

ARTICLE

Using Integrated Power Management Controls Systems

in Commercial, Industrial, and Mission-critical Facilities

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ABSTRACT

Electrical distribution systems in commercial and industrial facilities frequently experience inefficiencies caused by reactive power circulation, harmonic distortion, and voltage instability. These conditions increase electrical current, generate excess heat in electrical infrastructure, and reduce overall system efficiency.

This article presents measured performance results from installations with integrated power management control systems (PMCS) designed to optimize electrical operating conditions within facility distribution networks. Performance was evaluated across four facility types: a mission-critical military installation, a commercial office building, an industrial manufacturing facility, and an agricultural processing plant.

The results demonstrated consistent improvements including reductions in apparent power demand, reductions in reactive power circulation, improvements in power factor, and reductions in electrical current. In one installation verified by utility billing data, peak demand decreased by approximately 23% while facility production increased by approximately 25%.

These findings suggest that system-level electrical optimization technologies may provide an additional pathway for improving facility energy efficiency while simultaneously enhancing electrical infrastructure reliability and capacity utilization.

INTRODUCTION

Energy efficiency efforts in commercial and industrial facilities typically focus on improvements in lighting equipment, heating, ventilating, and air conditioning (HVAC) systems, building automation systems, and industrial processes. While these measures can produce energy savings, the electrical distribution system itself is often overlooked as a potential source of efficiency improvements. Electrical systems frequently operate under sub-optimal conditions due to excessive reactive power circulation, harmonic distortion from nonlinear loads, voltage instability and electrical noise, and inefficient power transfer conditions. These conditions increase electrical current flow without increasing useful work, resulting in increased conductor losses, transformer heating, and reduced equipment life.

Traditional solutions such as capacitor banks or automatic power factor correction panels primarily address reactive power but may not address broader system efficiency issues. This article examines measured results from installations of a power management control system (PMCS) using maximum power transfer solution technology (MPTS). They are designed to influence several electrical parameters simultaneously to improve power transfer efficiency and overall system performance.

ELECTRICAL SYSTEM LOSSES

Electrical losses in distribution systems occur through several mechanisms which include reactive power circulation, harmonic distortion, and electrical line losses.

Reactive Power Circulation

Inductive loads such as motors and transformers require reactive power to establish magnetic fields. However, reactive power does not perform useful work and increases electrical current within the distribution system. The relationship between real power, reactive power, and apparent power as expressed in Equation 1:

$$S^2 = P^2 + Q^2 \text{ (1) Wherein:}$$

S = apparent power (kVA)

P = real power (kW)

Q = reactive power (kVAR)

Reducing reactive power reduces apparent power and therefore reduces current flow within the electrical system.

Harmonic Distortion

Modern facilities contain numerous nonlinear loads such as variable frequency drives, switching power supplies, light emitting diode (LED) lighting drivers, and electronic control equipment. These types of loads generate harmonic currents which distort the sinusoidal waveform of electrical power. Harmonics increase root mean square (RMS) current levels and cause transformer overheating, increased conductor losses, neutral conductor overload, and reduced electrical efficiency. Mitigation of harmonic currents improves electrical waveform quality and reduces unnecessary current.

Electrical Line Losses

Electrical losses in conductors are governed by the relationship current (I) and conductor resistance (R): $\text{Losses} = I^2R$. Because current is squared in this equation, modest reductions in current can produce large reductions in electrical losses and heat generation. Mitigation of harmonic currents improves electrical waveform quality and reduces unnecessary current.

POWER MANAGEMENT CONTROLS SYSTEM

The power management control system is designed to improve electrical power transfer conditions within facility distribution networks by dynamically influencing electrical parameters such as impedance characteristics, reactive power circulation, and harmonic conditions. The system operates continuously to monitor electrical conditions and adjust network resonance characteristics to optimize power transfer efficiency. The technology is based on patented electrical optimization methods and is manufactured in accordance with recognized North American electrical safety standards including Underwriters Laboratories (UL) and Canadian Standards Association certification. Installation is performed in compliance with the National Electrical Code and applicable local electrical codes.

System Operating Concept

The power management control system continuously performs several functions:

- Monitoring electrical supply input and load demand characteristics.
- Matching impedance parameters within the electrical network.
- Adjusting electrical resonance characteristics of the network loop.
- Synchronizing and optimizing electrical output conditions.

This continuous monitoring and adjustment allow the system to respond dynamically to changing facility load conditions. PMCS provide continuous and consistent performance with power factors over 95%.

Figure 1 illustrates the conceptual operating process of the PMCS system. Figure 2 illustrates the integration of the system within a typical facility electrical architecture.

