relay are increasingly coordinated across a wider automated network using digital communication [17; 18; 20]. Both trends raise the same underlying question for an industrial engineer: what class of reserve switching technology is actually justified for a given load, and on what basis should that decision be made.

This question is rarely addressed directly in the literature, which tends to treat reliability at the level of the distribution network as a whole rather than at the level of an individual industrial load with its own tolerance for interruption. This paper addresses that gap. It first synthesizes recent research on reserve switching, substation automation, and adjacent protection technologies. It then uses that synthesis to build a practical framework, termed Criticality-Tiered Reserve Switching, that industrial engineers can use to align switching technology with load criticality rather than defaulting to a single scheme across an entire facility. The remainder of the paper is organized as follows: Section 2 reviews the relevant literature; Section 3 explains the methodology used to construct the framework; Section 4 reports the findings of the synthesis; Section 5 discusses the proposed framework in detail; Section 6 concludes.

Literature Review

1. Reliability of industrial and distribution networks. Reliability of electricity supply has traditionally been measured and improved at the level of the distribution network rather than the individual industrial connection point. Escalera, Hayes, and Prodanovic surveyed the techniques used to assess reliability in modern distribution networks and found that most established indices were designed for a passive, radially operated grid and struggle to capture the effect of active elements such as distributed generation or automated switching [10]. Jooshaki and colleagues approached the same problem from the planning side, formulating distribution expansion planning as a mixed-integer linear programme that explicitly incorporates incentive-based reliability regulation, showing that reliability targets are now an optimization constraint rather than an afterthought [12]. Parol and co-authors extended this by analysing medium-voltage networks that combine distributed generation with information and communication technology infrastructure, concluding that the communication layer has itself become a determinant of achieved reliability [21]. Kornilov and colleagues offer one of the few accounts grounded in a specific industrial context, describing the power-supply features of metallurgical iron-and-steel works and the operational constraints that make generic distribution-level solutions difficult to transplant onto heavy industrial sites [14].

2. Distributed generation, storage, and changing source conditions. The reliability calculus for reserve switching is also changing because the sources available for switching are no longer limited to two utility feeders. Aderibigbe and colleagues reviewed methods for the optimal placement of distributed generators to improve distribution reliability, underlining that where a generator sits in the network materially changes the value it delivers during a switching event [1]. Kumar, Saket, and colleagues carried out a broader review of reliability enhancement measures associated with renewable penetration, noting that intermittency introduces failure modes that switching schemes must anticipate rather than react to [16]. Voltage stability during and after a switching event is a related concern that is easy to overlook: Adetokun and Muriithi reviewed flexible alternating current transmission system devices for voltage stability enhancement in renewable-integrated grids, finding that fast reactive power support can reduce the voltage dip accompanying a reserve-switching transient, particularly where the reserve source is weaker than the one it replaces [2]. Energy storage adds a further dimension: Ayesha and co-authors reviewed how storage combines with other flexibility options to

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improve reliability, while Amini and colleagues framed resilience more broadly, arguing that storage-backed reserve capacity is becoming a design variable rather than a supplementary asset [5; 7]. Szott and colleagues demonstrated this concretely with a battery-based emergency supply intended to improve network reliability during switching events, illustrating that batteries are beginning to occupy functional territory once reserved for a second utility feeder [22].

3. Substation automation and digital protocols. A second major thread concerns the digitalization of the substation itself. Aftab and colleagues surveyed IEC 61850-based substation automation systems and documented how standardized communication has replaced point-to-point wiring with a shared digital bus, which is what makes coordinated, fast switching decisions across multiple bays practically feasible [3]. Kumar, Abu-Siada, and colleagues arrived at a similar conclusion in their own review, emphasizing that IEC 61850 adoption is now closely tied to the broader modernization of substation automation systems [15]. This digitalization is not without cost. Ashraf and colleagues examined denial-of-service attacks against IEC 61850-based substations and showed that the same communication layer that enables fast coordinated switching also becomes an attack surface, a point directly relevant to any facility considering a shift from hardwired to digital ABP logic [6].

