PQI
POWER QUALITY INTERNATIONAL

Exclusive e-Rated® Provider

POWER QUALITY INTERNATIONAL

PRODUCT APPLICATION GUIDE

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The Electrical Distribution System and Load Efficiency Problem
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PQI ACCOMPLISHMENTS IN POWER MAGNETICS

1965 – The Model XRB-2 Transformer Ratiometer™
1973 – The Model TCB-100 Capacitance – Dissipation Factor Bridge™
1982 – PDA-H Partial Discharge Analyzer™
1983 – Three-Phase Harmonic Analyzer
1986 – I_0Filter™
1990 – Distribution TransFilter™
1991 – HarMitigators™
2000 – Mini-Z
2001 – The PQI Solution™

US DOE 2016 Efficiency Requirements

For those who may not be aware, on April 18th, 2013, the United States Department of Energy (U.S. DOE) released the official Federal Register version of its Final Rule regarding Distribution Transformer minimum energy efficiency standards, formally referred to as, *'10 CFR Part 431 Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule'*. To quote the notice, 'The effective date of this rule is June 17, 2013. Compliance with the amended standards established for distribution transformers in this final rule is required as of January 1, 2016'.

What exactly does this mean to the transformer industry? In summary, it means that the NEMA TP 1 - 2002 standard for transformer efficiency remained in effect until December 31, 2015. On January 1, 2016, higher minimum levels for transformer efficiencies went into effect, requiring that all transformer manufacturers met or exceeded new minimum levels. Although the new U.S. DOE 2016 levels are higher than the previous NEMA TP 1 levels, they still don't quite meet some minimum efficiency levels previously proposed by the U.S. DOE in 2004, specifically DOE CSL 3, CSL 4 and CSL 5.

PQI Already Exceeds US DOE 2016 Requirements

Despite the fact that minimum efficiency levels that meet or exceed the new DOE 2016 legislation were not mandated until January 1, 2016, PQI has been designing and manufacturing ultra-efficient transformers that exceed the new minimum levels for nearly a decade, specifically DOE CSL 3 efficient transformers. As part of our continuous efforts to stay ahead of our competitors and the transformer industry in general, PQI is proud to announce that even higher efficiencies beyond DOE CSL 3 levels are now also available.

As of January 1, 2016, PQI's Type EY distribution transformers and Types DV, SY and DD harmonic mitigating transformers, with an ***e-Rated***® option, were available with a Z3 (DOE CSL 3), Z3+ (slightly higher than DOE CSL 3) or Z4 (DOE CSL 4) efficiency. All PQI transformers with a Z3, Z3+ or Z4 rating exceed the DOE 2016 efficiency requirements. These levels are unprecedented in the industry.

Table 1, entitled the 'Required vs. PQI e-Rated® Energy Efficiencies', provides a comparison between NEMA TP 1, NEMA Premium, DOE 2016 vs. PQI Z3, PQI Z3+ and PQI Z4 efficiency levels

In order to reduce Excitation (No Load) Losses, the PQI Z3, PQI Z3+ and PQI Z4 energy efficiencies were achieved by selecting higher grade, grain oriented magnetic core steels

.

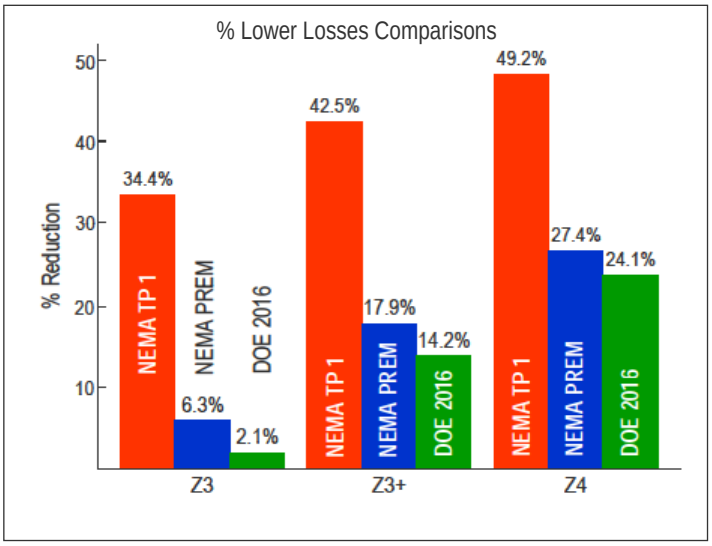
Required vs. PQI Energy Efficiencies [1]

