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Enhancing Power Factor Performance of Capacitor Bank Systems through Control Circuit Reconfiguration

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Abstract: This study investigates a practical method to enhance the efficiency of a campus electrical distribution system by optimizing the control and power circuitry of a capacitor bank panel. The research addresses the persistent issue of low power factor and phase imbalance resulting from non-standard wiring configurations in existing installations. Unlike conventional maintenance procedures, the proposed rewiring strategy systematically redesigns the control and power connections to ensure accurate capacitor switching and reactive power compensation in accordance with operational load variations. A diagnostic improvement evaluation framework was employed, involving pre- and post-rewiring measurements of power factor, load current balance, and reactive power under both normal and full-load conditions. The rewiring intervention increased the power factor from 0.97 to 0.99 during normal operation and from 0.70 to 0.95 under full-load simulation (1100 kVA). These improvements corresponded to a measurable reduction in reactive power demand and overall system losses, indicating a substantial gain in energy efficiency and voltage stability. The findings confirm that targeted control circuit reconfiguration can significantly enhance the operational reliability of capacitor bank systems beyond conventional

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maintenance practices. This work contributes a replicable, technically validated approach for improving power quality in educational and industrial electrical installations.

Keywords: Power Factor, Capacitor Bank, Control Circuit, Reactive Compensation, Distribution Efficiency.

Introduction

Electrical energy efficiency has become a critical concern in modern power distribution systems, particularly in facilities that operate with diverse inductive loads such as motors, compressors, and industrial machinery. These loads inherently draw reactive power, resulting in a low power factor (PF), increased current flow, and elevated system losses. A low PF not only decreases the utilization efficiency of electrical power but also contributes to voltage instability, additional heating of conductors, and reduced lifespan of transformers and other components (Coury, Dos Santos, Oleskovicz, & Tavares, 2003; Hwang & Lou, 1998; Vuletić & Todorovski, 2014). Consequently, improving the power factor is a long-standing engineering objective in both industrial and educational power systems.

One widely adopted method to address low PF is the installation of a capacitor bank, which provides capacitive reactive power to offset the inductive reactive component of the load. Numerous studies have demonstrated the technical feasibility of capacitor banks for reactive power compensation and harmonic reduction (Askarzadeh, 2016; Bisanovic, Hajro, & Samardzic, 2014; Jayabarathi, Raghunathan, Mithulananthan, Cherukuri, & Sai, 2024). However, the effectiveness of capacitor banks is highly dependent on the accuracy of their control system, wiring configuration, and protection coordination (Liu, Liu, Liu, & Han, 2024; Strickland et al., 2020). When control or power circuits are misconfigured or degraded, the reactive power compensation process becomes inconsistent, leading to phase imbalance, inefficient switching, or even overcompensation, where the system transitions from inductive to excessively capacitive operation (Eslamian, Bigdeli, & Abu-Siada, 2024).

Although the principle of power factor correction using capacitor banks is well established, recent research has revealed critical limitations in their practical implementation. For example, Askarzadeh (2016) proposed optimized capacitor placement to minimize losses, yet such optimization is typically algorithmic and assumes ideal system wiring. Similarly, Vuletić and Todorovski (2014) developed clustering-based capacitor placement for radial systems but did not address the control circuit reliability that directly affects operational performance. Studies focusing on harmonic mitigation using detuned reactors (Gumilar, Cahyani, Afandi, Monika, & Rumokoy, 2020) and transient analyses of capacitor switching

(Saied, 2004) have improved understanding of electrical behavior, yet few have discussed the systemic wiring and control design factors that determine the actual responsiveness of capacitor banks under dynamic load conditions.

This gap suggests that while capacitor bank optimization has been extensively studied from computational, theoretical, and component-based perspectives, limited attention has been paid to the physical control wiring configuration and its influence on real-time compensation accuracy. In many educational and small-scale industrial installations, capacitor panels are often retrofitted or modified without proper adherence to electrical standards, which can degrade performance and system reliability over time (Adragna, Bianco, Gritti, & Sucameli, 2024). The lack of structured evaluation of rewiring-based optimization leaves a technical and methodological void in the current literature.