4. Fast switching and protection in microgrids and critical infrastructure. Where switching speed matters most, the literature increasingly draws on microgrid protection research rather than conventional distribution practice. Altaf and colleagues catalogued the protection challenges specific to microgrids, noting that fault levels and current directions can reverse depending on which source is active, which complicates any switching logic that assumes a fixed network topology [4]. Beheshtaein and co-authors and Dagar and colleagues, in two separate but complementary reviews, reached a similar conclusion: protection and switching schemes designed for passive, radial networks are frequently unsuitable once a facility operates with parallel or alternating sources, and purpose-built adaptive schemes are required instead [8; 9].

5. Adaptive and learning-based switching logic. A closely related body of work on automatic reclosing, while nominally a distinct protection function, offers transferable insight into adaptive switching decision-making. Han and colleagues developed an adaptive single-pole reclosing scheme based on harmonic signatures of the secondary arc voltage, while Khan, Bi, and Jia reviewed the wider family of adaptive single-phase reclosing schemes for extra-high-voltage lines [11; 13]. Mehdi and colleagues extended this review across AC, DC, and hybrid transmission lines, concluding that adaptive, signal-based decision logic consistently outperforms fixed-time schemes [19]. Although reclosing and reserve switching serve different protection purposes, both depend on distinguishing a genuine, sustained loss of supply from a transient disturbance, and the decision architectures described in this literature are directly relevant to the design of fast ABP logic.

6. Self-healing distribution automation. Finally, a growing literature on self-healing distribution networks illustrates where reserve switching is heading at the system level. Lu and colleagues proposed a self-healing scheme based on mixed-integer linear programming intended to restore supply quickly and accurately after a fault [17]. Luo, Ge, and Xu examined how the quality of data transmission between distribution automation terminals affects the reliability actually delivered by such automated schemes, a finding with direct relevance to industrial ABP retrofits that rely on legacy communication infrastructure [18]. Meteab and colleagues proposed an efficient self-healing framework for smart distribution networks, reinforcing the broader trend of shifting switching decisions from a single local relay toward a coordinated, network-wide automation layer [20].

Taken together, this literature shows a field moving in two directions simultaneously: toward faster, more adaptive, and more digitally coordinated switching, and toward a wider range of source types that switching logic must accommodate. What is largely absent is a

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structured way of deciding how much of this sophistication a given industrial load actually needs, which is the gap this paper addresses.

Methods

This study follows a structured qualitative synthesis approach rather than a systematic review or empirical field study. Twenty-two peer-reviewed journal and conference publications, all dated between 2018 and 2025 and addressing power system reliability, protection, substation automation, or self-healing distribution networks, were selected from an initial reference set and organized into a content matrix built around six themes: distribution and industrial reliability assessment, distributed generation and storage, substation automation and digital protocols, microgrid and critical-infrastructure protection, adaptive and learning-based switching logic, and self-healing distribution automation. Each source was coded according to the switching-relevant parameters it reported or discussed, including typical switching or restoration time, the type of source configuration assumed, and the communication or protocol dependencies described.

These coded parameters were then used to construct the Criticality-Tiered Reserve Switching framework presented in Section 5. The switching-time bands assigned to each technology class draw on the ranges reported across the adaptive reclosing and microgrid protection literature [4; 8; 9; 11; 13; 19], while the criticality categories themselves were informed by the operational description of industrial power supply constraints given by Kornilov and colleagues for metallurgical facilities [14] and by the treatment of communication-dependent reliability in Luo, Ge, and Xu and in Parol and colleagues [18; 21]. Because the framework was built entirely from published descriptions rather than from field measurements at a specific plant, it should be understood as a conceptual decision-support tool rather than a validated engineering standard. This is an explicit limitation of the present study and is addressed further in the discussion. No proprietary or unpublished data were used; all supporting evidence is drawn from the twenty-two sources listed in the reference list.

Results

The synthesis produced six findings that structure the discussion that follows.

