PRODUCT APPLICATION GUIDE

Type Z **e-Rated®** I_0Filter™

Ultra-Efficient, Low Voltage, Zero-Sequence Harmonic Filter for High K-Factor, Phase-to-Neutral Connected Nonlinear Loads

Product Description

Type Z *e-Rated®* I_0Filters™ are highly effective, three-phase, four-wire, passive electromagnetic filters with ultra-low zero-sequence impedances. I_0Filters™ have been specifically designed to provide a parallel path for all zero-sequence harmonic currents, which are generated by phase-to-neutral connected nonlinear electronic loads. Power quality benefits are optimized when I_0Filters™ are installed as close as possible to these electronic loads.

I_0Filters™ alone will normally achieve the recommendations and requirements of IEEE Std. 519-1992 in single-phase, nonlinear load environments. When it becomes necessary to also mitigate the power quality problems associated with positive- and negative-sequence harmonic currents, Type Z filters may be applied in combination with Type YV and ZV directional I_0Filters™ and/or Type DY or DV Distribution TransFilters™.

Type YV and ZV directional I_0Filters™ are normally applied in series with sub-panels that supply single-phase nonlinear electronic loads. Whether specified at the design stage for new construction or applied in an existing sub-system, these filters are normally sized for connected kVA loading. Type YV and ZV filters may also be used to mitigate positive- and negative-sequence harmonic currents.

The application of zero-sequence harmonic filters will reduce the power quality limitations on branch circuit length and/or loading. These limitations are graphically detailed in two PQI publications entitled: (i) *'Neutral-to-Ground Voltage vs. Branch Circuit Length & Loading for Typical Nonlinear Electronic Workstation Loads'* and (ii) *'Neutral-to-Ground Voltage vs. Branch Circuit Length & Loading for Typical 120V Nonlinear Electronic Gaming Machine Loads'*.

Product Application

The benefits of an I_0Filter™ application are optimized when these devices are installed as close as possible to the sources of zero-sequence harmonic currents. This is typically accomplished by connecting the filters at each three-phase, four-wire panel that supplies single-phase, nonlinear loads.

The determination of preferred I_0Filter™ locations and ratings will be demonstrated in the following examples:

Case 1

With reference to *Figure 1,* the 120/208V subsystem includes a 45kVA, 480:120/208V Distribution Transformer that is connected to a 125A panel via a 3∅, 4W circuit.

If we assume that the panel will be used to supply 36kVA (45kVA x 0.8) in single-phase, nonlinear loads exclusively, then a 175A I_0Filter™ should be installed at the panel. The installation must be in accordance with the appropriate I_0Filter™ - Connection Diagram provided.

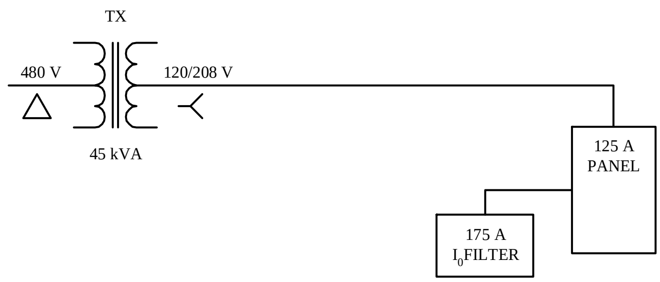


Figure 1

Under the above conditions, the calculation of the I_0Filter™ maximum rating ($I_{0\ Neutral}$) would be as follows:

$$I_{0\ Max\ Neut} = I_{FL\ Max\ \varnothing} \times HF_0 \times CF \times 3^{(1)} \qquad [1]$$

where:

- $I_{0\ Max\ Neut}$ - Maximum zero sequence harmonic current that could flow on the neutral conductor (I_0Filter™ rating).
- $I_{FL\ Max\ \varnothing}$ - Maximum fundamental current that would flow on the phase conductors at nameplate limits.
- HF_0 - Harmonic Factor for Zero Sequence Current is the ratio of the root-sum-square (rss) value of all of the zero sequence harmonic currents to the root-means-square (rms) value of the fundamental [use HF_0 = 0.6, as a typical value, rather than 0.8, the calculated value].
- CF - Code Factor (NEC or CEC) is the requirement that the load limiting apparatus (normally the panel's main circuit breaker) must not be loaded beyond 80% of its rating.
- $3^{(1)}$ - This multiplier is required because the three maximum zero sequence harmonic phase currents ($I_{0\ Max\ \varnothing}$) add arithmetically at the X_0 Terminal of the distribution transformer and return to their source via the neutral conductor.