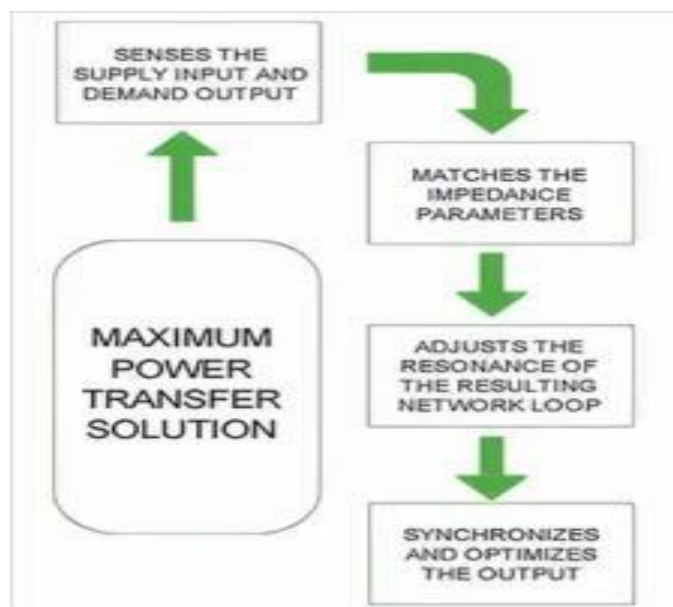


Figure 1. Operating process of the PMCS system.

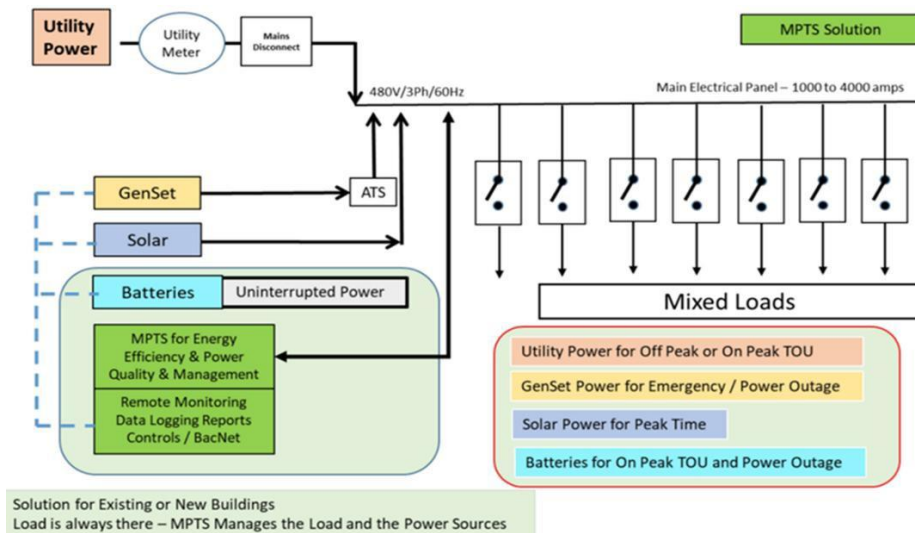


Figure 2. Integration of the PMCS within a typical facility electrical architecture.

ELECTRICAL SYSTEM INTEGRATION

The system is installed in parallel with the electrical distribution network and interacts with existing infrastructure including utility power supply/transformers, main electrical panels, generators, solar generation systems, battery energy storage systems and facility loads. Figure 3 shows typical connections. Multiple systems can be used in each electrical field or network.

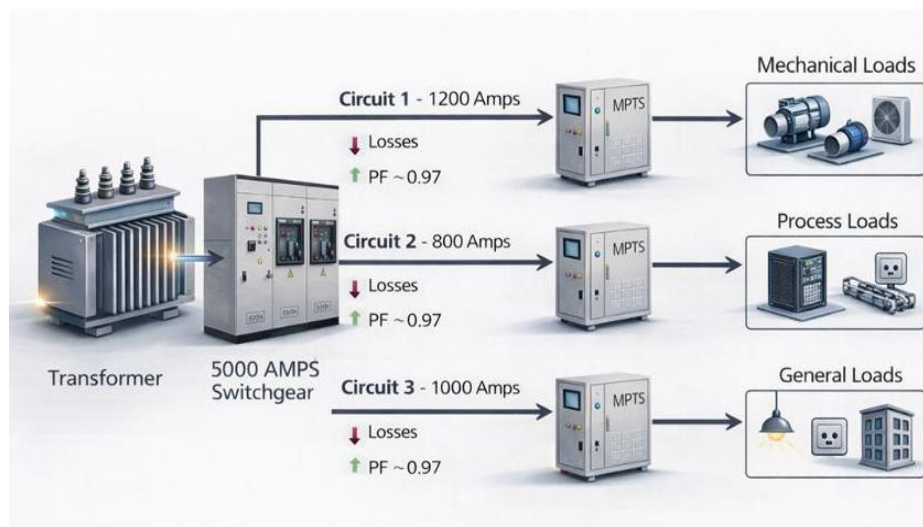


Figure 3. System configuration and connections.

