

TECHNICAL PAPER

Power Management Controls System using MPTS Technology

Technical Paper for an Electrical Engineer / Professor

The MPTS Power Management Controls System is built on the principle of real-time impedance matching in polyphase (Three phase) AC networks, applying Jacobi's law of impedance (RLC) matching as its foundation.

In simple terms, Jacobi's law tells us that for maximum power transfer and minimum losses, the source impedance and load impedance should be complex conjugates. In practice, most electrical networks are rarely at this balance—due to reactive loads (motors, VFDs, transformers), nonlinear devices, and harmonic content that distort voltage/current waveforms.

How MPTS “does what it does”:

1. **Continuous Measurement & Modeling** – The system samples voltage and current waveforms thousands of times per second, building a dynamic RLC model of the connected network. This includes real power (P), reactive power (Q), apparent power (S), harmonic spectrum, and impedance at fundamental and harmonic frequencies.
2. **Dynamic Impedance Matching** – Using high-speed power electronics, MPTS absorbs the precise reactive components needed (capacitive or inductive) such that the network's effective load impedance is brought toward the conjugate of the source impedance. This creates a lowest-impedance operating point—a condition where the system naturally minimizes circulating reactive power, harmonic distortion, and losses.
3. **Phase Angle Optimization** – By actively aligning voltage and current phasors (rather than statically shifting them like capacitor banks do), or unlike active filters that rely on IGBTs, MPTS achieves this with a passive electronic network. It continuously processes and manages displacement power factor, transients, and harmonic distortion simultaneously. This restores near-unity power factor without risk of overcorrection or resonance.
4. **System-Level Impact** – The result of operating at this matched-impedance point is a measurable reduction in:
 - Apparent power (kVA) demand on transformers and feeders.
 - RMS current flow (hence, I^2R losses).
 - Harmonic circulation and waveform distortion.
 - “Thermal stress and heat buildup”- Heat rejection in motors, transformers, and switchgear.
5. **Adaptive Control** – Unlike static capacitor banks or APFC panels, or traditional power conditioners, or voltage stabilizers, or surge and spike suppressant equipment, MPTS automatically recalculates and adjusts corrections to maintain source–load impedance matching as loads change. This ensures the system remains at or near the lowest impedance point across all dynamic conditions. The major difference with MPTS technology is that it is not a [parasitical load unlike all the other technologies/products.

In short:

MPTS operationalizes Jacobi's law of impedance matching in real time.

By dynamically adjusting the electrical environment to create the most favorable impedance point between source and load, it achieves what static correction methods cannot: continuous optimization of power quality, efficiency, and system stability.

Mathematical backing — conjugate impedance matching

Per-phase model and definitions

Treat one phase of the three-phase network (per-phase analysis).

Let the source voltage (phasor, RMS) be V . Let source impedance be

$$\text{Source Impedance } Z_s = R_s + jX_s$$

and the load impedance (including whatever MPTS makes the effective load appear as) be

$$\text{Load Impedance } Z_l = R_l + jX_l$$

The line current phasor is

$$I = V / (Z_s + Z_l)$$

Real power delivered to the load (per phase) is

$$P_{\text{load,ph}} = |I|^2 R_l = |V|^2 R_l / |Z_s + Z_l|^2.$$

For a balanced three-phase system multiply per-phase results by 3.

2) Conjugate matching condition (why $Z_l = Z_s^*$ appears)

Maximizing real power $P_{\text{load,ph}}$ with respect to the complex load impedance leads to the well-known conjugate matching condition:

$$Z_l = Z_s^* \quad (\text{i.e. } R_l = R_s, X_l = -X_s).$$

Sketch of reasoning: $P_{\text{load,ph}} = |V_{th}|^2 R_l / |Z_s + Z_l|^2$. For fixed V_{th} and given the parametric freedom in Z_l , the numerator is proportional to R_l while the denominator is $|Z_s + Z_l|^2$. Varying the complex components of Z_l shows the extrema occur when the imaginary part of Z_l cancels the imaginary part of Z_s and the real parts match — i.e. $Z_l = Z_s^*$. This is the classic maximum-power transfer result for phasors.

Comment on interpretation: conjugate matching *maximizes real power transfer* from a fixed-voltage source into the load. In the context of MPTS, the system does **not** blindly force conjugate matching to increase losses — rather, it actively shifts the effective reactive terms so that the **voltage and current phasors align**, reducing net reactive exchange and apparent power (kVA) for a given real power demand. In practice the control objective can be framed as minimizing $|Z_s + Z_l|$ with constraints that avoid excessive current or thermal stress at the interface and that suppress harmonics.