kVA Rating	NEMA TP 1 2002 [2] CSA C802.2	NEMA Premium [2]	DOE 2016 [3]	PQI Z3 exceeds CSL 3 [4]	PQI Z3+	PQI Z4 exceeds CSL 4 [4]
15	97.00	97.90	97.89	97.97	98.25	98.43
30	97.50	98.25	98.23	98.29	98.52	98.68
45	97.70	98.39	98.40	98.45	98.66	98.81
75	98.00	98.60	98.60	98.64	98.82	98.95
112.5	98.20	98.74	98.74	98.77	98.93	99.05
150	98.30	98.81	98.83	98.86	99.01	99.12
225	98.50	98.95	98.94	98.97	99.10	99.20
300	98.60	99.02	99.02	99.04	99.16	99.26
500	98.70	99.09	99.14	99.16	99.26	99.35
750	98.80	99.16	99.23	99.24	99.33	99.41
1000	98.90	99.23	99.28	99.29	99.38	99.45

Table 1

Notes: [1] Efficiency values are measured at 35% of nameplate rating.
[2] The efficiency of transformers manufactured after January 1, 2007, but before January 1, 2016 must meet the efficiency requirements of NEMA TP 1-2002 (US) or CSA C802.2-12 (Canada).
[3] The efficiency of transformers manufactured after January 1, 2016 must meet the US DOE 2016 efficiency requirements.
[4] PQI Z3 & Z4 efficiencies exceed the requirements of DOE Candidate Standard Levels 3 & 4 (CSL 3 & CSL 4) respectively.

Ultra-Low Losses



Transformers with Z3, Z3+ & Z4 Efficiencies
vs.
NEMA TP 1, NEMA Premium™ & US DOE 2016 Efficiencies
Figure 1

and by improving core architectures. Impedance (Load) Losses were reduced by improving winding architectures.

The Reduction in Total Losses (No Load + Load Losses), required to achieve the results given in *Table 1,* are detailed in *Figure 1.*

The Measurement of Total Losses & Efficiencies under Linear & Nonlinear Loading

Please contact PQI for application recommendations and costs for the various efficiencies offered.

UL Certificate of Compliance

Power Quality International, LLC has successfully completed the 2 year long life-cycle testing of its insulation system for Cast Coil Transformers and received a UL Certificate of Compliance per UL1562 and IEEE Std. C57.12.01-2005 standards. PQI can now display an Underwriters Laboratories (UL) logo for Cast Coil Transformers up to 10MVA, 34.5kV, 180°C Insulation Class.

Power Quality International has produced Canadian Standards Association (CSA) Approved Cast Coil Transformers since 1997 with numerous installations across North America and around the world.

The addition of UL Certification in addition to CSA Approval is a testament to the enviable track record of quality, performance and reliability of Power Quality International's Cast Coil Transformers

CSA & UL Qualification as a Test Facility

Both CSA and UL have approved PQI's Concord, Ontario manufacturing facility as a Qualified Product Evaluation and Test Facility**.** Measurements and test data generated during product evaluation is now accepted by both CSA and UL for product approval. We are proud of this achievement which reflects their confidence in our measurement and test capabilities, and in our professionalism when generating accurate and reliable evaluations.

Cast-Coil Assembly fr om a Power TransFilter™

Seismic Qualification and Pre-Certification

Power Quality International's Medium and Low Voltage Class, Dry-Type and Cast-Coil Transformers have been 'shake table' tested for seismic withstand capability. These steps were undertaken in an effort to better serve the needs of the US Department of Defense, and our clients in California and other locations in North America where OSHPD Seismic Pre-Certification is required for transformers and other power distribution devices. It gives us great pleasure to announce that we have received Seismic Pre-Certification for all of our Medium and Low Voltage Class, Dry Type and Cast-Coil Transformers.

To accommodate our largest transformers, which weigh more than 26,000 lbs., a military laboratory was selected to perform the 'shake table' tests.

The sample selection and test criteria were planned in accordance with the requirements of the International Building Code 2012 (IBC2012), the California Building Code 2013 (CAB2013) and the National Building Code of Canada 2010 (NBC2010). In addition, the transformers specifically met the requirements of OSHPD (Office of Statewide Health Planning and Development of California). As previously mentioned, OSHPD has a program to 'pre-certify' devices, based on actual shake table testing.