First, reliability research is still predominantly conducted at the distribution-network level, using aggregate indices that do not translate directly into a switching-time requirement for an individual industrial load [10; 12]. Second, there is a clear and largely unaddressed gap between the sub-cycle to sub-second switching capability demonstrated in microgrid and critical-infrastructure protection research and the multi-second switching times still common in conventional industrial practice, particularly at heavy industrial sites of the kind described by Kornilov and colleagues [4; 8; 9; 14]. Third, IEC 61850-based digital communication is what makes fast, coordinated switching across multiple bays practically achievable, but it introduces a cybersecurity exposure that a purely electromechanical scheme does not carry [3; 6; 15]. Fourth, the decision logic developed for adaptive automatic reclosing, which must distinguish a genuine fault from a transient disturbance using signal characteristics rather than a fixed timer, is conceptually transferable to reserve switching, even though the two functions serve different protection purposes [11; 13; 19]. Fifth, the reliability actually delivered by an automated switching scheme is bounded by the quality of its supporting communication infrastructure, not just by the switching logic itself, which means legacy communication links can silently undermine an otherwise well-designed ABP retrofit [17; 18; 20]. Sixth, energy storage is increasingly proposed not merely as backup capacity but as an alternative reserve source in its own right, which changes what a switching scheme needs to accomplish, since it may be switching between two live sources rather than from a failed source to a de-energized one [5; 7; 22].

Read together, these findings indicate that the reliability improvements achievable through modern ABP technology are unevenly distributed: they are readily available where the literature has concentrated its attention, in microgrids and critical infrastructure, digitally

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instrumented substations, and self-healing distribution schemes, but they are not automatically available to a conventional industrial facility unless someone deliberately maps that facility's loads onto the appropriate class of switching technology. That mapping is precisely what is missing from the literature reviewed above, and it is the contribution this paper makes in the following section.

Discussion

1. The case for a criticality-based approach. The literature reviewed in Section 2 describes a wide spectrum of reserve switching capability, from electromechanical schemes operating in the range of one to several seconds, through microprocessor-based fast ABP switching in the low hundreds of milliseconds, to genuinely uninterrupted, synchronized transfer in the tens of milliseconds or less [4; 8; 9; 11; 13; 19]. Industrial facilities, however, rarely specify their switching scheme on a load-by-load basis; instead, a single technology class is often applied uniformly across the site, driven as much by historical practice as by an explicit assessment of what each load can actually tolerate. Kornilov and colleagues make clear that even within a single metallurgical facility, process sections differ substantially in how sensitive they are to a brief interruption [14]. Treating such a facility as a single reliability problem, rather than as a collection of loads with different tolerances, both overspends on some circuits and underprotects others. Table 1 summarizes the technology classes referenced throughout this paper and the switching-time bands associated with each.

Table 1. **Classification of automatic reserve switching (ABP) technology**

Technology class	Typical switching time	Switching principle	Representative sources
Conventional electromechanical ABP	1 s to several seconds	Voltage/undervoltage relay detects loss of source; contactor or breaker closes reserve feeder after a fixed time delay	[14]
Standard microprocessor-based ABP	0.3 s to 1.5 s	Digital relay logic with configurable blocking, sequencing and interlock conditions	[3; 15]
Fast (high-speed) ABP	Approx. 0.1 s to 0.3 s	Adaptive, signal-based fault discrimination; coordinated over a digital communication bus	[4; 8; 9; 11; 13; 19]
Uninterrupted / synchronized transfer	Tens of milliseconds or less	Check-synchronizing or static transfer switch; continuous monitoring of phase angle and magnitude between sources	[6; 17; 20]

Source: developed by the author

2. The Criticality-Tiered Reserve Switching framework

Building on the six findings above, this paper proposes a four-tier framework, summarized in Table 2 that assigns each class of industrial load to a switching technology proportionate to its actual tolerance for interruption. Tier 0 covers loads whose interruption threatens personnel safety or causes irreversible process or equipment damage within a few tens of milliseconds, such as furnace control systems, continuous casting drives, or safety instrumented systems; these loads justify uninterrupted or near-uninterrupted transfer, typically requiring synchronized, check-synchronizing switching supported by high-speed digital communication of the kind enabled by IEC 61850 [3; 15]. Tier 1 covers high-value continuous production loads that can tolerate a short but not negligible interruption, matching