3) Effect on apparent power (kVA) and currents — power factor math

Complex (apparent) power per phase:

$$S_{\text{ph}} = V_{\text{ph}} I^* = P_{\text{ph}} + jQ_{\text{ph}}.$$

For a three-phase balanced load:

$$S_{3\phi} = 3V_{\text{ph}} I^* = P + jQ, \quad |S| = \frac{P}{\text{PF}}.$$

If real power demand P is fixed, improving power factor from PF_1 to PF_2 reduces required kVA:

$$\Delta \text{kVA} = P \left(\frac{1}{\text{PF}_1} - \frac{1}{\text{PF}_2} \right).$$

And line current for three-phase:

$$I = \frac{P}{\sqrt{3} V_{\text{line}} \text{PF}}.$$

Numeric example (illustrative):

- $P = 500 \text{ kW}$, $V_{\text{line}} = 480 \text{ V}$.
- Improve PF from 0.70 to 0.96.

Compute:

$$\text{kVA}_1 = \frac{500}{0.70} = 714.29 \text{ kVA}, \quad \text{kVA}_2 = \frac{500}{0.96} = 520.83 \text{ kVA},$$

$$\Delta \text{kVA} = 193.46 \text{ kVA} \quad (27.08\% \text{ reduction}).$$

Line currents:

$$I_1 = \frac{500,000}{\sqrt{3} \cdot 480 \cdot 0.70} \approx 859.15 \text{ A}, \quad I_2 \approx 626.47 \text{ A}.$$

PF improvement → substantial kVA and current reduction.

4) Impact on I²R losses

Distribution losses scale as $I^2 R_{\text{line}}$ (three-phase):

$$P_{\text{loss}} = 3I^2 R_{\text{line}}.$$

Given $I_2 < I_1$, fractional reduction in conductor loss:

$$\frac{\Delta P_{\text{loss}}}{P_{\text{loss},1}} = 1 - \left(\frac{I_2}{I_1} \right)^2.$$

Using the example currents above:

$$1 - (626.47/859.15)^2 \approx 1 - 0.53 \approx 0.47,$$

so roughly a 47% reduction in line I²R losses (depends on R_{line} and exact currents).

5) Frequency-dependent/harmonic view

For harmonic order h with angular frequency $\omega_h = h\omega_1$, define:

$$Z_s(h), Z_l(h).$$

Harmonic current at order h :

$$I(h) = \frac{V(h)}{Z_s(h) + Z_l(h)}.$$

Thus the magnitude of harmonic currents is controlled by the frequency-dependent sum $Z_s(h) + Z_l(h)$.

MPTS's action can be viewed as shaping $Z_l(h)$ (a complex, frequency-dependent quantity) so that for problematic harmonic orders the net denominator increases (reducing harmonic currents) or the phase relationships reduce circulation between source and loads. In short: **frequency-selective impedance shaping** reduces individual harmonic currents and their circulation.

6) Putting the math back into system-level control language

- MPTS measures V and I (all relevant harmonics) to estimate $Z_s(\omega)$ and $Z_l(\omega)$ across frequencies.
- The controller computes the desirable $Z_l(\omega)$ adjustments (i.e., what reactive/inertial response to inject or absorb at each frequency) to: (a) align the dominant fundamental phasors (reduce Q), (b) minimize $|Z_s + Z_l|$ at targeted frequencies under the control policy, and (c) avoid creating resonant conditions.
- Practically this yields reduced $|S|$ (kVA), reduced RMS current, reduced I²R losses, and lower harmonic currents — consistent with the equations above.

Notes & caveats

- Conjugate matching strictly maximizes real power transfer from a *given fixed source* to a *targeted load(s)*

— but unconstrained matching can increase currents and thermal stress. In most custom solutions, this is a concern but not with the use of MPTS technology.

In power-system control, the objective is typically *minimize apparent power for a required P , minimize Q , and suppress harmful harmonics*, rather than unconstrained maximum power transfer.

The controller therefore uses the conjugate-matching principle selectively (and frequency-dependently) with constraints.

- Stability/resonance must be actively avoided:

Any frequency-shaping action must be verified against system modal responses.

This is why the MPTS control loops include safeguards and adaptive tuning.