If we determine that the panel will not be used to supply 100A (125A x 0.8) of single-phase, nonlinear loads, then the rating of the I_0Filter™ can be calculated by substituting $I_{FL\ Max\ \varnothing}$ in the formula [1] with the actual fundamental current that will flow on the phase conductors ($I_{FL\ Act\ \varnothing}$) in order to supply the single-phase nonlinear loads only. Again, the installation must be in accordance with the appropriate I_0Filter™ - Connection Diagram.

Case 2

With reference to *Figure 2*, the 120/208V subsystem includes a 75kVA, 480:120/208V distribution transformer that is connected to two 125A panels via two 3∅, 4W circuits

If we assume that each panel will be used to supply 100A ([25A x 0.8]/2) of single-phase nonlinear loads exclusively, then a 150A I_0Filter™ should be installed at each panel. The installations must be in accordance with the appropriate I_0Filter™ - Connection Diagram.

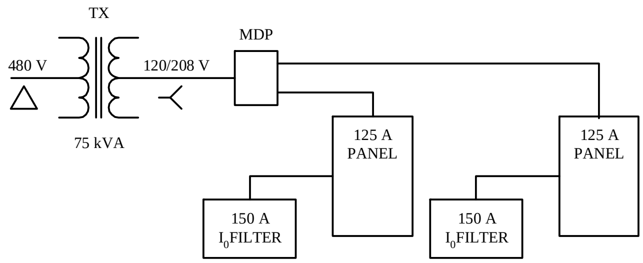


Figure 2

Under the above conditions, the calculation of the I_0Filter™ ratings would be as given in formula [1].

If we determine that either Power Panel will not be used to supply 100A of single-phase, nonlinear loads, then the rating of its I_0Filter™ can be calculated by substituting

$I_{FL\ Max\ \varnothing}$ in the formula [1] with $I_{FL\ Act\ \varnothing}$, in order to supply the single-phase, nonlinear loads only. Again, the installation must be in accordance with the appropriate I_0Filter™ - Connection Diagram.

As a variation of this case, the 120/208V subsystem may include a 75kVA, 480:120/208V distribution transformer which is connected to two 125A panels via a single 3∅, 4W circuits. If the two panels are closely spaced, it may be possible to use a single I_0Filter™ that would serve both panels. In this case the filter should be applied at the panel that is closest to the distribution transformer and should be rated as in Case 1.

Case 3

With reference to *Figure 3,* the 120/208V subsystem shown includes a 1500kVA, 13800:120/208V power transformer that is connected to multiple panels via a 3∅, 4W bus duct circuit.

If we assume that each panel connected to the bus duct will be used to supply 3331A (4164A x 0.8) in single-phase, nonlinear loads exclusively, then multiple I_0Filter™, with a total capacity of 5996A, should be strategically located on the bus duct.

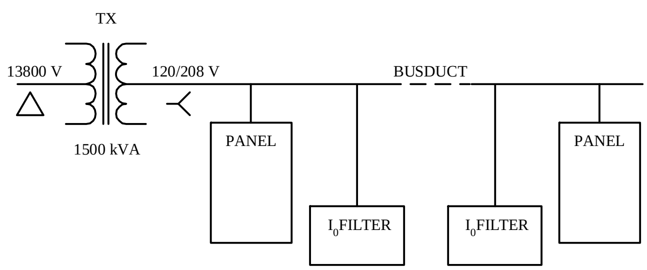


Figure 3

Under the above conditions, the calculation of total capacity of the I_0Filter™ ratings would be as given in formula [1].

If we determine that the panels will not be used to supply 3331A of single-phase nonlinear loads, which will most likely be the case, the total capacity of all I_0Filter™ can be calculated by substituting $I_{FL\ Max\ \varnothing}$ in formula [1] with $I_{FL\ Act\ \varnothing}$ in order to supply the single-phase, nonlinear loads only. Again, multiple I_0Filters™ should be strategically located on the bus duct.

General

It is important to understand that, where the possibility of $I_{0\ Max\ Neut}$ at a particular panel has not been addressed, the future addition of single-phase, nonlinear loads at that panel may cause its now underrated I_0Filter™ to become overloaded.