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the low-hundreds-of-milliseconds range demonstrated in fast microprocessor-based ABP and in adaptive protection schemes drawn from the reclosing literature [4; 8; 9; 11; 13; 19]. Tier 2 covers auxiliary and balance-of-plant loads, such as ventilation, water treatment, or general lighting, for which conventional electromechanical or standard microprocessor-based ABP in the one-to-several-second range remains appropriate and cost-effective. Tier 3 covers non-essential loads for which manual or delayed switching is acceptable and automatic reserve switching is not economically justified.

Table 2. **Proposed Criticality-Tiered Reserve Switching (CTRS) framework**

Tier	Representative loads	Max. tolerable interruption	Required switching class	Key enablers
Tier 0	Furnace control, continuous casting drives, safety instrumented systems	Tens of milliseconds	Uninterrupted / synchronized transfer	IEC 61850 digital bus; check-synchronizing relays
Tier 1	High-value continuous production lines	0.1 s to 0.3 s	Fast microprocessor-based ABP	Adaptive, signal-based decision logic
Tier 2	Auxiliary and balance-of-plant loads (ventilation, water treatment, lighting)	1 s to several seconds	Standard microprocessor-based or electromechanical ABP	Conventional protection relays
Tier 3	Non-essential loads	Not time-critical	Manual or delayed switching	None required

Source: developed by the author

The framework also specifies, for each tier, the appropriate synchronization and communication dependency. Tier 0 and Tier 1 switching decisions benefit from the same signal-based, adaptive logic that Han, Khan, and Mehdi describe for reclosing, since both problems reduce to distinguishing a genuine sustained loss of supply from a transient event using the electrical signature of the disturbance rather than a fixed timer [11; 13; 19] (See Figure 1). Where a facility has already invested in IEC 61850-based substation automation, that same digital bus can carry the interlocking and synchronization signals that Tier 0 and Tier 1 switching require, at the cost of the cybersecurity exposure documented by Ashraf and colleagues, which must be addressed through the same network segmentation and monitoring practices recommended for substation automation generally [6]. For facilities that already operate a self-healing distribution automation layer, the tiered framework proposed here can be nested within that wider scheme, with Tier 0 and Tier 1 loads prioritized in any automated restoration sequence following the logic described by Lu, Meteab, and colleagues [17; 20] (See Figure 2).

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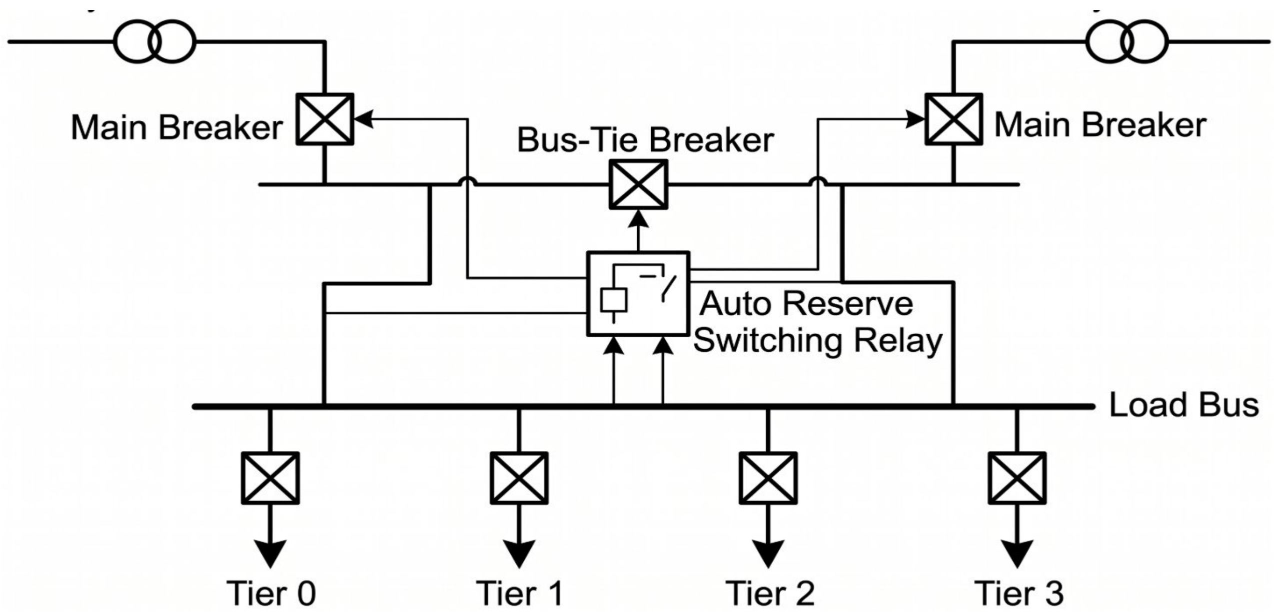

