

The Current Flows and Does No Work

— At **90** degrees of phase, **2000** VA still flows while the real power is **0** — Halve the power factor from **1** to **0.5** and the same work needs **2** times the current and **4** times the line loss — What flows and what works are two different quantities — [Paper 356]

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— *From thinking to syncing.* —

Abstract

It is tempting to think that current flowing means work being done. This paper asks whether the two are the same quantity—the answer is that they are not, and one can be zero while the other is at its maximum. No new mathematical theorem and no new law is claimed. First, at 200 V and 10 A the apparent power is **2000** VA regardless of phase (Section 2). Second, this is the core of the paper. At 90 degrees of phase the real power is **0** (Section 2). Third, 10 A still flows there, and the wire heats up exactly as much (Section 3). Fourth, halving the power factor from 1 to 0.5 multiplies the current for the same 1500 W by **2.0000** (Section 3). Fifth, and multiplies the line loss by **4.0000**, because it goes as the square (Section 3). Sixth, the separator is the phase difference, not the size of the current (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed—power factor, apparent power, reactive power, and power-factor correction are all standard. We do not build electrical engineering—three-phase circuits, unbalanced loads, and harmonic distortion theory are not entered. They are named and no more. We design no equipment—sizing power-factor correction capacitors is not the subject. We do not treat tariffs—the design of utility power-factor discounts is not the subject. Transients are not treated—only steady sinusoids; inrush current and switching are not the subject. Distorted waveforms are not treated—the definition of power factor with harmonics (distortion power factor) is named and no more. Relation to earlier papers: Paper 350 showed dead time eating the phase without touching the amplitude—there too phase alone decided the outcome. Here phase decides how much work is done. Paper 351 showed standing and sitting on a swing separated by a phase relation—the shape of one apparatus holding two mechanisms is the same. Paper 300 showed whether two things share a root is decidable—by that test, apparent power and real power have distinct roots. Paper 313 showed the corpus using “synchrony” in four senses—“power” has the same shape. What is added is giving real and reactive power at seven phase angles, showing the real power going to zero at 90 degrees while the apparent power stays 2000 VA, giving the doubled current and quadrupled loss of a halved power factor as numbers, and putting the separator on phase difference.

1. Notation and the Question

Setting: Take $V = 200$ V, $I = 10$ A, with ϕ the phase difference between voltage and current.

$$S = VI, \quad P = VI \cos \phi, \quad Q = VI \sin \phi, \quad S = \sqrt{P^2 + Q^2}$$

Observation 1.1

There are three “powers”. Apparent S , real P , reactive Q —all carry the dimension of voltage times current, yet are written VA, W, and var.

Observation 1.2

They are written apart because they are different quantities of the same dimension. Sharing a dimension does not make two things the same quantity—this paper looks at that point in numbers.

Observation 1.3

A wire heats by current. The loss is $I^2 R$, fixed by I and not by P —a current doing no work heats the wire exactly as much.

Question: Is what flows the same quantity as what works?

2. At 90 Degrees the Work Goes to Zero

Calculation 2.1: The three powers against phase (computed in this paper).

Phase [deg]	Power factor $\cos \phi$	Real power [W]	Reactive power [var]
0	1.000000	2000.00	0.00
15	0.965926	1931.85	517.64
30	0.866025	1732.05	1000.00
45	0.707107	1414.21	1414.21
60	0.500000	1000.00	1732.05
75	0.258819	517.64	1931.85
90	0.000000	0.00	2000.00

Observation 2.2

This is the core of the paper. At 90 degrees the real power is **0**—neither the voltage nor the current has fallen at all, and only the work disappears.

Observation 2.3

The apparent power stays **2000 VA**. $\sqrt{P^2 + Q^2} = 2000.0000$ VA— P has merely moved into Q ; the total has not budged.

Observation 2.4

The ammeter goes on reading 10 A. An ammeter knows nothing of phase——watch only the needle and the vanishing of the work is invisible.

Observation 2.5

The same shape as Paper 350. There a dead time at the phase without touching the amplitude——here phase alone decides the work. In both, an instrument that measures size cannot see it.

3. Halve the Power Factor, Quadruple the Loss

Calculation 3.1: Current and loss needed to deliver the same 1500 W (computed in this paper).

Power factor	Current ratio	Line loss I^2R ratio	Phase [deg]
1.0000	1.0000	1.0000	0
0.5000	2.0000	4.0000	60

Observation 3.2

Twice the current, four times the loss. Because loss goes as the square of current——halving the power factor raises the burden in two stages.

Observation 3.3

That fourfold is heat nobody uses. The real power is still 1500 W——the added threefold goes entirely into warming the transmission line.

Observation 3.4

Which is why utilities watch the power factor. The same work needs thicker wire——plant capacity is fixed by S , not by P .

Observation 3.5

Sixty degrees is not an extreme condition. A power factor of 0.5 appears routinely in a lightly loaded induction motor——90 degrees is an idealisation, but 60 is a field value.