OSHPD insists that all devices, including transformers, installed in California hospitals and related facilities are 'pre-certified' by OSHPD. Generally speaking, nearly all other new construction in California is also specifying OSHPD Seismic Pre-Certification as a requirement.

A detailed test report was prepared by an independent engineering firm detailing the test parameters and the

maximum limits of seismic withstand capability that the sample products successfully demonstrated. Based on and supported by this report, PQI is now able to qualify and certify its products for seismic withstand capability and also provide formal certificates (product and/or installed geographic location specific) when specified by customers.

As required by the aforementioned codes, PQI transformers demonstrated their ability to function after the seismic tests.

- From 85 lbs. (7.5 kVA) to 748 lbs. (1500 kVA) Seismic Certification Limits – SDS=2.5g, z/h=1.0, Ip=1.5
- From 748 lbs. (55 kVA) to 21,950 lbs. (8500 kVA) Seismic certification Limits – SDS=2.1g, z/h=1.0, Ip=1.5

PQI can provide unit and/or geographic site specific Seismic Qualification and Compliance Certificates when specified.

For additional information contact Power Quality International, LLC.

Dry-Type Coil Assembly from a Power TransFilter™

NOTE: These certification limits apply for solid base mounted transformers. Seismic requirements of anchors and anchoring requirements should be addressed by building and site engineers. Complete installation site and appliance specific analysis can be performed to determine anchoring and anchoring bed detail recommendations at additional cost.

Type TM Integrated Transformer Performance Meters

Type TM Integrated Performance Meters™ are installed on all PQI e-Rated™ Distribution Class Transformers. In addition to their revenue class metering and data logging capabilities, these integrated meters, with CSA C802.5 compliant software, determine each transformer's Total Losses and Energy Efficiency under their measured nonlinear loading profiles.

In addition, PQI's IEEE Std. C57.110 compliant software also determines each transformer's No-Load Losses and Load Losses, including its nonlinear 'Penalty Loss' component, and EPA Environmental Benefits. In its 'Transformer Comparison mode', given the cost of each transformer and the cost of energy, the software will compare the performance of any two transformers, including A/C costs, and calculate an annual saving, payback and return-on-investment, in a 'substitution' or a 'before end-of-life replacement' scenario.

These best-in-class multifunction power and energy meters may also be used as data gathering devices for intelligent electrical distribution or plant automation systems. All monitored data is available via a digital RS485 communication port running Modbus RTU and DNP 3.0 protocols.

Additional communication options include Ethernet, Profibus DP, and BACnet. With its flexible, modular I/O and communication options, the Type TM metering system is the most versatile and cost-effective solution available. With these capabilities, the Type TM Integrated Performance Meter is LEED® Qualified for EA Credit Points.

Integrated Transformer Performance Meter

Type DV Distribution TransFilter™ for Single-Phase Nonlinear Loads

Type DV Harmonic Mitigating Transformers for single-phase nonlinear loads are ultra-efficient, three-phase, single or dual output harmonic mitigating transformers that have been specifically designed to supply phase-to-neutral connected, nonlinear electronic loads. When correctly applied, these transformers reduce voltage distortion to less than 5% THD_V and eliminate the network communication problems caused by high neutral-to-ground voltages at the loads.

Application – Type DV Distribution TransFilters™, in low to medium kVA ratings, are typically used as 'stand-alone' solutions; that is, without the application of zero-sequence harmonic filters. High kVA ratings may also be used as 'stand-alone' solutions if total secondary circuit length and/or loading can be controlled. Maximum circuit length and/or loading can be determined by referring to the '*Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Non-Linear Electronic Workstation Loads*' graph [1], which is available upon request.

Distribution TransFilter™

Type GY Distribution TransFilter™ for 240-Volt Gaming Machine Loads

Type GY Distribution TransFilters™ are ultra-efficient, three-phase, single or dual output harmonic mitigating transformers that have been specifically designed to supply phase-to-phase connected 230-volt and 240-volt gaming machines. These transformers reduce voltage distortion to less than 4% THD_V at the gaming machines and eliminate the potential network communication problems experienced by phase-to-neutral connected machines. When supplied at 208-volts, gaming machines' switch-mode power supplies operate at the low end of their voltage bandwidth. Supplying these units at 240-volts will typically reduce their load current by 13% and their I^2R losses by 25%. Voltage optimization reduces losses and heat, and increase efficiency and system capacity.