Figure 1. Industrial Dual-Feeder Power Supply Schematic
Source: developed by the author

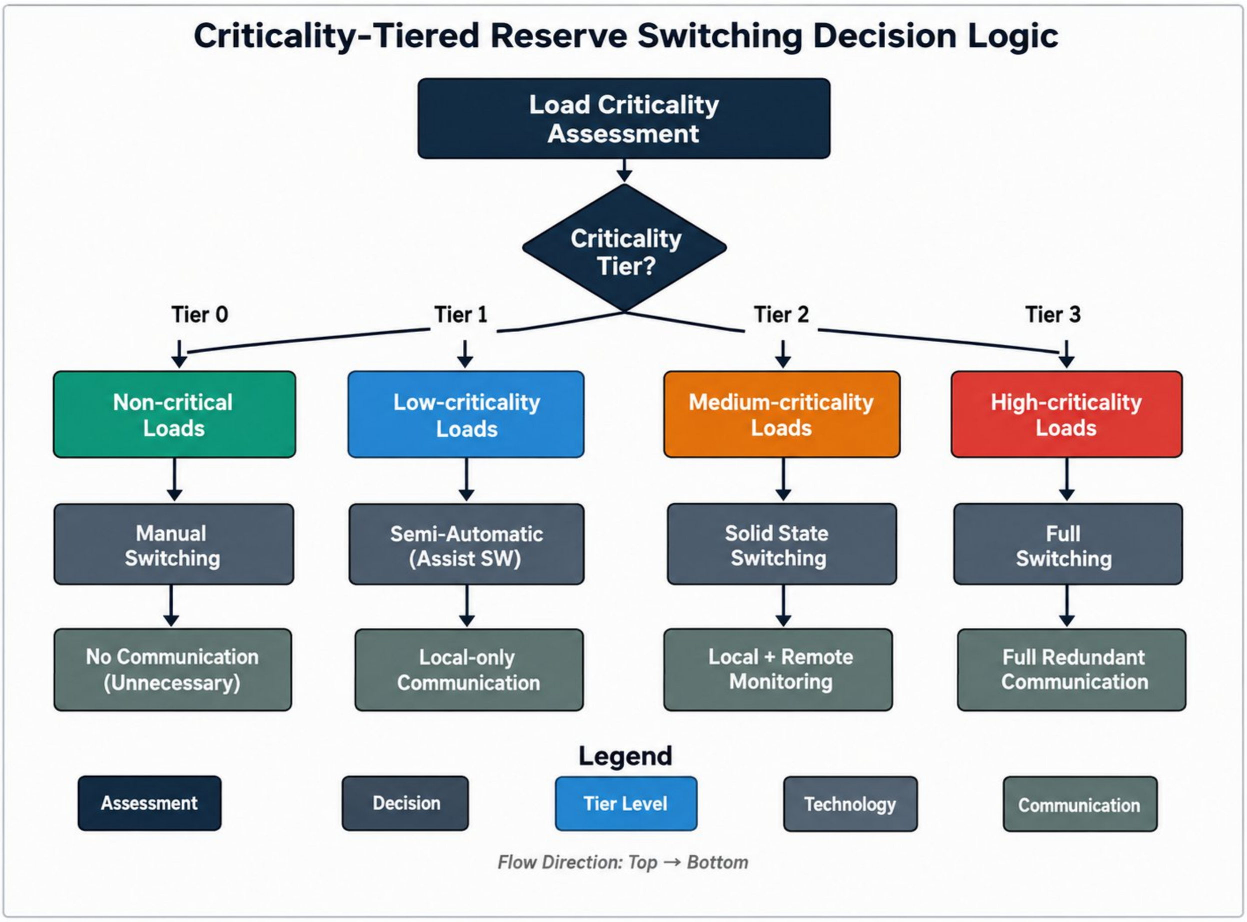

Figure 2. **Criticality-Tiered Reserve Switching Flowchart**
Source: developed by the author

3. Where energy storage fits. Storage complicates the tier assignment in a useful way. Where energy storage of adequate capacity is available, as demonstrated by Szott and colleagues, a Tier 0 or Tier 1 load can potentially be served without waiting for reserve switching at all, since the storage bridges the interruption directly [22]. This does not eliminate