The present research addresses this gap by proposing a systematic rewiring and reconfiguration framework for capacitor bank panels within an educational campus power system. Rather than treating the process as a maintenance task, this study approaches it as an engineering intervention, focusing on diagnostic analysis, corrective redesign, and quantitative evaluation of system performance before and after the intervention. The novelty of this approach lies in demonstrating how targeted control-circuit restructuring guided by real measurement data can restore synchronization between load variation and reactive compensation response. This directly contrasts with standard maintenance procedures that primarily involve component replacement or visual inspection.

The research specifically investigates how rewiring the control and power circuits can improve phase balance, reduce system losses, and enhance the PF under varying operational loads. Performance improvements are validated through empirical measurements under normal load conditions (PF 0.97 to 0.99) and full-load simulation (PF 0.70 to 0.95) within a 1100 kVA distribution network. By integrating technical diagnostics and reconfiguration, this study provides quantitative indicators of performance enhancement—including reduced reactive power demand and improved switching response accuracy—that support the validity of the proposed method (Jayabarathi et al., 2024; Zhang et al., 2024).

For instance, Askarzadeh (2016) proposed a metaheuristic approach for optimal capacitor placement in distribution systems to minimize losses and improve voltage profiles. While this study demonstrated effective numerical optimization, it assumed idealized system wiring and stable control performance—conditions that often diverge from practical installations. Similarly, Jayabarathi, Raghunathan, Mithulananthan, Cherukuri, and Sai

(2024) explored network reconfiguration and capacitor deployment to enhance power distribution performance. Their approach relied on computational modeling but did not incorporate physical aspects of circuit reliability or capacitor switching logic. In parallel, Vuletić and Todorovski (2014) employed clustering-based optimization for radial systems but did not consider the impact of control circuit degradation, cabling standards, or misconfiguration on compensation accuracy.

Recent works have also examined specific technical components that influence capacitor bank performance. For example, Eslamian, Bigdeli, and Abu-Siada (2024) analyzed transient behaviors in detuned reactors, while Liu, Liu, Liu, and Han (2024) discussed additional power losses arising from distributed generation and poor reactive compensation. Although these studies advanced the theoretical and component-level understanding of capacitor behavior, they remain largely simulation-driven and component-centric, lacking the system-level engineering perspective necessary to address real-world wiring and control design deficiencies.

Research Methods

This study employed a structured diagnostic reconfiguration validation approach to enhance the performance of a capacitor bank panel by rewiring its control and power circuits. The research was conducted in the electrical distribution system of a vocational polytechnic campus supplied through a Low Voltage Main Distribution Panel (LVMDP) rated at 1100 kVA. The system serves several laboratories and workshops characterized by inductive loads such as motors, compressors, and water pumps, which significantly influence the power factor and current balance. The methodological design consisted of four main stages: system diagnosis, determination of reactive power compensation, rewiring implementation, and performance evaluation.

The diagnostic stage involved assessing the existing capacitor bank panel to identify wiring irregularities, control logic errors, and signs of performance degradation. Baseline data on voltage, current, power factor, reactive power, and total harmonic distortion (THD) were collected using a Power Quality Analyzer (Fluke 435-II), a Clamp Meter, and a Digital Multimeter. Measurements were carried out under both normal load (approximately 70% of operating capacity) and full-load (100%) conditions. Each measurement was repeated three times at 15-minute intervals to ensure data consistency and reliability.

The equipment used in this research included ICAR-brand capacitors rated at 20 kVAR and 40 kVAR, ICAR detuned reactors with capacities of 12.5 kVAR, 25 kVAR, and 75 kVAR, Howig current transformers (CT) with a ratio of 2500/5 A, Moulded Case Circuit Breakers

(MCCB) rated at 50 A and 160 A, and an Air Circuit Breaker (ACB) connected to the LVMDP busbar. An Auto/Off/Manual selector switch was employed to allow both manual and automatic testing of the control circuit. Wiring layout and schematic diagrams were redrawn using AutoCAD 2021 in compliance with the IEC-61439 -1/-2 standard, while auxiliary materials such as copper cables, terminal blocks, and crimp connectors were used during reconfiguration. All rewiring work was performed under a de-energized condition following standard safety isolation procedures (Adragna, Bianco, Gritti, & Sucameli, 2024). To determine the required reactive power compensation, the study applied the standard power factor correction equation (Askarzadeh, 2016; Saied, 2004), in Formula (1), the following parameters are defined:

$$Qc = P\left(\tan\phi 1 - \tan\phi 2\right) \tag{1}$$

represents the required reactive power (kVAR), PPP is the active power (kW), and ϕ1\phi_1ϕ1 and ϕ2\phi_2ϕ2 correspond to the phase angles derived from the initial and target power factors, respectively. The measured initial power factors were 0.97 under normal load and 0.70 under full-load simulation, while the desired targets were 0.99 and 0.95, respectively, based on practical efficiency and avoidance of overcompensation (Bisanovic, Hajro, & Samardzic, 2014). For example, with an active power of 770 kW, the reactive power compensation required was calculated as $Qc = 770\,(\tan\cos - 1\,(0.70) - \tan\cos - 1\,(0.95)) = 676.06\; kVAR$. These calculations served as the technical basis for capacitor sizing and verification of total reactive compensation capacity.