Application – Type GY transformers may be used as 'stand-alone' solutions, when supplying phase-to-phase connected gaming machines.

Type RV Distribution TransFilters™ for Remote Load Centers

Type RV Harmonic Mitigating Transformers are ultra-efficient, three-phase, dual output distribution transformers that have been specifically designed to supply phase-to-neutral connected nonlinear electronic loads that are supplied by Remote Load Centers. These transformers reduce voltage distortion to less than 5% THD_V at their loads. These patented transformers also cancel the zero-sequence harmonic neutral currents in the two 'shared neutral' feeder circuits that supply their Remote Load Centers. This characteristic significantly reduces neutral-to-ground voltage at the Remote Load Centers and their loads.

Application – Type RV transformers are typically used as 'stand-alone' solutions; that is, without the application of zero-sequence harmonic filters, if total secondary circuit length and/or loading can be controlled. Maximum circuit length and/or loading can be determined by referring to the '*Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Non-Linear Electronic Workstation Loads*' graph.

Type SY Distribution TransFilters™ for 240-Volt Server Loads

Type SY Harmonic Mitigating Transformers are ultra-efficient, three-phase, single or dual output distribution transformers that have been specifically designed to supply phase-to-phase connected 230-volt and 240-volt server loads. These transformers reduce voltage

distortion to less than 5% THD_V at the servers and eliminate the potential network communication problems experienced by phase-to-neutral connected servers. When supplied at 208-volts, servers' switch-mode power supplies operate at the low-end of their voltage bandwidth. Supplying these units at 240-volts will typically reduce the servers' load currents by 13% and their I^2R losses by 33%. Voltage optimization reduces losses and heat, and increases efficiency and system capacity.

Application – Type SY Distribution TransFilters™ may be used as 'stand-alone' solutions, when supplying phase-to-phase connected servers.

Type EY Distribution Transformers for Linear through High K-Factor Loads

Type EY Distribution Transformers are ultra-efficient, three-phase, single output distribution transformers that have been specifically designed to supply linear or nonlinear electronic loads. These transformers exceed the energy efficiency requirements of NEMA TP1-2002, CSA C802.2-00 and US DOE Candidate Standard Level 3, 3+or 4. The transformers are available in standard K-factor ratings of K1, K4, K9 & K13.

Application – Type EY transformers may be used as a preferred alternative to conventional DOE 2016 transformers. Type EY transformers may also be used in power quality solutions, which include the application of zero-sequence harmonic shunt or series filters, when supplying phase-to-neutral connected nonlinear loads, if total secondary circuit length and/or loading cannot be controlled. Maximum circuit length and/or loading can be determined by referring to the '*Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Non-Linear Electronic Workstation Loads*' graph [1], which is available upon request.

APPLICATION GUIDE

Transformer Type	General Purpose		Harmonic Mitigating	
PQI Product	*Type T*	*Type EY **e-Rated**®*	*Type DV, GY, RV, SY **e-Rated**®*	
Energy Efficiency	*Standard Efficiency US DOE 2016*	*Ultra-Efficiency PQI Z3, Z3+, Z4*	*Standard Efficiency US DOE 2016*	*Ultra-Efficiency PQI Z3, Z3+, Z4*
BENEFITS				
Low First Cost				
Reduced Power Cost				
Ultra-Low Core Losses				
Reduced No-Load Losses due to Harmonics				
Reduced Transformer Heating & A/C Costs				
Reduced THD_V (<5%) due to Harmonics				
Reduced Load Losses due to THD_V				
Reduced Circuit Heating & A/C Costs				
Improved S-M Power Supply 'Ride-Through'				
Improved Primary Phase Current Balance				
Assured System – Load Compatibility				

Note: The foregoing is intended as a general application guide for the selection of the most appropriate transformer type. However, to optimize the performance of a distribution system and its loads, PQI supports the application of its products with engineering assistance on a free-of-charge basis. To provide this service, PQI requires 'as proposed' or 'as built' one-line diagrams and detailed panel schedules. If the system designer incorporates PQI's recommendations, PQI will guarantee an IEEE Std 519 outcome throughout the distribution system.

Type Z Zero-Sequence Harmonic Shunt Filter for High K-Factor Phase-to-Neutral Connected Loads

Type Z Zero-Sequence Harmonic Filters are ultra- effective, three-phase, four-wire, passive electromagnetic shunt filters with ultra-low zero-sequence impedance. These filters have been specifically designed to provide a parallel path for all zero-sequence harmonic currents that are generated by phase-to-neutral connected nonlinear electronic loads.