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the value of ABP, but it changes its role from the sole safeguard to one layer in a defense that also includes local storage, consistent with the broader argument made by Ayesha, Amini, and Kumar and colleagues that reliability is increasingly a system-level property rather than the output of any single device [5; 7; 16] (See Figure 3).

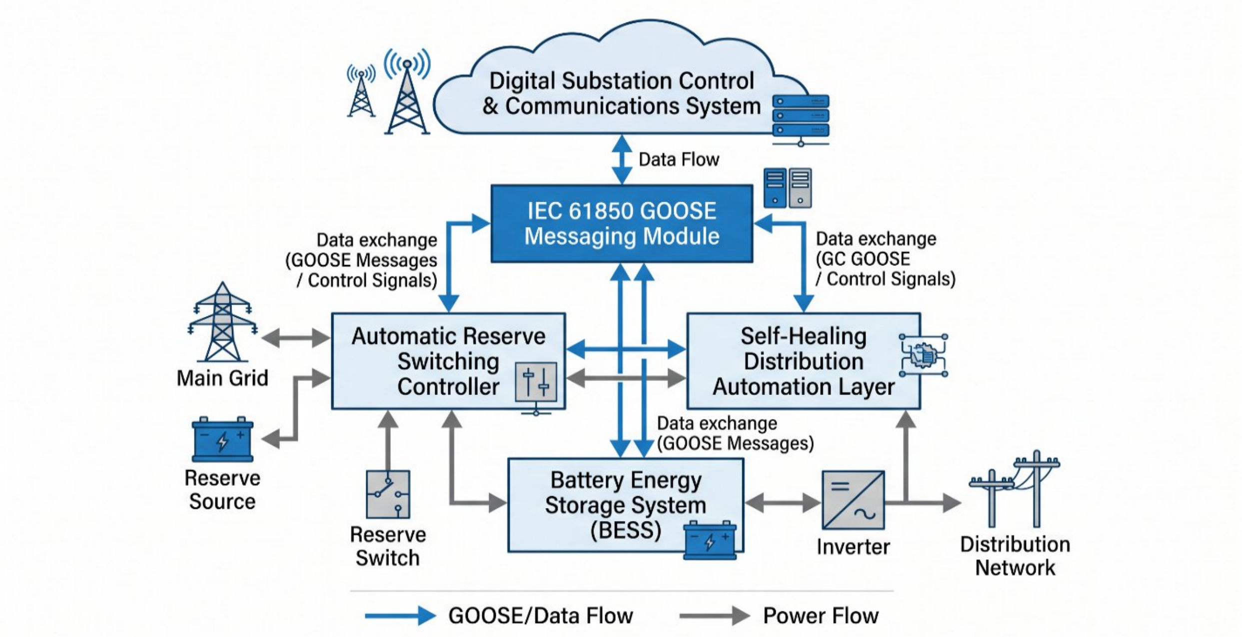

Figure 3. **Conceptual Architecture Diagram of Digital Substation with IEC 61850 GOOSE, Reserve Switching, BESS, and Self-Healing Automation**

