

Optimizing the Efficiency of Electrical Distribution Systems and their Loads reduces Energy Consumption and Utility Costs

Much has already been done to save electrical energy and reduce utility costs. Early on, inefficient load replacement and load management were seen as 'low hanging fruit'. The question is, are there any unclaimed 'gold nuggets'?

Beyond the savings typically achieved, PQI has succeeded in further reducing utility costs by reducing the Penalty Losses in electrical distribution systems and their loads. This is the wasted energy you may not have thought about – the valuable unclaimed 'gold nuggets'.

What are these Penalty Losses? – Penalty Losses are defined as consumed power that does not contribute directly to the intended work. Unavoidable transformer, circuit and load losses at 60Hz are excluded.

Penalty Losses in the Circuits

A distribution system's circuit Penalty Losses include losses due to reactive load currents, unbalanced load currents, load-generated harmonic currents and neutral currents.

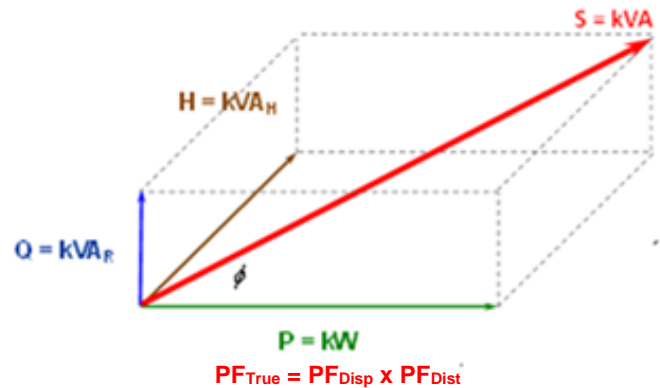
While the relationship between harmonics, reactance and 'penalty losses' is complex and difficult to generalize, the well-established concept of Power Factor does provide a measure of the relationship, if harmonics are incorporated into the Power Factor definition, as shown in *Figure 1*.

Penalty Losses in the Loads

Load Penalty Losses include losses due to distortion of the supply voltages' sinusoidal waveforms. In an Ohms Law relationship with the distribution system's harmonic impedances, harmonic currents generate harmonic voltages which distort the fundamental voltage waveform.

The Calculation of Circuit and Load Penalty Losses

With reference to *Figure 2*, we now have a tool to measure 'penalty losses' in a circuit. However, as an alternative to measuring or estimating 'penalty losses' in individual circuits and loads, PQI has developed the mathematical tools and procedures for conservatively estimating 'penalty losses' based on measured or historical True, Displacement and Distortion Power Factors.



Three-Dimensional Vector Diagram

Figure 2

The PQI Solution™

These mathematical equations have now been incorporated into The PQI Calculator™ under Circuit and Load Penalty Losses, as shown in *Figure 3*. In addition to comparing the performance of a conventional distribution transformer and a Power or Distribution TransFilter™, the impact of circuit and load 'penalty losses' mitigation can be included to produce a combined financial and environmental benefit.

Given a complete set of One-Line Diagrams, Panel Schedules and Architectural Drawings for a proposed new system, our engineers can develop a conservative estimation of each transformer's load characteristics, including P in kW, PF_{DISP} , PF_{DIST} and PF_{TRUE} . These estimations are then compared to published and historical information found in:

- The CSA C802.4 and C802.5 Guides
- The Cadmus Group Survey Results
- The nationalgrid Transformer Replacement Program Guide and
- Historical outcomes for similar system configurations and load profiles

Improving efficiency significantly reduces energy consumption and utility costs. PQI offers engineered energy optimized solutions to consulting engineers, facility managers+---- and ESCOs on a 'no charge basis.

ENERGY LOSS CALCULATOR			
	Total	Loss	Cost
Effective	3.92 kW	204 U	0.02 \$/hr
Reactive	-0.52 kvar	4 U	0.00 \$/hr
Unbalance	0.18 kVA	0 U	0.00 \$/hr
Distortion	2.48 kVA	81 U	0.01 \$/hr
Neutral	21.1 A	218 U	0.03 \$/hr
Total			533.5 \$/yr

07/26/14	12:51:42	120V 60Hz 3Ø WYE	ENS0160
CU LENGTH	DIAMETER	METER	RATE
200 ft	12 AWG		0.12 /kWh
			HOLD
			RUH

204W Unavoidable 60Hz Losses
4W Penalty Losses

81W Penalty Losses
218W Penalty Losses
303W Total Penalty Losses (TPL)

TPL as a % of Effective kW (3.92)
 $(303 \times 100) / 3920 = 7.73\%$

FLUKE Model 435, Series 2
Power Quality and Energy Analyzer
Figure 2

The PQI Calculator™										
Circuit and Load Penalty Losses										
Pre-Mitigation										
kVA Rating	Xfmr Load %	PF _{Dist}	kVA	kW	Losses Mult.	Unavoidable 60Hz Losses (W)		Total Losses (W)	Annual Cost (\$)	
						5%	of Xfmr Load (W)		Cost of Energy = \$ / kWh	
75	15.00%	0.65	11.2500	7.3100	2.37		365.5	501.0	\$0.14	
									\$614.43	
Post-Mitigation										
kVA Rating	Xfmr Load %	PF _{Dist}	kVA	kW	Losses Mult.	Unavoidable 60Hz Losses (W)		Total Losses (W)	Annual Cost (\$)	
						5%	of Xfmr Load (W)		Cost of Energy = \$ / kWh	
75	9.56%	0.95	7.1670	6.8090	1.11		340.5	37.5	\$0.14	
									\$45.93	
								kWh	Annual Cost (\$)	
								Savings	Savings	
								4061	\$568.50	

The PQI Calculator
Circuit and Load Penalty Losses
Figure 3

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