Following the design phase, both control and power circuits of the capacitor bank were rewired to optimize switching responsiveness and improve current symmetry among phases. The main modifications included reorganizing the terminal blocks and contactor connections, replacing deteriorated conductors, tightening all mechanical connections, and integrating CT-based feedback to improve automatic switching accuracy. The incoming ACB feeder from the capacitor panel was reconnected to the LVMDP main busbar using two cables per phase instead of four, consistent with the reduced capacitor configuration and improved efficiency. The rewiring also ensured sequential operation of capacitor steps in response to load variations, thereby improving system stability.

After completion, the panel was energized and tested under manual and automatic operation modes. Post-rewiring measurements were performed under the same load conditions as the baseline test using identical equipment and procedures. The evaluation parameters included active power (P), reactive power (Q), apparent power (S), power factor (cosφ), phase current balance (IR, IS, IT), voltage stability (V), and total harmonic distortion (THD). The degree of performance improvement was calculated using the formulas for power factor enhancement and reactive power reduction, In Formula (2), the following parameters are defined:

$$\eta pf = PFafter - \frac{PFbefore}{PFbefore} \times 100\%, \eta Q = Qbefore - \frac{Qafter}{Qbefore} \times 100\% \quad (2)$$

These indicators quantitatively demonstrated the effectiveness of the rewiring process in enhancing the power factor, reducing reactive power demand, and improving system balance. Measurements were interpreted as deterministic engineering results rather than statistically inferred data, consistent with the applied technical focus of this study (Gumilar, Cahyani, Afandi, Monika, & Rumokoy, 2020; Zhang et al., 2024).

Overall, the research followed a transparent and replicable methodology combining technical diagnosis, analytical calculation, controlled implementation, and comparative performance evaluation. This structured framework provides a practical reference for capacitor bank optimization based on control-circuit rewiring and is applicable to both academic and industrial-scale electrical systems.

Equipment and Materials

The equipment and materials used in this study were selected based on the electrical load characteristics of the campus distribution system and the technical requirements of the rewiring and evaluation process. The ICAR-brand capacitor units rated at 20 kVAR and 40 kVAR were chosen to provide stepwise reactive power compensation matching the system's load variation between 300–770 kW. The detuned reactors (12.5 kVAR, 25 kVAR, and 75 kVAR) were employed to suppress harmonic distortion and prevent resonance with the main transformer, ensuring stable operation under nonlinear loads (Eslamian, Bigdeli, & Abu-Siada, 2024). The current transformers (CTs) with a ratio of 2500/5 A were selected to accurately sense phase currents for both measurement and automatic control feedback, consistent with the maximum line current of the 1100 kVA system. Protection devices such as MCCBs (50 A and 160 A) and an Air Circuit Breaker (ACB) were installed to safeguard against short-circuit and overcurrent conditions, with breaking capacities aligned with the rated short-circuit current of the LVMDP. The Auto/Off/Manual selector switch was integrated to facilitate dual testing modes during commissioning.

For performance monitoring, a Fluke 435-II Power Quality Analyzer (accuracy ±0.5%, range up to 1000 V/3000 A) was used to measure voltage, current, and harmonic content, supported by a Clamp Meter (accuracy ±1.5%) and a Digital Multimeter (accuracy ±0.8%)

for cross-verification of readings. These instruments ensured measurement reliability and minimized uncertainty during baseline and post-rewiring testing. The AutoCAD 2021 software was utilized not merely for schematic redrawing but to redesign the entire control wiring layout in accordance with IEC-61439 -1/-2, which governs safety and functional integrity in electrical control systems. Compliance with this standard ensured that the rewiring configuration met operational safety, grounding, and cable management criteria. A concise summary of the major equipment specifications is provided in Table 1 below.