Source: developed by the author

4. Limitations and directions for further work. The framework proposed here is conceptual and has been built from published descriptions of switching technology and industrial practice rather than from field measurements at a specific site; validating the proposed tier boundaries against interruption-cost data from real industrial facilities is an important next step. The optimization approach used by Jooshaki and colleagues for distribution expansion planning under reliability regulation offers a plausible template for formalizing the tier-assignment decision as an investment optimization problem rather than an engineering judgement call, and this is a promising direction for future work [12]. Communication quality, shown by Luo and colleagues to materially affect delivered reliability, should also be assessed explicitly before assigning any load to Tier 0 or Tier 1, since the fastest switching logic available cannot compensate for an unreliable communication path [18].

Conclusions

Automatic reserve power switching remains one of the most direct and cost-effective tools available for protecting industrial power supply against interruption, but the literature reviewed in this paper shows that its most advanced forms, fast microprocessor-based and uninterrupted switching supported by digital substation communication, remain concentrated in microgrid, critical-infrastructure, and self-healing distribution research rather than in general industrial practice. Conventional industrial facilities frequently apply a single switching technology uniformly across sites with markedly different load criticality, a practice that both overspends on low-criticality circuits and leaves the most sensitive processes underprotected. The Criticality-Tiered Reserve Switching framework proposed in this paper offers a structured alternative, matching each class of industrial load to a proportionate switching technology, synchronization method, and communication dependency. The framework also clarifies how energy storage and self-healing distribution automation fit alongside conventional ABP rather than replacing it outright. Because the framework was developed through literature synthesis

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rather than field validation, its practical value now depends on testing it against real interruption-cost and reliability data at industrial sites, and on integrating it more formally with investment-planning methods already established in the reliability literature.

References

1. Aderibigbe, M. A., Adoghe, A. U., Agbetuyi, F., & Airoboman, A. E. (2021). A review on optimal placement of distributed generators for reliability improvement on distribution network. 2021 IEEE PES/IAS PowerAfrica, 1–5. https://doi.org/10.1109/PowerAfrica52236.2021.9543266
2. Adetokun, B. B., & Muriithi, C. M. (2021). Application and control of flexible alternating current transmission system devices for voltage stability enhancement of renewable-integrated power grid: A comprehensive review. Heliyon, 7(3), e06461. https://doi.org/10.1016/j.heliyon.2021.e06461
3. Aftab, M. A., Hussain, S. M. S., Ali, I., & Ustun, T. S. (2020). IEC 61850 based substation automation system: A survey. International Journal of Electrical Power & Energy Systems, 120, 106008. https://doi.org/10.1016/j.ijepes.2020.106008
4. Altaf, M. W., Arif, M. T., Islam, S. N., & Haque, M. E. (2022). Microgrid protection challenges and mitigation approaches–A comprehensive review. IEEE Access, 10, 38895–38922. https://doi.org/10.1109/ACCESS.2022.3165011
5. Amini, F., Ghassemzadeh, S., Rostami, N., & Sohrabi Tabar, V. (2023). Electrical energy systems resilience: A comprehensive review on definitions, challenges, enhancements and future proceedings. IET Renewable Power Generation, 17(7), 1835–1858. https://doi.org/10.1049/rpg2.12705
6. Ashraf, S., Shawon, M. H., Khalid, H. M., & Muyeen, S. M. (2021). Denial-of-service attack on IEC 61850-based substation automation system: A crucial cyber threat towards smart substation pathways. Sensors, 21(19), 6415. https://doi.org/10.3390/s21196415
7. Ayesha, Numan, M., Baig, M. F., & Yousif, M. (2023). Reliability evaluation of energy storage systems combined with other grid flexibility options: A review. Journal of Energy Storage, 63, 107022. https://doi.org/10.1016/j.est.2023.107022
8. Beheshtaein, S., Cuzner, R., Savaghebi, M., & Guerrero, J. M. (2019). Review on microgrids protection. IET Generation, Transmission & Distribution, 13(6), 743–759. https://doi.org/10.1049/iet-gtd.2018.5212
9. Dagar, A., Gupta, P., & Niranjan, V. (2021). Microgrid protection: A comprehensive review. Renewable and Sustainable Energy Reviews, 149, 111401. https://doi.org/10.1016/j.rser.2021.111401
10. Escalera, A., Hayes, B., & Prodanović, M. (2018). A survey of reliability assessment techniques for modern distribution networks. Renewable and Sustainable Energy Reviews, 91, 344–357. https://doi.org/10.1016/j.rser.2018.02.031
11. Han, J., Lee, C.-M., & Kim, C.-H. (2021). Adaptive single-pole auto-reclosing scheme based on secondary arc voltage harmonic signatures. Energies, 14(5), 1311. https://doi.org/10.3390/en14051311
12. Jooshaki, M., Abbaspour, A., Fotuhi-Firuzabad, M., Moeini-Aghtaie, M., & Lehtonen, M. (2019). MILP model of electricity distribution system expansion planning considering incentive reliability regulations. IEEE Transactions on Power Systems, 34(6), 4300–4316. https://doi.org/10.1109/TPWRS.2019.2914516
13. Khan, W. A., Bi, T., & Jia, K. (2019). A review of single phase adaptive auto-reclosing schemes for EHV transmission lines. Protection and Control of Modern Power Systems, 4, 18. https://doi.org/10.1186/s41601-019-0133-5
14. Kornilov, G. P., Abdulveleev, I. R., Gazizova, O. V., & Koptsev, L. A. (2021). Power supply at metallurgical iron-and-steel works: Features and development prospects. Metallurgist, 65(7–8), 783–793. https://doi.org/10.1007/s11015-021-01216-8

