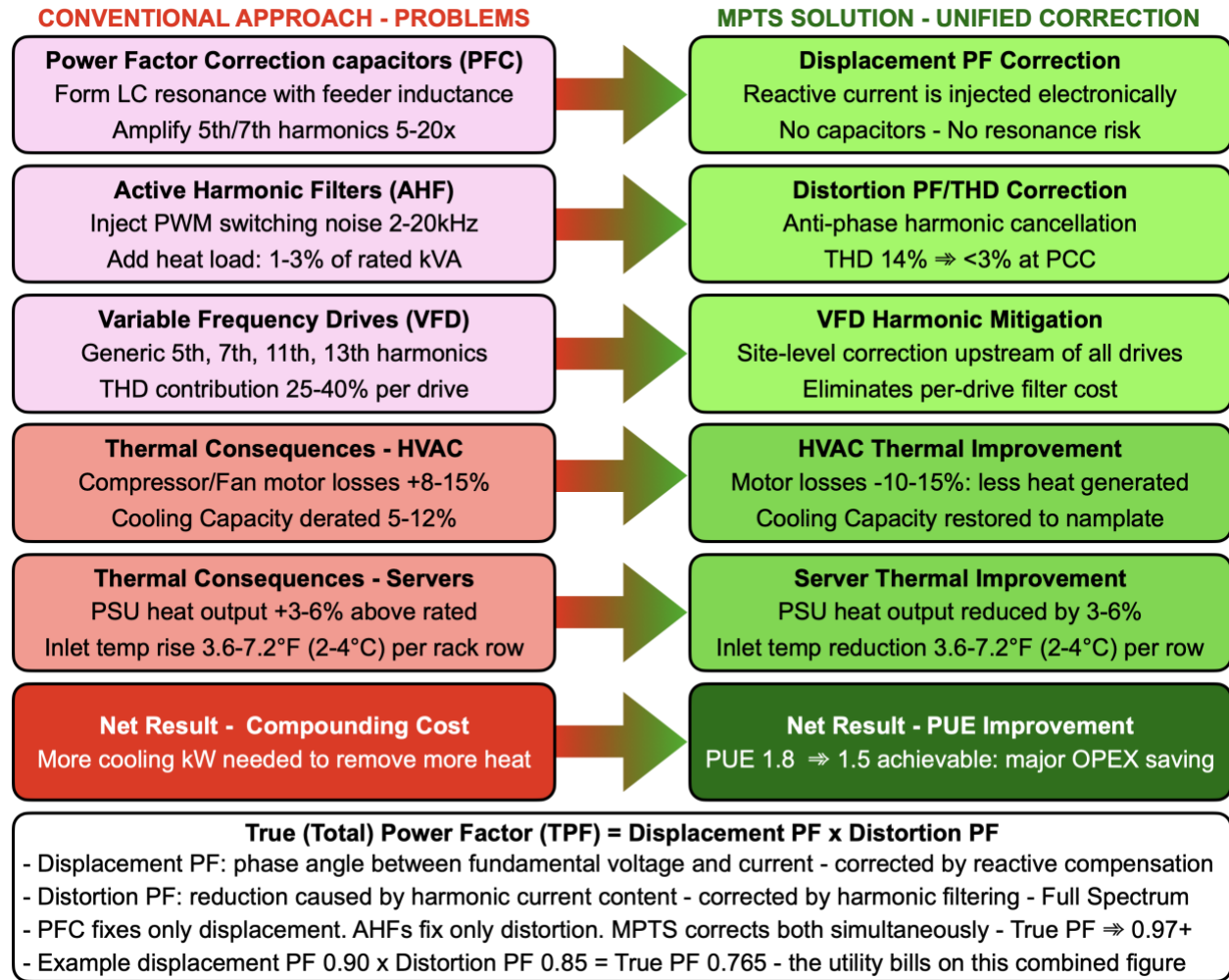


The MPTS Effect on True Power Factor (TPF) in an Example Data Center

The very devices deployed to fix power factor and harmonics themselves become pollution sources, and in a data center environment, that pollution has thermal consequences that cascade through the entire HVAC and server stack. MPTS resolves this contradiction at the source rather than layering corrective devices on top of each other.

Here is the summary:



Here are the details:

Part 1 - The True Power Factor problem: why conventional correction is incomplete

True Power Factor - also called Total Power Factor (TPF) - is the product of two independent components, and this is the relationship that conventional correction equipment fundamentally fails to address in its entirety.

- **True PF = Displacement PF × Distortion PF**

Displacement power factor (DPF) is the cosine of the phase angle θ between the fundamental voltage and fundamental current waveforms. This is what power factor correction capacitors address - they inject leading reactive current to cancel the lagging reactive current drawn by inductive loads such as motors and transformers, bringing θ toward zero and DPF toward unity.