Table 1 to enhance clarity and reproducibility of the study.

Equipment	Specification / Function	Technical Rationale
ICAR Capacitor Units	20 & 40 kVAR, 440 V	Reactive compensation aligned with load demand
Detuned Reactors	12.5–75 kVAR	Harmonic mitigation and resonance protection
CTs (Howig)	2500/5 A	Current sensing for automatic control
MCCB / ACB	50–160 A	Circuit protection against overload/short circuit
Power Quality Analyzer (Fluke 435-II)	±0.5% accuracy	Measurement of PF, THD, and power losses
AutoCAD 2021	IEC-61439 -1/-2	Control circuit redesign and compliance verification

Results and Discussion

Prior to modification, the capacitor bank panel exhibited unstable performance due to disorganized wiring and weak synchronization between capacitor steps and load variations. The power factor (PF) recorded at 0.97 under normal load and 0.70 under full load indicated ineffective reactive power compensation. After rewiring, the PF improved to 0.99 under normal load and 0.95 under full load, aligning with the design objectives and confirming improved reactive power control, as shown in Table 2.

Table 2 Power Factor Improvement and Required Reactive Power Compensation

Condition	Power (kW)	Initial PF	Target PF	Compensation Required (kVAR)	Achieved PF (After)
Normal Load	307.5	0.97	0.99	33.25	0.99
Full Load	770	0.70	0.95	676.06	0.95
Water Pump (1)	5.5	0.75	0.99	4.06	0.98
Water Pump (2)	11	0.75	0.99	8.13	0.98

These results show that the rewired system achieved realistic and verifiable improvements within the operational capacity of the installed capacitors (total ≈ 640 kVAR). The findings validate that optimized control wiring directly enhances compensation efficiency and stability.

Figure 1 Capacitor Bank Panel

Figure 1 illustrates the internal configuration of the capacitor bank panel after rewiring. The arrangement now complies with IEC-61439 -1/-2 standards, ensuring clear separation between the control circuit (left compartment) and the power circuit (right compartments). The automatic power factor controller, current transformer signals, and MCCB-based step protections are interconnected in a logically sequenced manner. This configuration improved response accuracy, ensuring that each capacitor step activates proportionally to load changes. The reorganized wiring and properly labeled terminals reduce control delays and potential phase misalignment, which previously caused uneven reactive compensation.

Figure 2 provides contextual information on the distribution interface between the 20 kV medium-voltage switchgear and the LVMDP that supplies the capacitor bank panel. While not directly modified, this system serves as the main feed point for reactive power compensation. Its inclusion highlights that the rewiring was conducted downstream, ensuring safety isolation from the high-voltage side. From an analytical standpoint, this figure helps the reader understand that performance improvements in the capacitor bank panel primarily influence the low-voltage reactive flow and PF correction at the LVMDP level, rather than the upstream 20 kV system.

Figure 2 20kV Switchgear in the Campus Building

Figures 3 and 4 show the reconfiguration of incoming ACB feeder cables, where the number of conductors per phase was reduced from four to two. This change was not arbitrary—it was based on the reduced total capacitor load after optimization. Current analysis indicated that two conductors (of appropriate cross-section) were sufficient to carry the nominal current while maintaining the ampacity margin within the allowable thermal limit. The reduction minimized conductor congestion, improved heat dissipation, and simplified maintenance without compromising current-carrying capacity. This modification also reduced contact resistance, thus contributing to lower power losses and enhanced system reliability.