ISSN: 2787-9364

15. Kumar, S., Abu-Siada, A., Das, N., & Islam, S. (2021). Toward a substation automation system based on IEC 61850. Electronics, 10(3), 310. https://doi.org/10.3390/electronics10030310
16. Kumar, S., Saket, R. K., Dheer, D. K., Holm-Nielsen, J. B., & Sanjeevikumar, P. (2020). Reliability enhancement of electrical power system including impacts of renewable energy sources: A comprehensive review. IET Generation, Transmission & Distribution, 14(10), 1799–1815. https://doi.org/10.1049/iet-gtd.2019.1402
17. Lu, J., Su, J., Zhao, R., Chen, F., Wang, Q., & Yan, W. (2024). A fast and accurate self-healing scheme for intelligent distribution networks using mixed integer linear programming. IEEE Access, 12, 21586–21595. https://doi.org/10.1109/ACCESS.2024.3362798
18. Luo, F., Ge, N., & Xu, J. (2023). Power supply reliability analysis of distribution systems considering data transmission quality of distribution automation terminals. Energies, 16(23), 7826. https://doi.org/10.3390/en16237826
19. Mehdi, A., Kim, C.-H., Hussain, A., Kim, J.-S., & Hassan, S. J. U. (2021). A comprehensive review of auto-reclosing schemes in AC, DC, and hybrid (AC/DC) transmission lines. IEEE Access, 9, 74325–74342. https://doi.org/10.1109/ACCESS.2021.3077938
20. Meteab, F., Tousi, B., & Omran, M. (2025). Efficient self-healing framework for smart distribution networks. Scientific Reports, 15, 31124. https://doi.org/10.1038/s41598-025-16929-y
21. Parol, M., Wasilewski, J., Wojtowicz, T., Arendarski, B., & Komarnicki, P. (2022). Reliability analysis of MV electric distribution networks including distributed generation and ICT infrastructure. Energies, 15(14), 5311. https://doi.org/10.3390/en15145311
22. Szott, M., Wermiński, S., Jarnut, M., Kaniewski, J., & Benysek, G. (2021). Battery energy storage system for emergency supply and improved reliability of power networks. Energies, 14(3), 720. https://doi.org/10.3390/en14030720

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