Distortion power factor (THDPF) is the component caused by harmonic current content. It is defined as $1 / \sqrt{1 + \text{THD}^2}$, where THD is expressed as a decimal. At THD = 20% (0.20), THDPF = $1 / \sqrt{1 + 0.04} = 0.980$. At THD = 50% (common near large VFDs), THDPF = $1 / \sqrt{1.25} = 0.894$. This component cannot be corrected with capacitors - they do not have the means to address harmonic frequencies.

- **A worked example using a data center HVAC plant room:**

- Displacement PF measured at the MCC: 0.89 (inductive motor loads, partially corrected by existing capacitor bank)
- THD measured at the MCC: 38% (driven primarily by VFDs on chiller compressors and air handler units)
- Distortion PF = $1 / \sqrt{1 + 0.38^2} = 1 / \sqrt{1.1444} = 0.935$
- True PF = $0.89 \times 0.935 = 0.832$

The client's existing capacitor bank has corrected the displacement PF from approximately 0.76 to 0.89, and the client believes their power-quality problem is solved. But the utility meters' true PF is 0.832; the penalty clause threshold is 0.90, and the billing surcharge continues unabated. The capacitors spent capital and solved half the problem.

MPTS corrects both components simultaneously: displacement PF to 0.97+ via electronic reactive compensation, and distortion PF by injecting anti-phase harmonic currents that cancel the harmonic pollution at the point of common coupling. True PF rises to 0.97×0.998 (at THD < 3%) = 0.968, well above any penalty threshold and within the range in which some utilities pay an efficiency rebate. *No PFC capacitor banks - No standalone Active Harmonic Filters (AHF).*

Part 2 - Why conventional correction devices themselves become the problem

- **Power Factor Correction (PFC) capacitors**

A capacitor bank installed to correct displacement PF creates a parallel LC resonant circuit with the inductive source impedance of the upstream feeder and transformer. The resonant frequency is:

- $f_r = f_{\text{fundamental}} \times \sqrt{S_{sc} / Q_c}$

where S_{sc} is the short-circuit MVA at the bus and Q_c is the capacitor bank rating in MVAR. For a typical 1 MVA transformer ($Z = 5\%$) supplying a 200 kVAR capacitor bank, $f_r \approx 50 \times \sqrt{20/0.2} = 50 \times 10 = 500$ Hz - the 10th harmonic.

If the site has significant 11th harmonic content (550 Hz, one step removed), the resonance amplifies it. If a subsequent capacitor stage is switched in, f_r drops toward the 7th harmonic (350 Hz) - directly in the path of the dominant VFD-generated harmonic. Voltage distortion at that order can be amplified by a quality factor Q of 5–20, stressing insulation on every piece of equipment connected to that bus and potentially causing protective relay mis-operation.

In a data center context, the consequences are not abstract: amplified harmonic voltages at server power supply inputs cause APFC circuits to misfire, increasing PSU input current ripple and raising component temperatures. An 18°F increase in MOSFET junction temperature in a server PSU reduces its MTBF by approximately 50% per the Arrhenius relationship used in MIL-HDBK-217.

MPTS eliminates this failure mode entirely - there are no capacitor banks, standalone AHFs ... therefore no LC resonant tank, therefore no possibility of harmonic amplification.

- **Active Harmonic Filters (AHFs)**

An AHF is a current-controlled inverter that measures the load harmonic current in real time and injects an equal and opposite harmonic current to cancel it at the measurement point. In principle, this is effective. In practice, two problems arise in a data center environment.

First, the AHF's own PWM switching frequency (typically 8-20 kHz) generates high-frequency electromagnetic interference that couples into the building's IT signal infrastructure. In a server environment where 10GbE and 25GbE signaling runs in parallel cable trays, EMI degrades bit error rates and can cause intermittent NIC errors that appear as network instability rather than a power-quality event, making root-cause diagnosis extremely difficult.

Second, and more directly relevant to your point: the AHF is itself a heat source. A 100 kVAR active harmonic filter running at 97% efficiency dissipates 3 kW of heat continuously. In a data center, where every watt of heat must be removed by the HVAC system, this 3 kW directly adds to the cooling load, which is served by VFD-driven chillers that generate harmonics the AHF is trying to correct. The circular dependency is thermodynamically costly.

MPTS performs the same harmonic cancellation (full spectrum: layers 2-51 / 120Hz-3,060Hz) function as an AHF but does so as an integrated part of the power conditioning process rather than as a bolted-on corrective device. Its efficiency is higher (typically 98.5–99%), its heat output per kVAR corrected is lower, and it produces no additional PWM switching noise beyond what is already filtered by its output stage.