Application – Type Z parallel connected shunt filters are normally applied at branch circuit sub-panels, via a coordinated three-phase molded case circuit breaker, if the sub-panels are supplied by Type DV Harmonic Mitigating Transformers or, conventional transformers, and/or long 120/208-volt feeder circuits. Maximum allowable branch circuit length and/or loading can be determined by referring to the '*Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Non-Linear Electronic Workstation Loads*' graph [1], which is available from PQI.

Type YZ Zero-Sequence Harmonic Series Filters for High K-Factor, Phase-to-Neutral Connected Loads

Type YZ Zero-Sequence Harmonic Filters are three-phase, four-wire, passive electromagnetic series filters, with ultra-low load-side zero-sequence impedance but high line-side zero-sequence impedance. These filters have been specifically designed to provide a parallel path for all zero-sequence harmonic currents that are generated by phase-to-neutral connected nonlinear electronic loads. Type YZ filters can also be used to cancel positive- and negative-sequence harmonic currents.

Type Z™ Zero-Sequence Harmonic Filter

Application – Type YZ series connected shunt filters are normally applied at the load-end of long feeder circuits (i.e. at the line-side of sub-panels), if the sub-panels are supplied by Type DV Harmonic Mitigating Transformers or, conventional transformers, and/or long 120/208-volt feeder circuits. Maximum allowable branch circuit length and/or loading can be determined by referring to the '*Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Non-Linear Electronic Workstation Loads*' graph [1], which is available from PQI.

Type Mini-Z™ Zero-Sequence Harmonic Shunt Filter

Type Mini-Z® Zero-Sequence Harmonic Shunt Filters for the Load-End of 3Ø, 4W or 6W Branch Circuits

Type Mini-Z® Zero-Sequence Harmonic Filters are ultra-effective, three-phase, four- or six-wire, passive electromagnetic shunt filters with ultra-low zero-sequence impedance. These filters have been specifically designed to provide a parallel path for all zero-sequence harmonic currents that are generated by phase-to-neutral connected nonlinear electronic loads.

Application – Type Mini-Z® filters are normally applied at pre-wired office partitions, 'home run' junction boxes and equipment racks, via an internal three-phase molded case circuit breaker, if the non-linear electronic loads are supplied by Type DV Harmonic Mitigating Transformers or conventional transformers with long 120/208-volt feeder and/or branch circuits.

Type DD *Drive TransFilter*™ for Motor Drive Loads

Type DD Harmonic Mitigating Drive TransFilters™ are ultra-efficient, three-phase, four-wire, single or multiple-output drive isolation transformers that have been specifically designed to supply three-phase, three-wire, nonlinear adjustable speed drives (ASD). These transformers reduce voltage distortion to less than 5% THD_V at their loads. Although not specifically required by the ASD, the X_0 terminals of these transformers are

normally grounded in order to prevent phase-to-ground voltage excursions beyond the √3 value of the phase-to-phase voltage, a common cause of ASD failure under system fault conditions.

Application – Type DD Drive TransFilters™ may be used as 'stand-alone' solutions, when supplying phase-to-phase connected adjustable speed drives.

Motor Guard Filters™ for Motors that are supplied by Remote PWM Drive

Pulse width modulated motor drive output filters are LCR networks have been specifically designed to mitigate the steep voltage wave front produced by the PWM adjustable frequency drives and to limit voltage reflection in long circuits connecting AFDs to their motors.

Application – Motor Guard Filters may be used as 'stand-alone' solutions when the circuit connecting the PWM adjustable frequency drives to the motors are greater than 150 feet

Type HQ Active HarmVar Filters™ for Harmonic Current Mitigation and VAR Compensation for a Leading or Lagging True Power Factor Condition

Type HQ Active HarmVar Filter™

The Type HQ Active HarmVar Filter optimizes power system performance by combining the use of proven IGBT technologies with leading edge DFT/FFT algorithms enabling the simultaneous and/or discrete execution of harmonic (VAR_H) and reactive (VAR_Q) compensation methods in real-time.

The active filter's unique design and unequaled performance enable it to be successfully applied in virtually any power distribution system where power quality, reliability and efficiency are essential. Depending upon its location within the system, the filter can provide harmonic or reactive VAR compensation for the entire system or specific loads.