Similarly, where one or more panels in a system has not been equipped with an I_0Filter™, the future addition of single-phase, nonlinear loads at these panels may cause connecting circuits, and now underrated I_0Filters™ at other panels, to become overloaded.

In the single-phase, nonlinear load environments described above, I_0Filters™ alone will normally achieve the recommendations and requirements of IEEE - Std. 519-1992. When it becomes necessary to mitigate the power quality problems associated with positive- and negative-sequence harmonic currents, the following related PQI HarMitigator™ products may be applied separately or in combination with the I_0Filter™.

- Power TransFilter™
- Distribution TransFilter™
- Drive TransFilter™

Type Mini-Z® **e-Rated®** I_0Filters™

When branch circuits' neutral-to-ground voltages and voltage distortions cannot be economically controlled by other means, Mini-Z® zero-sequence harmonic filters may be applied at the load-end of three-phase, four-wire 'shared neutral' branch circuits or three-phase, six-wire branch circuits.

Mini-Z I_0Filter™

In 'landscaped' office environments, filters may be conveniently connected to pre-wired partitions via the partition manufacturer's standard wire-way connection cable, as shown in the photograph and *Figure 4*. Where the partitions are not pre-wired or in private office applications, filters may be connected at a branch circuits' 'home run' junction boxes.

The application of Mini-Z® filters in new distribution systems eliminates the need to oversize 'shared neutral' conductors or install separate neutral conductors for each phase in the branch circuit. Similarly, the application of filters in existing systems eliminates the need to replace branch circuits with undersized 'shared neutrals'. In either case, Mini-Z® filters will eliminate the need to de-rate circuits or panels. The de-rating of conventional distribution transformers can be reduced from approximately 45% to less than 15%. As a result, filters significantly reduce capital costs and power costs while providing significant performance and power quality improvements.

Mini-Z® filters alone will normally achieve the recommendations and requirements of IEEE Std. 519-1992 in single-phase, nonlinear load environments. When it becomes necessary to mitigate the power quality problems associated with positive- and negative-sequence harmonic currents, these filters may also be applied in combination with Type DY or DV Distribution TransFilters™.

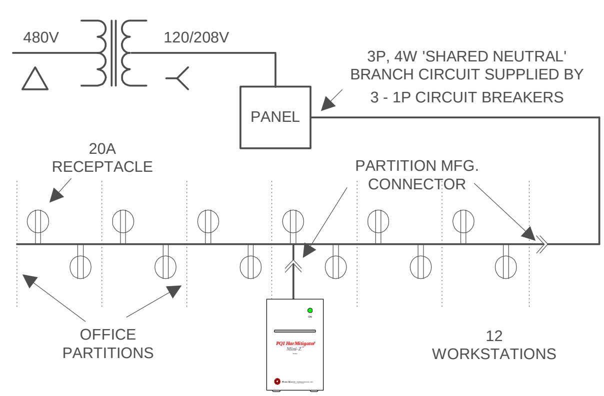
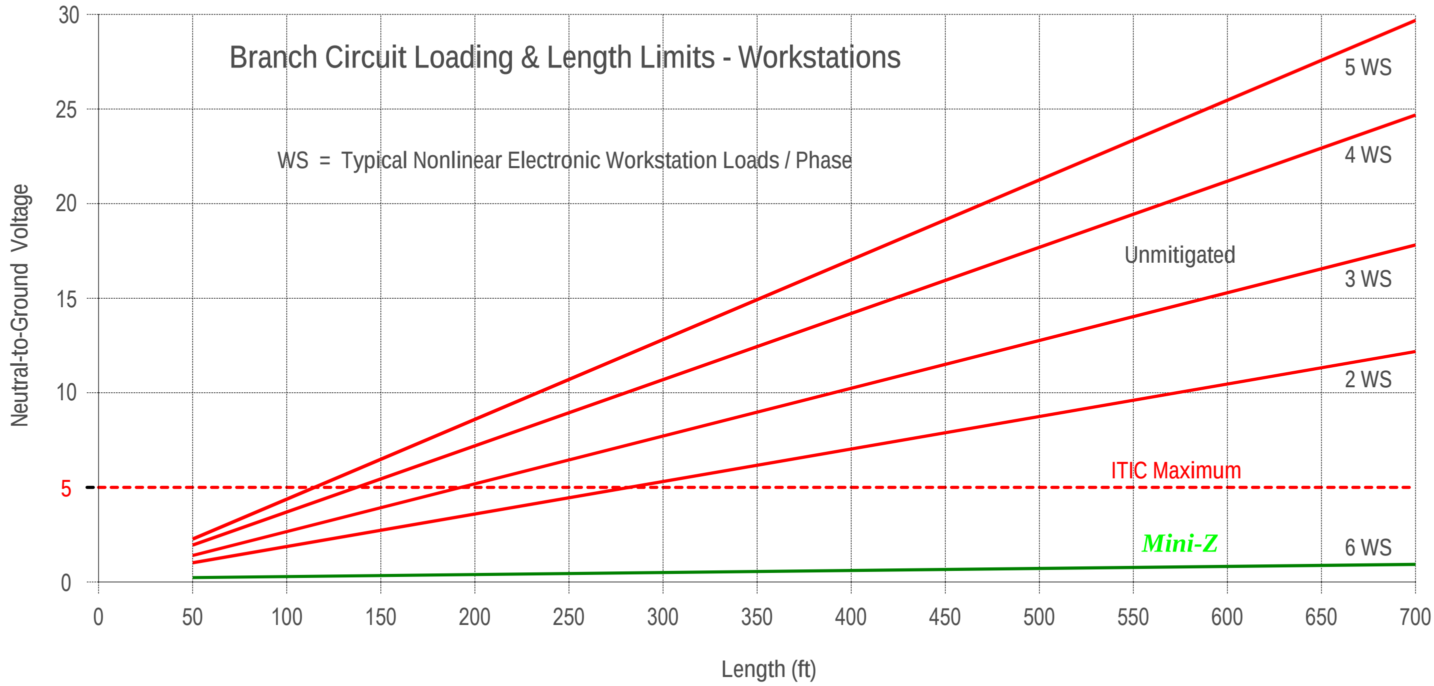