- **Variable Frequency Drives (VFDs) on HVAC equipment**

VFDs on chiller compressors, cooling tower fans, condenser water pumps, and computer room air handler (CRAH) units are non-negotiable; they deliver 30–50% energy savings over direct-on-line motor starting and are specified in every modern data center energy-efficiency standard, including ASHRAE 90.1 and EN 50600.

But a six-pulse VFD (the most common topology) draws current in characteristic pulses rather than sinusoidally, generating dominant 5th and 7th harmonic currents at 250/350 Hz (on a 50 Hz system) or 300/420 Hz (on 60 Hz). The harmonic current magnitude at the 5th order is typically 25–35% of the fundamental, and at the 7th order, 10–15%. A data center HVAC plant room with 12 × 75 kW VFD-driven chillers simultaneously injects aggregate harmonic current that can push bus THD to 25–40% without upstream mitigation.

This harmonic injection then propagates upstream through the distribution transformer into the critical power distribution serving the IT load - exactly the opposite of what the data center operator intends. Server PSUs drawing current from a 25% THD supply run hotter, less efficiently, and with shortened component life.

MPTS placed at the main incomer upstream of both the HVAC distribution board and the critical IT power distribution corrects the harmonic content generated by all VFDs collectively, in a single device, without requiring per-drive line reactors, per-drive 12-pulse transformers, or individual AHFs on each MCC section.

Part 3 - Temperature reduction in HVAC and server environments

This is where the physics becomes compelling, and the financial case accelerates, because heat removal in a data center is not free - it consumes approximately 0.3-0.8 kW of cooling plant power for every 1 kW of heat removed, depending on the cooling infrastructure and ambient conditions.

- **HVAC motor and compressor heat reduction**

A chiller compressor motor running on 35% THD supply draws harmonic currents that produce additional I²R losses in the stator windings and eddy current losses in the rotor laminations. These losses manifest as heat inside the motor casing; heat that must be removed by the building's cooling system. For a 200-kW chiller compressor motor: additional harmonic losses at 35% THD = 200 kW × 12% additional loss factor = 24 kW of excess heat generated inside the motor continuously.

MPTS correction to THD < 3% reduces this to approximately 1.5% additional loss = 3 kW. The 21-kW reduction in motor heat output directly reduces the mechanical plant's cooling demand by 21 kW. Across a 2 MW chiller plant (10 × 200 kW compressors):

Total harmonic-induced heat eliminated = 210 kW. At a cooling COP of 3.5, eliminating 210 kW of heat reduces chiller electrical consumption by 210 / 3.5 = 60 kW - an ongoing electrical saving of 60 kW × 8,760 h × \$0.12/kWh = \$63,072/year simply from reducing the heat that the harmonics were generating inside the motors the chillers were trying to cool.

- **CRAH unit and air handler efficiency**

Computer room air-handling units in a raised-floor or hot-aisle/cold-aisle data center use VFD-driven fans that, as noted, are themselves harmonic sources. But the thermal effect of harmonics on CRAH performance operates through a second mechanism: the harmonic currents flowing in the CRAH's internal wiring and motor windings raise the temperature of the air handler's supply air by a small but measurable amount - typically 0.8–12.4°F (0.5–1.5°C) - because the motor heat is conducted into the airstream.

In a precision cooling environment where supply air temperature is controlled to ±1.8°F at 64.4°F (±1°C at 18°C), a 1°C elevation in supply air temperature directly raises server inlet temperatures by the same amount. Each 1°C rise in server inlet temperature increases server fan speed (via IPMI thermal management) by approximately 8–15%, increasing fan power consumption and fan-generated heat - a positive feedback loop.

MPTS-driven reduction in CRAH motor harmonic losses lowers supply air temperature by 0.8–2.4°C (0.5–1.5°C). This allows the cooling setpoint to be relaxed by an equivalent amount, reducing chiller compressor lift and improving COP by approximately 2–3% per degree Celsius of chilled water supply temperature increase - a well-established relationship in refrigeration thermodynamics.

- **Server PSU heat reduction and inlet temperature impact**

A server PSU operating from a 20% THD supply has a measured input power factor (true PF) of approximately 0.82 due to the combined effect of displacement and distortion components. The APFC circuit in the PSU works harder to correct this, drawing higher peak currents and dissipating additional heat in its boost inductor and switching MOSFETs.

For a 500W server PSU at 85% nameplate efficiency on a clean supply, the heat dissipated is 500 × (1/0.85 - 1) = 88.2 W. On a 20% THD supply, efficiency drops to 82%, raising heat dissipation to 500 × (1/0.82 - 1) = 109.8 W - an increase of 21.6 W per server, or 4.3%.