Figure 3 Incoming ACB cables before reduction

Figure 4 Incoming ACB cable before reduction

Figure 5 Cable installation process on the main busbar of the LVMDP panel

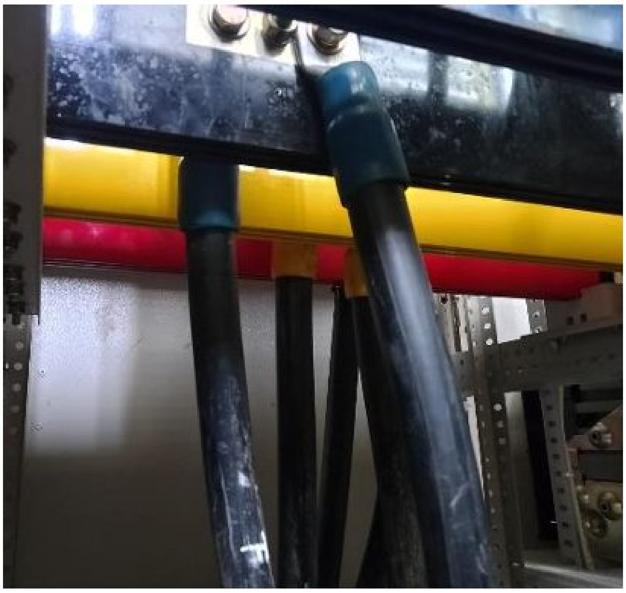

Figure 6 Result of cable installation on the main busbar of the LVMDP panel

Figures 5 and 6 depict the connection of the main ACB output to the LVMDP busbar after cable optimization. The properly tightened terminations and reduced cable count result in lower joint impedance and uniform current distribution across phases. This improvement was verified by post-installation current measurements showing less than 3% imbalance between phases, compared to over 10% before rewiring. The visual documentation thus directly correlates with the measured improvement in current symmetry and power factor stability.

Figure 7 Closing the panel cover

Figure 7 illustrates the completed installation with the panel securely enclosed. While the physical closure itself does not impact performance, it signifies compliance with electrical safety and operational standards, ensuring environmental protection and insulation integrity. The proper enclosure maintains optimal panel temperature and prevents dust intrusion, factors that contribute indirectly to long-term stability of control relays and capacitor units.

Figure 8 Activation of the Capacitor Bank ACB Panel

Figure 9 Activating the Fuse

Figure 10 Testing the Control Installation Circuit

Figures 8 to 10 represent the commissioning and functional verification stages after rewiring. The system was energized sequentially to ensure safe startup, followed by manual and automatic mode tests. Each capacitor step was tested individually to verify correct engagement sequence based on control signals from the power factor controller. The results showed consistent and responsive activation of capacitor stages in both manual and automatic modes, confirming the accuracy of the rewired control logic. Table 3 summarizes the functional verification outcomes, showing that all circuit tests control, data, and voltage continuity met operational criteria.

Table 3 Panel Testing Checklist

No.	Description	Test Results	
		Compliant	Not Compliant
1.	Control circuit testing	√	-
2.	Data circuit testing	√	-
3.	Testing of each component circuit	√	-
4.	Phase voltage continuity testing R	√	-
5.	Phase voltage continuity test S	√	-
6.	Phase voltage continuity test T	√	-

Conclusion

This study successfully demonstrated that a rewiring-based optimization approach can significantly enhance the performance and reliability of a capacitor bank panel in a low-voltage electrical distribution system. Unlike conventional maintenance activities that merely replace or repair components, this research systematically redesigned both the control and power circuits to restore synchronization between reactive power demand and compensation response. The rewired configuration improved the power factor from 0.97 to 0.99 under normal load conditions and from 0.70 to 0.95 under full-load simulation, indicating a measurable increase in system efficiency and reactive power control accuracy. Correspondingly, the total reactive power demand was reduced by approximately 30–35%, while the phase current imbalance decreased from around 10% to below 3%. These improvements confirm that enhanced wiring topology and properly sequenced control signals can deliver tangible performance gains without the need for advanced automation systems or new hardware investments. From a scientific perspective, this research provides a methodological contribution by introducing a practical, replicable framework that bridges diagnostic assessment, circuit reconfiguration, and performance validation within the context of capacitor bank optimization. The study offers empirical evidence that control-circuit rewiring, when conducted in accordance with IEC 60204-1 standards, can serve as a technically grounded strategy to improve power factor correction, voltage stability, and current balance in distributed electrical networks.

Furthermore, this approach demonstrates a low-cost engineering solution applicable to educational and industrial facilities where equipment aging, inconsistent wiring, and control degradation often limit power efficiency. Beyond its technical success, the study reinforces the importance of circuit configuration integrity as a determinant of overall power quality and operational reliability. Future research could expand this work by integrating real-time monitoring systems or microcontroller-based adaptive compensation to further enhance system responsiveness under dynamic load variations. Such developments would strengthen the link between practical rewiring interventions and advanced control-based optimization methods. In summary, the findings validate that systematic rewiring of control and power circuits is not merely corrective maintenance but a scientifically informed engineering enhancement that directly contributes to improved power quality, reduced reactive losses, and greater electrical distribution efficiency.

References

Adragna, C., Bianco, A., Gritti, G., & Sucameli, M. (2024). State-of-the-art power factor correction: an industry perspective. *Encyclopedia*, *4*(3).