4. Same Dimension, Different Quantity

Observation 4.1

P , Q and S share a dimension. All are $[ML^2T^{-3}]$ ——they are still written W, var and VA, because they cannot be added.

Observation 4.2

P and Q add orthogonally. $S = \sqrt{P^2 + Q^2}$, not $S = P + Q$ ——at 45 degrees $P = Q = 1414.21$, and S is 2000, not 2828.

Observation 4.3

Distinct roots by the criterion of Paper 300. Agreement of dimension is not evidence of a shared root——this is the dimensional version of Paper 300's “agreement of numbers alone does not establish a shared root”.

Observation 4.4

To be stated honestly——calling reactive power “waste” goes too far. It is needed to build magnetic fields, and motors turn on it——what is wasteful is carrying it from far away, which is why correction is done near the source.

5. The Separator: Phase Difference

Observation 5.1

The separator—the phase difference between voltage and current, not the size of the current.

Phase	Current	Real power	Heating of the wire
0 deg	10 A	2000 W	the same
90 deg	10 A	0 W	the same

Observation 5.2

The left and right columns agree and only the middle differs. Neither the current nor the heating changes, and the work goes from 2000 W to 0 W—one quantity, the phase difference, moves that and nothing else.

Observation 5.3

The separator can be moved. Put a capacitor in parallel and the phase difference shrinks—not by reducing the current but by aligning its direction with the voltage. That is the content of power-factor correction.

Observation 5.4

Set the phase to 0 and the reactive power is zero too. Because $\sin 0 = 0$ —a check that the formula is doing the work.

Observation 5.5

To be stated honestly—2000 VA and the factor 4.0000 are values at 200 V and 10 A stated explicitly. Another circuit gives other numbers—what does not move is only that loss goes as the square of current and that the real power vanishes at 90 degrees.

Observation 5.6

One last thing——no single instrument can tell “flowing” from “working”.The ammeter goes on reading 10 A——telling them apart needs an instrument that measures the phase between two quantities. A tool that measures a quantity and a tool that measures a relation are different tools.

6. The Census and the Close

1. Apparent power 2000 VA (Section 1): independent of phase.
2. Real power 0 at 90 degrees (Calculation 2.1): only the work disappears.
3. $\sqrt{P^2 + Q^2} = 2000.0000$ VA there (Observation 2.3): the total has not budged.
4. The ammeter reads 10 A (Observation 2.4): it knows nothing of phase.
5. Power factor 0.5 gives 2.0000 times the current (Calculation 3.1): for the same 1500 W.
6. And 4.0000 times the loss (Calculation 3.1): it goes as the square.
7. At 45 degrees $P = Q = 1414.21$ (Observation 4.2): S is 2000, not 2828.
8. Same dimension, different quantity (Observation 4.1): they cannot be added.
9. Phase 0 gives zero reactive power (Observation 5.4): the formula is doing the work.
10. Reactive power is not waste (Observation 4.4): carrying it far is.

Closing: It is tempting to think that current flowing means work being done——and with direct current that is right. With alternating current the two are different quantities——at 200 V and 10 A the apparent power is 2000 VA regardless of phase, but at 90 degrees the real power is 0. Neither the voltage nor the current has fallen at all, and only the work disappears. $\sqrt{P^2 + Q^2} = 2000.0000$ VA is unchanged — P has merely moved into Q . And the ammeter goes on reading 10 A——because an ammeter knows nothing of phase, and watching only the needle, the vanishing of the work is invisible. The line loss is $I^2 R$, so a current doing no work heats the wire exactly as much. The burden rises in two stages——halve the power factor from 1 to 0.5 and delivering the same 1500 W takes 2.0000 times the current and 4.0000 times the line loss, because loss goes as the square of current. The real power is still 1500 W, so the added threefold goes entirely into warming the transmission line. A power factor of 0.5 (a phase of 60 degrees) is a field value, appearing routinely in a lightly loaded induction motor. Sharing a dimension does not make two things the same quantity—— P , Q and S all carry the same dimension, yet $S = \sqrt{P^2 + Q^2}$ and not $S = P + Q$. At 45 degrees $P = Q = 1414.21$ and S is 2000, not 2828. This is the dimensional version of Paper 300’s “agreement of numbers alone does not establish a shared root”. One thing separates them——the phase difference between voltage and current, not the size of the current. At 0 degrees and at 90 degrees the current and the heating are identical, and only the work moves from 2000 W to 0 W. So correction works not by reducing the

current but by aligning its direction with the voltage. To be said honestly——calling reactive power “waste” goes too far: it is needed to build magnetic fields and motors turn on it. What is wasteful is carrying it from far away, which is why correction is done near the source. The 2000 VA and the factor 4.0000 hold at 200 V and 10 A. One last thing——no single instrument can tell “flowing” from “working”. Telling them apart needs an instrument that measures the phase between two quantities. A tool that measures a quantity and a tool that measures a relation are different tools.

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