Type MY Distribution Transformers for 240-Volt Motors

Type MY Harmonic Mitigating Transformers are ultra-efficient, three-phase, single or dual output distribution transformers that have been specifically designed to supply phase-to-phase connected 230-volt and 240-volt motors. These units provide a voltage that is within the motors' required bandwidth, reducing their load current and I^2R losses. Type MY transformers can also be applied as harmonic mitigating transformers when the motors are controlled by harmonic-generating AC or DC Drives.

Application – Type MY transformers may be used as 'stand-alone' solutions, when supplying phase-to-phase connected motors and/or motor drives.

Type T, K-Rated Distribution Transformers Exceed DOE 2016 Efficiency Requirements

Type T, K-Rated Distribution Transformers are three-phase, single output distribution transformers that have been specifically designed to supply linear or nonlinear electronic loads. These transformers exceed the energy efficiency requirements of US DOE 2016. Type T transformers are available in standard K-factor ratings of K1, K4, K9 & K13.

Application – Type T transformers may be used as a preferred alternative to conventional DOE 2016 transformers.

Type PV Power TransFilters™ for High Capacity Dimmable Lighting Systems

Type PV Harmonic Mitigating Dry-Type or Cast-Coil Power Transformers for high K-Factor loads are ultra-efficient, three-phase, single or dual output harmonic mitigating transformers that have been specifically designed to supply phase-to-neutral connected, nonlinear electronic loads. When correctly applied, these transformers reduce voltage distortion to less than 5% THD_V.

Application – Type PV Power TransFilters™ are typically used as 'stand-alone' solutions; that is, without the application of zero-sequence harmonic filters, to supply high capacity, dimmable lighting systems in large, live performance theaters.

Type PY Power TransFilter™ for Medium K-Factor Loads

Type DV Harmonic Mitigating Dry-Type or Cast-Coil Power Transformers for medium K-Factor loads are ultra-efficient efficiency, three-phase, single or dual output power transformers that have been specifically designed to supply phase-to-phase and phase-to-neutral connected, nonlinear electronic loads. These transformers reduce voltage distortion to less than 5% THD_V and eliminate the network communication problems caused by high neutral-to-ground voltages at the loads.

Application – Type PY Power TransFilters™ may be used as 'stand-alone' solutions, when supplying phase-to-phase connected nonlinear loads, or phase-to-neutral

Dry-Type & Cast-Coil Power TransFilter™

connected nonlinear loads, when used in combination with Type Z Zero-Sequence Harmonic Filters. if total secondary circuit length and/or loading cannot be controlled. Maximum circuit length and/or loading can be determined by referring to the '*Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Non-Linear Electronic Workstation Loads*' graph, which is available upon request.

The Electrical System and Load Efficiency Problem

'Penalty losses' are defined as consumed power that does not contribute directly to the intended work.

Note: Normal circuit and transformer losses at 60Hz [50Hz] are excluded.

Distribution system 'penalty losses' include losses due to reactive load currents, unbalanced load currents, nonlinear load-generated harmonic currents and zero-sequence neutral currents. 'Penalty losses' also include excessive excitation [no-load] losses in oversized power and distribution transformers and elevated impedance [load] losses due to nonlinear load-generated harmonic currents.

Load 'penalty losses' include losses due to distortion of the supply voltages' sinusoidal waveforms and losses due to low voltage, when the loads are electronic.

The PQI Solution ™

IEEE 519-1992 compliance is the first step towards reducing energy consumption. Harmonic current reductions in the distribution system and voltage distortion improvement at the loads are essential.

Given a facility's electrical distribution system drawings, panel schedules and load types, PQI engineers will identify the 'penalty losses' that may impact power quality and diminish system and load efficiencies. Analysis software will then be used to quantify these 'penalty losses' and simulate any proposed system and/or apparatus revisions.

In North America, low voltage distribution systems typically include dry-type distribution transformers. Fortunately, harmonic mitigating transformer alternatives can be used to reduce load-generated harmonic currents in the distribution system and reduce voltage distortion at their source and loads. They can also be designed to function as primary phase current balancers that reduce or even eliminating secondary zero-sequence harmonic neutral currents.

PQI engineers use IEEE Std. C57.110 and CSA C802.5 compliant engineering software (The PQI Calculator™) to quickly and accurately determine and compare the excitation, impedance and total losses, and efficiencies of any two transformers under any anticipated or measured nonlinear load profile. The software can also be used to compare an existing and proposed transformer in a replacement scenario.