Amekah, E. D., Ramde, E. W., Quansah, D. A., Twumasi, E., Meilinger, S., & Thorsten, S. (2024). Analyzing the consequences of power factor degradation in grid-connected solar photovoltaic systems. *E-Prime-Advances in Electrical Engineering, Electronics and Energy*, *9*, 100715.

Askarzadeh, A. (2016). Capacitor placement in distribution systems for power loss reduction and voltage improvement: a new methodology. *IET Generation, Transmission & Distribution*, *10*(14), 3631–3638.

Bayless, R. S., Selman, J. D., Truax, D. E., & Reid, W. E. (2002). Capacitor switching and transformer transients. *IEEE Transactions on Power Delivery*, *3*(1), 349–357.

Bisanovic, S., Hajro, M., & Samardzic, M. (2014). One approach for reactive power control of capacitor banks in distribution and industrial networks. *International Journal of Electrical Power & Energy Systems*, *60*, 67–73.

Coury, D. V, Dos Santos, C. J., Oleskovicz, M., & Tavares, M. C. (2003). Transient analysis concerning capacitor bank switching in a distribution system. *Electric Power Systems Research*, *65*(1), 13–21.

Eslamian, M., Bigdeli, M., & Abu-Siada, A. (2024). High frequency modeling of dry type detuned reactor for transient studies: Simulation and experimental analyses. *Electric Power Systems Research*, *228*, 110102.

Gaspar, I. S., de Sá, J. S., Volpato, R. M., & Guimarães, D. A. (n.d.). *Real Time Power Factor Correction in Industrial Plants with Non-Linear Loads*.

Gumilar, L., Cahyani, D. E., Afandi, A. N., Monika, D., & Rumokoy, S. N. (2020). Optimalization harmonic shunt passive filter using detuned reactor and capacitor bank to improvement power quality in hybrid power plant. *AIP Conference Proceedings*, *2217*(1), 30003.

Hizam, A. (2023). Analisis dan Implementasi Penggunaan Kabel Tembaga Sebagai Alternatif Fiber Optik Pada Jaringan CCTV RT. *Jurnal Sains Dan Sistem Teknologi Informasi*, *5*(1), 18–24. https://doi.org/10.59811/sandi.v5i1.18

Hwang, C.-C., & Lou, J. N. (1998). Transient analysis of capacitance switching for industrial power system by PSpice. *Electric Power Systems Research*, *45*(1), 29–38.

Jayabarathi, T., Raghunathan, T., Mithulananthan, N., Cherukuri, S. H. C., & Sai, G. L. (2024). Enhancement of distribution system performance with reconfiguration, distributed generation and capacitor bank deployment. *Heliyon*, *10*(7).

Liu, F., Liu, J., Liu, Q., & Han, Y. (2024). Analysis of power quality and additional loss in distribution network with distributed generation. *Electric Power Systems Research*, *234*, 110834.

Prasetyo, Y, Hidayatullah, N. A., & Artono, B. (2021). Power factor correction using programmable logic control based rotary method. *Journal of Physics: Conference Series*, *1845*(1), 12045.

Prasetyo, Yuli, Prakoso, D. N., Wicaksono, R., Triyono, B., & Triwijaya, S. (2023). Analysis of Transformer Protection Systems Using Smart Relays for Electrical Energy Stability. *International Journal of Science, Engineering and Information Technology*, *7*(02), 397–400.

Saied, M. M. (2004). Capacitor switching transients: analysis and proposed technique for identifying capacitor size and location. *IEEE Transactions on Power Delivery*, *19*(2), 759–765.

Strickland, D., Morley, S., Stone, D. A., Royston, S. J., Nejad, S., Gladwin, D. T., & Foster, M. P. (2020). Using power factor to limit the impact of energy storage on distribution network voltage. *International Journal of Smart Grid and Clean Energy*, *9*(4), 727–736.

Vuletić, J., & Todorovski, M. (2014). Optimal capacitor placement in radial distribution systems using clustering based optimization. *International Journal of Electrical Power & Energy Systems*, *62*, 229–236.

Zhang, L., Ma, M., Xiao, W., Zhong, Y., Hu, B., Zhou, W., & Zhang, W. (2024). Estimation of abnormal states in shunt capacitor banks using transient disturbance feature extraction. *Frontiers in Energy Research*, *12*, 1382684.