Figure 4



Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Nonlinear Electronic Workstation Loads

Notes

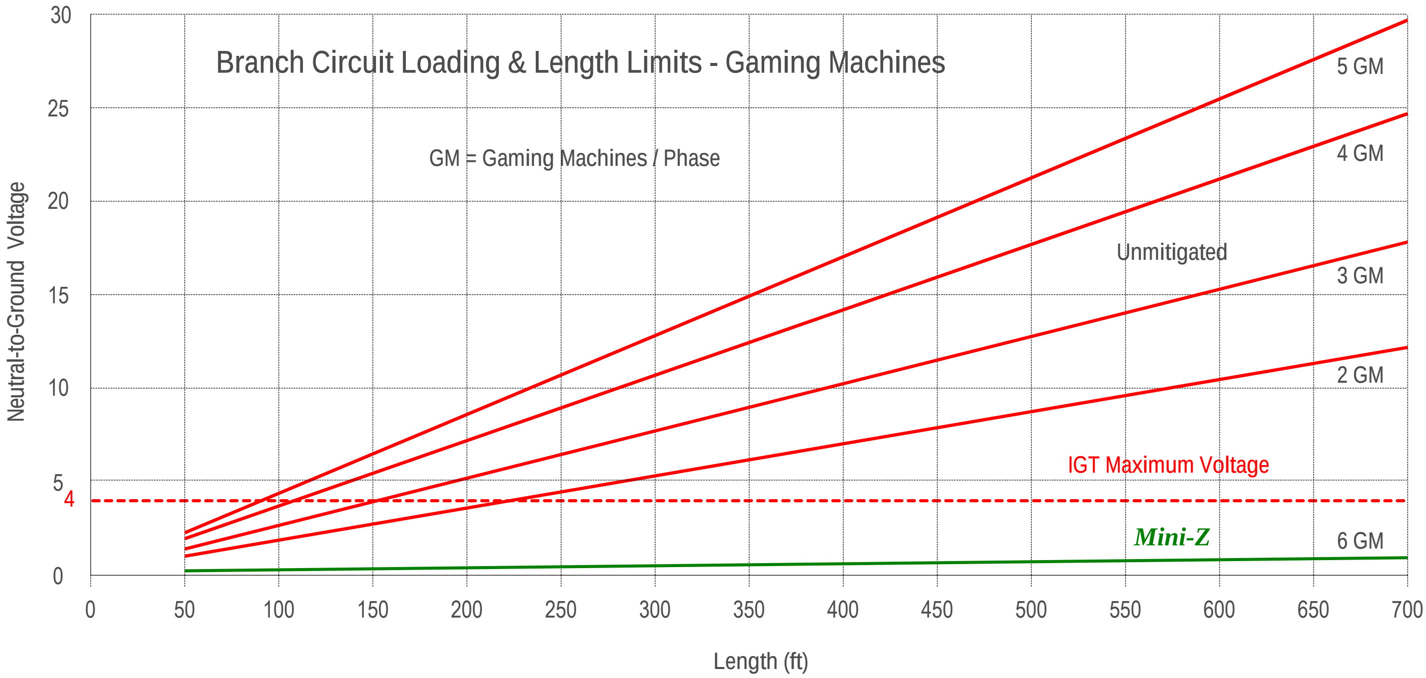
1) Information Technology Industry Council (ITIC) recommends <5V neutral-to-ground at business machines (with all machines on-line), in order to provide a warranty.