Given the cost of each transformer or a single transformer in a replacement scenario and the utility rates, the software calculates the annual energy savings, including A/C costs, payback and return-on-investment on incremental or replacement costs, return-on-investment and EPA environmental benefits.

Power Quality International offers its engineering services, in support of its products, on a 'no charge' basis to system designers.

With the implementation of our proposals, PQI will guarantee compliance with IEEE Std. 519-1992 recommendations regarding voltage distortion at the utility's 'point of common coupling' and the system's loads. Given sufficient information in a 'new construction scenario', PQI will also provide the financial estimates and EPA benefits detailed in The PQI Solution™.

Given sufficient information in a transformer replacement scenario, PQI will guarantee a financial outcome and act on behalf of the facility owner to obtain any available rebates offered by the local electrical utility.

PQI ACCOMPLISHMENTS IN POWER MAGNETICS

With its technical and manufacturing 'know how', PQI was first to develop and commercialize a number of leading-edge power magnetic technologies and products. These accomplishments, some of which are listed here, provide cost-effective solutions to various technical, power quality and energy efficiency problems.

1965 – The founder of PQI, while an employee of Ontario Hydro-Electric Power Commission, developed the first Three-Phase Transformer Ratiometer. This instrument measured the true turns-ratio of any single- or three-phase power transformer, distribution transformer or voltage transformer with an accuracy of 1 turn in 100,000 (±0.001%) or a current transformer, with an accuracy of 1 turn in 10,000 (±0.01%). The instrument was also capable of detecting internal impedance changes, such as loose connections, burned tap-changer contacts or turn-to- turn insulation deterioration.

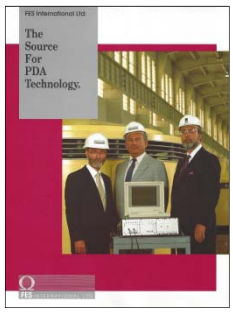
The Model XRB-2 Transformer Ratiometer™, after 50 years of service, remains the most accurate and reliable field instrument for confirming a transformer's turn-to-turn windings ratio.

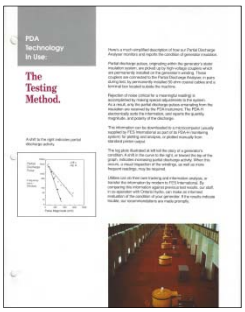
1973 – First to develop a compact, lightweight, precision Low Voltage, Capacitance – Dissipation Factor Bridge for accurately measuring the dielectric properties of the insulation systems in oil-filled medium and high voltage class power, voltage and current transformers, bushings, cables, motors and breakers. When used in areas of high electrostatic interference, the instrument's integrated 50Hz or 60Hz interference suppression system allows measurements under conditions that are beyond the scope of most conventional capacitance bridges.

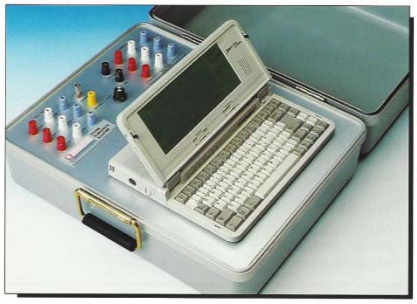
The Model TCB-100 is an extremely useful measuring instrument for determining the dielectric properties of medium and high voltage devices.

1982 – First 'on-line' Partial Discharge Analyzers that monitor the condition of stator winding insulation systems in hydroelectric generators.

PDA-H® technology remains the 'world standard' for failure avoidance and maintenance optimization. This technology is now used on turbo-alternators and medium voltage class motors.







1983 – First to develop a Three-Phase Power Harmonic Analyzer that measures harmonic currents, voltage magnitudes and phase angles, up to the 50th harmonic, then calculates total harmonic distortion of current and voltage, harmonic power flow for each individual harmonic, system impedance at each harmonic frequency, kVT or IT products for each harmonic and Telephone Interference Factor. This project led to the development of the first Fluke, Model 41 Harmonic Analyzers.

1986 – First electromagnetic Zero-Sequence Harmonic Filters that shunt zero-sequence harmonic currents from a three-phase, four-wire sub-system.

I_0Filters™ provide alternatives to de-rating conventional distribution transformers, applying K-Rated distribution transformers or increasing feeder circuits' neutral conductors, in an environment that is rich with zero-sequence harmonic currents.