This architecture allows the system to operate in both existing and new facilities without major modifications to electrical infrastructure. With this configuration, the utility transformer and customer electrical network operates cooler and more efficiently.



Figure 4. Electrical room equipment in chemical plant.



There are common issues associated poorly designed configurations. Prior to installation of the power management control system, transformers exhibit overloading, experience temperatures of 85 to 95 °C, and can be continuously loaded beyond 100% of its design capacity. These conditions cause energy to be wasted, insulation to be degraded, reduce transformer life, and risk premature failure. Signs of stress include oil decolorization, hot spots, premature aging and wear.

After installation of the PMCS (see Figure 4), transformers operate at lower temperatures (65 to 75 °C), and operate at about 85% of rated capacity. This improves operating efficiency (-14%), reduces electrical heat losses and energy use (-15% to -20%), improves reliability, reduces maintenance, and extends transformer life (+30% to 50%). Healthy transformer operation means that oil stays clear and cleaner, and operational temperatures.

CASE STUDIES

Power management controls systems can be used for commercial, industrial, government buildings, and applications. There are hundreds of these systems installed in the U.S. and around the world.

Case Study 1: NORAD Cheyenne Mountain, Mission-critical Installation

One of the earliest installations occurred at the Cheyenne Mountain Air Force Station, located in Colorado Springs, Colorado, which supports NORAD operations. This mission-critical facility requires extremely stable electrical power to support national defense operations. Facility characteristics include a transformer capacity of 1,200 kVA. Monitoring data was provided by the facility engineers. Measured results showed:

- peak demand reduction of approximately 73 kW
- power factor improvement from 0.298 to 0.811
- reactive power reduction of approximately 83 kVAR

Long-term monitoring indicated cumulative energy savings exceeding 401,500 kWh and avoided carbon emissions of approximately 750,805 pounds of CO₂.

Case Study 2: AVCO Center

The AVCO Center is a 12-story, 142,300 ft² commercial office located in Los Angeles, California (see Figure 5, left). It offers a range of office and retail spaces, from about 1,000 to over 12,000 ft². The building served is by a 3,000 kVA transformer. Three PMCS units using maximum power transfer solution technology (MPTS) were installed and monitored over a two- week electrical fingerprint period (see Figure 5, right). Measured results showed:

- Supply power reduced from 390 kVA to 321 kVA
- Reactive power reduced from 216 kVAR to 6.9 kVAR
- Power factor improved from 0.85 to 0.99

This represents:

- 17.8% reduction in apparent power
- 96.8% reduction in reactive power
- 16% improvement in power factor

These improvements effectively released additional electrical capacity within the building distribution system.

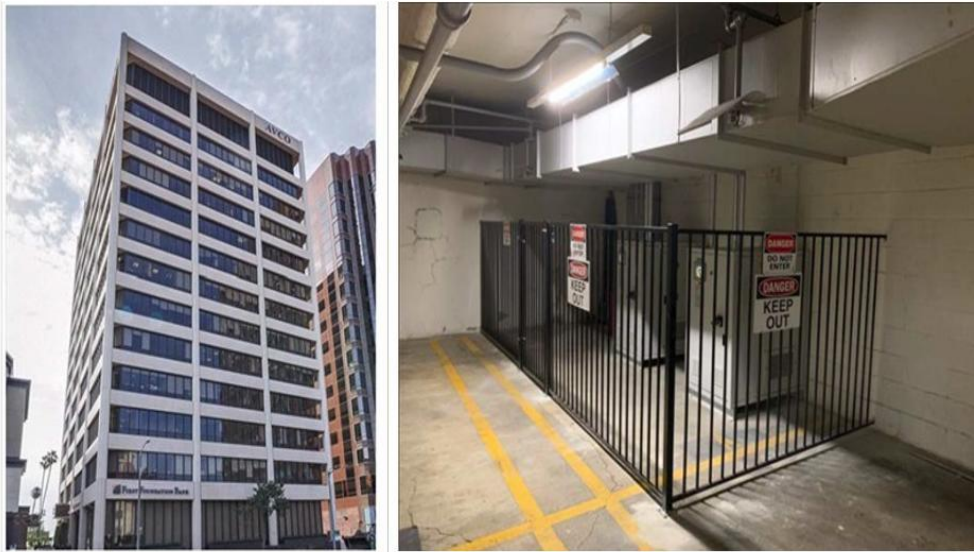


Figure 5. Building elevation (left), PMCS equipment using MPTS technology (right).