2) Since the neutral-to-ground voltages shown in the graph are approximately zero at the line-end of the branch circuits (the distribution panel), the graph assumes that the distribution system's neutral conductor is grounded within a few feet of the panel. If the panel is remote from the neutral's grounding point (distribution transformer), approximately 1 volt / 100 feet of neutral-to-ground voltage will be generated by the feeder circuit, regardless of the conductor size. This can be factored into the graph by subtracting this voltage from the 'ITIC Maximum' (i.e. with 50' of feeder circuit between the distribution transformer, the grounding point, and the distribution panel, the 5 volt ITIC limit must be reduced to a 4.5 volt limit).

3) Where feeder circuit length imposes an unreasonable reduction in branch circuit length and/or loading, an I_0Filter™ (zero-sequence harmonic filter) may be applied at the distribution panel that supplies the branch circuits.

4) Where feeder circuit and/or branch circuit lengths impose an unreasonable reduction in branch circuit length and/or loading, a Mini-Z® (zero-sequence harmonic filter) may be applied at the load-end of the three-phase, four-wire 'shared neutral' or three-phase, six-wire branch circuits (i.e. at the branch circuit's 'home run' junction box or at a pre-wired office partition's receptacle bus).

5) The branch circuits considered in this graph are three-phase, four-wire 'shared neutral' circuits. If the branch circuits are configured with a separate neutral conductor for each phase conductor, zero sequence neutral currents will be reduced by approximately 66%. However, neutral current will now include the fundamental and all positive and negative sequence harmonic currents. The reduction of neutral-to-ground voltages is marginal. However, circuits with separate neutral conductors produce twice the 'voltage drop'. All issues considered, 'shared neutral' circuits are preferred.



Neutral-to-Ground Voltage vs. Branch Circuit Loading and Length for Typical Non-Linear Electronic Gaming Machine Loads

Notes:

1) International Gaming Technologies (IGT) requires <4V neutral-to-ground at gaming machines (with all machines on-line), in order to authorize use and provide a warranty.

2) Since the neutral-to-ground voltages shown in the graph are approximately zero at the line-end of the branch circuits (the distribution panel), the graph assumes that the distribution system's neutral conductor is grounded within a few feet of the panel. If the panel is remote from the neutral's grounding point (distribution transformer), approximately 1 volt / 100 feet of neutral-to-ground voltage will be generated by the feeder circuit, regardless of the conductor size. This can be factored into the graph by subtracting this voltage from the 'IGT Maximum' (i.e. with 50' of feeder circuit between the distribution transformer, the grounding point, and the distribution panel, the 4 volt IGT limit must be reduced to a 3.5 volt limit).

5) Where feeder circuit length imposes an unreasonable reduction in branch circuit length and/or loading, an I_0Filter™ (zero-sequence harmonic filter) may be applied at the distribution panel that supplies the branch circuits.

6) Where feeder circuit and/or branch circuit lengths impose an unreasonable reduction in branch circuit length and/or loading, a Mini-Z®(zero-sequence harmonic filter) may be applied at the load-end of the three-phase, four-wire 'shared neutral' or three-phase, six-wire branch circuits (i.e. at the branch circuit's 'home run' junction box).

5) The branch circuits considered in this graph are three-phase, four-wire 'shared neutral' circuits. If the branch circuits are configured with a separate neutral conductor for each phase conductor, zero sequence neutral currents will be reduced by approximately 66%. However, neutral current will now include the fundamental and all positive- and negative- sequence harmonic currents. The reduction of neutral-to-ground voltages is marginal. However, circuits with separate neutral conductors produce twice the 'voltage drop'. All issues considered, 'shared neutral' circuits are preferred.