1990 – First to develop and apply Harmonic Mitigating Transformers that shunt zero-sequence harmonic currents with ultra-low zero-sequence impedance windings and cancel positive- and negative- sequence harmonic currents within their secondary windings.

Distribution TransFilters™ provide an alternative to de-rated conventional distribution transformers or applying K-Rated distribution transformers. These ultra-efficient transformers meet their published efficiencies in the nonlinear environment for which they're designed.

1991 – First complete line of Harmonic Filters and Harmonic Mitigating Transformers that shunt or cancel zero-sequence harmonic currents and/or cancel positive- and negative-sequence harmonic currents.

HarMitigator™ products, which include harmonic mitigating power, distribution and drive isolation transformers, reactors and filters, provide the means to implement The PQI Solution™.

2000 – First electromagnetic Zero-Sequence Harmonic Filter that shunts zero-sequence harmonic currents at the load-end of a branch circuit.

Mini-Z™ filters provide an alternative to de-rating conventional distribution transformers, applying K-Rated distribution transformers, increasing 'shared' neutral conductors or configuring branch circuits with separate neutral conductors, in an environment that is rich with zero-sequence harmonic currents.

2001 – First computer program that will calculate a solution for harmonic current, 'penalty loss' and power cost reductions, and system performance and power quality improvement.

The PQI Solution™ includes the consulting services of a professional engineering specialist who will provide guidance in the selection and application of PQI's technically advanced, ultra- efficient e-Rated® products. This service is offered on a no-fee-basis to system designers. If our recommendations are fully implemented, PQI will guarantee compliance with the power quality requirements of IEEE Std 519-1992 – IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems. The proper selection of products and application of our engineered solution will result in the most cost-effective optimization of system and load efficiency and compatibility. Implementation of our recommendations will also result in an increase in our standard warranty from 10 years to 20 years.

2003 – First to develop a Technology Demonstration Vehicle that demonstrates all harmonic related 'power quality' issues, and compares the accuracy of the Power-In – Power-Out, Loss Measurement Method and the Voltage & Current Differential, Loss Measurement Method.

2003 – First to use a sophisticated computer program that is in compliance with IEEE Std. C57. 110-1998, that allows our engineers to recalculate any transformer's linear losses and efficiency into its nonlinear losses and efficiency, which is based on a specific harmonic current profile.

The PQI Calculator™ will compare the performance of any two transformers and calculate a payback and return-on-investment.

2003 – First to develop a Transformer Excitation & Impedance Loss Measurement Instrument, based on the earlier Voltage & Current Differential, Loss Measurement Method.

Transformer Performance Analyzer™ limits the efficiency calculation error to ±0.033%, when measuring a transformer's excitation and impedance losses under linear or any nonlinear load condition.

2015 – First to receive a UL Certificate of Compliance per UL1562 for our Harmonic Mitigating, Medium Voltage, Cast-Coil Power Transformers. Both CSA and UL have approved our manufacturing facility as a Qualified Product Evaluation and Test Facility. Measurements and test data generated during product evaluation is now accepted by both CSA and UL for product approval.

Power TransFilters™ have also received Seismic Pre-Certification in accordance with the requirements of the International Building Code 2012 (IBC2012), the California Building Code 2013 (CAB2013) and the National building Code of Canada 2010 (NBC2010). In addition, the transformers specifically met the requirements of OSHPD (Office of Statewide Health Planning and Development of California).

2015 – First to offer three Transformer Efficiencies that Exceed DOE 2016 efficiency requirements, under the linear or nonlinear load environments for which they were designed.

PQI's Standard Z3 Efficiency Rating exceeds the US DOE 2016 requirements. Optional Z3+ and Z4 (US DOE CSL 4) efficiencies are available when their additional cost produces an attractive payback and return-on-investment.

2016 – First to provide an Integrated Multifunction Transformer Performance Meter on all e-Rated® medium voltage power and low voltage distribution class transformers. In addition to their revenue class metering and data logging capabilities, these integrated meters, with CSA C802.5 compliant software, determine each transformer's Total Losses and Efficiency under their measured nonlinear loading profiles.

In addition, IEEE Std C57.110 compliant software determines each transformer's No-Load Losses and Load Losses, including its nonlinear 'Penalty Loss' component and EPA Environmental Benefits. In its 'transformer comparison mode', given the cost of each transformer and the cost of energy, the software will also compare the performance of any two transformers, including A/C costs, and calculate an annual saving, payback and return-on-investment, in a 'substitution' or 'before end-of-life replacement' scenario.