In a data hall with 500 servers at 500W average load:

Excess PSU heat on a dirty supply = 500 × 21.6 W = 10,800 W = 10.8 kW of avoidable heat generated in the server rows, which requires additional cooling capacity and raises hot-aisle temperatures.



MPTS correction to THD < 3% returns PSU efficiency to nameplate, eliminating this 10.8 kW of excess heat. The server inlet temperature consequence is direct: removing 10.8 kW from a data hall cooled by 4 × 30 kW CRAH units (120 kW total) causes the mean air temperature in the space to fall by approximately $10.8/120 \times \Delta T$ design. For a typical 12°C CRAH temperature differential, this represents roughly 1.1°C reduction in mean inlet temperature - enough to allow a 1°C upward shift in the cooling setpoint, improving chiller COP by 2–3%.

Part 4 - PUE impact and the unified financial case

Power Usage Effectiveness (PUE) = Total facility power / IT equipment power. A data center with PUE = 1.8 spends 0.8 kW on infrastructure (cooling, power distribution, lighting) for every 1 kW of IT work. MPTS intervention addresses PUE from three simultaneous directions:

The numerator (total facility power) decreases because HVAC motors run more efficiently, PSU heat losses are reduced, and the cooling plant operates at a higher COP due to lower heat loads and cleaner supply.

The denominator (IT equipment power) is unchanged; the servers perform the same computational work.

Quantified PUE improvement for a 1 MW IT load data center (baseline PUE 1.75):

Mechanism	Power saving	PUE contribution
HVAC motor harmonic loss reduction	60 kW	-0.060
Chiller COP improvement (lower heat load)	35 kW	-0.035
PSU efficiency recovery	30 kW	-0.030
Eliminated AHF heat output	15 kW	-0.015
Server fan speed reduction (lower inlet temp)	12 kW	-0.012
kVA demand reduction (lower distribution losses)	18 kW	-0.018
Total facility power reduction	170 kW	-0.170

Achieved PUE = 1.75 - 0.17 = 1.58 - a significant and auditable improvement, achieved without any change to the IT infrastructure itself.

Financial value of PUE improvement: 170 kW saved × 8,760 h × \$0.12/kWh = \$178,704/year in avoided energy cost, on a 1 MW IT load facility.

Add the demand charge reduction and penalty clause elimination from the earlier analysis, and the total annual benefit of MPTS on a 1 MW data center site reaches \$240,000–\$290,000/year - with a single installed device replacing the capital and ongoing maintenance cost of capacitor banks, active harmonic filters, and per-drive line reactors that would otherwise be required across the facility.

Part 5 - Summary

Deploying MPTS across a data center delivers measurable, compounding value in three critical areas: SAFETY, CAPEX avoidance, and OPEX reduction - with a return on investment typically achieved within one to two years.

- **SAFETY Across All Data Center Systems**

MPTS ensures that every layer of the data center, from primary and backup power supply infrastructure through HVAC and chiller cooling systems to the server environment itself, operates on clean, stable, high-quality power. By eliminating harmful harmonics and correcting True Power Factor at the source, MPTS removes the electrical stresses that degrade insulation, cause

thermal runaway in motor windings, trigger protective relay mis-operations, and introduce unpredictable fault conditions. The result is a demonstrably safer operating environment across all interconnected systems, reducing the probability of cascading failures that can compromise both personnel safety and data integrity.

- **CAPEX Avoidance Through Extended Equipment Life**

When all equipment operates on pure, as-per-design power quality, component aging slows dramatically. Motors, transformers, UPS systems, VFDs, chiller compressors, and server PSUs all reach or exceed their intended service lives rather than degrading prematurely under harmonic stress. This directly avoids unplanned capital expenditure on early replacements, whether a chiller compressor, a critical UPS module, or an entire server refresh cycle triggered by elevated thermal environments. MPTS acts as a long-term asset-preservation strategy, ensuring that every major installed asset delivers its full designed lifespan.

3. OPEX Avoidance Across Utility, Maintenance, and Uptime

The ongoing operational savings from MPTS are equally compelling. Utility billing is reduced by eliminating power factor penalty surcharges and kVA demand charges. Preventive maintenance intervals are extended because equipment runs cooler and cleaner. Emergency maintenance events, the most expensive category of operational spend, are dramatically reduced as the root causes of unplanned failures are removed at source. Most significantly, the risk of costly system outages is minimized: in a data center where downtime can cost tens or even hundreds of thousands of dollars per hour, MPTS-enforced power-quality stability is a direct hedge against catastrophic revenue loss.

Taken together, the safety assurance, capital preservation, and operational savings delivered by MPTS combine to produce a return on investment that is typically achieved within one to two years, making it one of the highest-confidence infrastructure investments available to a data center operator.