Table 1. Reinstall vs. post-installation comparison.

	kVAh Supplied Power	kVArh Reactive Power	EE Electrical Efficiency
14 Days Avg. PreINSTALL	390.1	216.2	0.85
14 days Avg. PostINSTALL	320.8	6.9	0.99
%Chg	-17.8% reduction	-96.8% reduction	16.47% Increase
	/ Hour	/ Year	Per Life
Avg. Capacity Released per Hour	69.3 kVAh	607 MVAh	12,140 MVAh
Avg CO2 Emission Reduction	62.4 lbs	269.8 MT	5396 MT

Case Study 3: Injection Molding Facility

The Pen Plast, Peninsula Plastics injection molding plant is located in Fort Eire, Ontario (see Figure 6). The plant manufactures products and components for the retail, agricultural, food and beverage, medical and healthcare sectors. It operates in continuous production and was evaluated using both instrumentation measurements and utility billing data.

- Average electrical demand decreased from: 636 kVA to 465 kVA
- Real power demand decreased from: 563 kW to 444 kW
- Power factor improved from: 0.73 to 0.98

Independent instrumentation tests demonstrated apparent power reductions of approximately 58% during controlled operating conditions.



Figure 6. Site and installed project components.

Case Study 4: Porterville Citrus

A citrus packing plant in Terra Bella, California, provided a detailed verification of an agricultural processing plant. This case study was possible due to the availability of utility billing data and interval monitoring. Following installation, PG&E utility bills and 15-minute interval electrical measurements were analyzed. Average seasonal demand values were: 562 kW (2016), 551 kW (2017), 524 kW (2018), and 425 kW (2019).

Despite a 25% increase in plant production, electrical demand dropped approximately 23%. Electrical panel instrumentation indicated:

- average current reduction of 21%
- peak current reduction of 17%
- peak kW reduction of 17%
- power factor improvement from 0.77 to 0.99

Reactive power was reduced from 247 kVAR to 57 kVAR. Energy efficiency improvements and reductions in CO₂ emissions were identified using the MPTS.



Figure 7. Citrus packaging plant using two PMCS units

ELECTRICAL MECHANISMS BEHIND CURRENT REDUCTION

The observed performance improvements across the installations can be explained through several electrical system mechanisms.

Reactive power reduction: Reducing reactive power decreases apparent power and therefore reduces electrical current. Lower current reduces conductor losses and transformer heating.

Harmonic mitigation: Mitigation of harmonic distortion reduces RMS current levels and improves electrical waveform stability. Improved waveform conditions reduce heating in transformers and electrical conductors.

Reduction of electrical line losses: Lower current reduces I^2R losses within conductors. Because current is squared in the loss equation, reductions in current can significantly reduce electrical losses.

Surge and voltage disturbance limitation: Electrical stabilization also reduces voltage disturbances such as spikes and transient events, reducing stress on electrical equipment and improving system reliability.

CONCLUSIONS

Electrical distribution systems represent an under-recognized opportunity for improving energy efficiency and infrastructure performance in commercial and industrial facilities. Across all installations examined in this study, consistent improvements were observed due to the use of power management control systems. These included reduced electrical current, improved power factor, reduced reactive power circulation, and improved electrical stability. These improvements contribute to reduced electrical losses, improved transformer utilization, and increased electrical infrastructure reliability.

Case study results indicate that system-level electrical optimization may provide a complementary strategy for improving facility energy performance while enhancing infrastructure resilience. Measured results from multiple installations demonstrate that electrical optimization technologies can reduce electrical demand, improve power factor, reduce reactive power circulation, and decrease electrical

losses. For example, in a detailed case study for Porterville Citrus, it was verified through utility billing data that electrical demand was reduced approximately 23% while facility production increased by approximately 25%.

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AUTHOR BIOGRAPHY

Adil Khan is an energy professional specializing in electrical system optimization, power quality improvement, and advanced energy management technologies. His work focuses on enhancing electrical infrastructure efficiency, performance, and reliability across commercial, industrial, and mission-critical facilities. He is both an electrical and mechanical engineer with a strong background in applications engineering, where he develops practical, system-level solutions for complex challenges in new and existing electrical networks. He is particularly focused on bridging the gap between engineering theory and real-world implementation to deliver measurable performance improvements. In addition, he holds an MBA, enabling him to align technical solutions with business objectives and deliver economically viable outcomes for clients.