

Powerline Surge Elimination

(using surge cancellation)

by

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Introduction

This paper describes a new, patent pending filter technology which totally cancels surge voltage at the output. Power quality products using this technology can operate over an 85 to 265 VRMS range since only dynamic clamping and filtering is used.

Terms like response time, clamping voltage, suppressed voltage, let-through voltage, Joule rating, maximum current rating, etc. are not relevant for this new technology, since no surge voltage appears at the output, even with worst-case surges and 1,000 worst-case surge endurance is standard.

Definitions

Category B Surges

This paper deals with worst-case powerline disturbances within a building, as described by IEEE C62.41 -2002 as Category B locations¹. In essence, this means an environment where powerline disturbances can be as large as 6,000 Volts, 3,000 Amps, lasting up to 50 microseconds, called herein Category B surges.

Series-Mode Power Quality Filter:

A filter characterized by an input impedance large enough to limit surge current to 60% or less of maximum Category B values.

Let-Through Voltage

Let-through voltage is defined herein as the peak voltage measured at the filter output leads within 100 microseconds of the applied Category B Combination Wave. If this

peak voltage is equal to or less than the power wave peak voltage, the surge has been totally canceled (eliminated) as the residual surge voltage is confined within the normal powerline voltage envelope and cannot damage connected power supplies.

Electronic systems are becoming more prevalent and sensitive, while powerline surges are continually being generated by the well documented ways, exposing this sensitive equipment to disruption and damage.

A power quality filter that operates effectively over a wide supply voltage range and **totally cancels** residual surge voltage from protected equipment for the worst-case surges, while having a certified endurance of over 1,000 worst-case (Category B) surges was a recent design goal. To our surprise and delight, it took very little extra circuitry to make this dramatic improvement!

Series-Mode Technology Endurance

Series-Mode filter technology has always exhibited 1,000 surge worst-case (Category B) surge endurance², with very low let-through voltage.

Series-Mode Technology Voltage Range

In 2002, the standard voltage range of 120 Volt Series-Mode filter technology was extended so it would operate effectively from 85Vrms to 175Vrms, with 240 Volt products operating from 85Vrms to 265Vrms³. This patented technology is called WVR (Wide Voltage Range).

Total Surge Cancellation (TSC)

While always capable of low let-through voltage, **total surge cancellation** has now been added to proven Series-Mode filter technology. This is accomplished by simply adding additional windings to the former input surge inductor, converting it to a transformer, or adding a separate current transformer. By properly phasing one of the secondary windings, a canceling voltage is developed in this winding. When this canceling voltage is subtracted from the suppressed surge voltage, total cancellation results, since the residual voltage falls below the normal powerline peak voltage, effectively eliminating any surge related effects on connected equipment.

This new filter technology now has the following characteristics:

- It can operate effectively over the entire 85 to 265 volt range, since it contains no fixed clamping voltage components. It is entirely dynamic.
- It is not sacrificial; it will not fail for even 1,000 worst case Category B

surges.

- It provides total surge cancellation, making it suitable for the most sensitive equipment and most critical applications.
- It operates effectively under brown-out and voltage swell (temporary overvoltage) conditions.
- It limits surge current and controls surge current di/dt , minimizing coupling to adjacent wiring.

Imagine: A single power quality filter that totally cancels (truly eliminates) surges, works equally well at 120 volts, **and** 240 volts RMS, and does not wear out!

TSC-WVR™ Block Diagram

This new Total Surge Cancellation, Wide Voltage Range (TSC-WVR™) technology uses reliable linear and non-linear filter concepts and consists of several building blocks:

1. A high voltage, high current linear input transformer with secondary windings is used to provide surge current limiting, control surge current di/dt on the powerline, offers a controlled input impedance

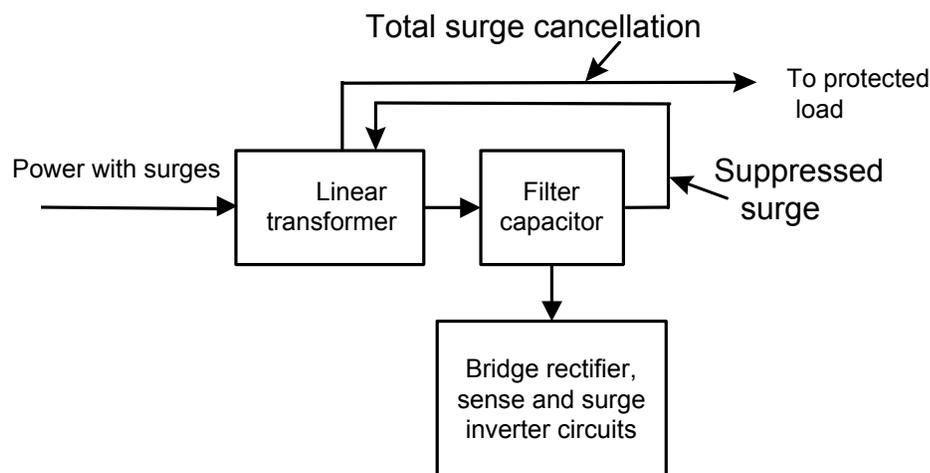


Figure 1, TSC-WVR™ Simplified Block Diagram

for carrier current environments, and develops a total surge canceling voltage.

2. A filter capacitor works in conjunction with the input transformer series inductance. This provides low pass filtering for noise and surges within the power wave voltage envelope.
3. A bridge rectifier functioning as a peak voltage detector, detects surges which exceed the power wave peak voltage.
4. A peak detecting capacitor associated with the bridge rectifier limits the surge peak voltage, controls dv/dt and integrates the incoming surge energy for subsequent signal processing.
5. A multiple section filter is connected to the peak detector with the bandwidth and thresholds set to sense dangerous surge energy levels.
6. Once the filter circuit determines a surge is potentially dangerous, a surge inverter activates at a pre-determined safe incremental voltage level to actually invert the surge and bring it below the power wave voltage peak, rendering the rest of the surge benign.
7. A transformer winding adds a surge canceling voltage to the final filter output terminal.

All the above components are chosen to operate within their safe surge ratings for at least 1,000 surges, so no performance degradation takes place, assuring the designs can exceed 1,000 surge endurance requirements.

No thermal fuses, alarm circuits or other "catastrophic failure" fuses are required since no sacrificial components are used. The risk of filter failure down-time from these components is therefore eliminated. The core technology has a 15 year record with no surge related failures.

How It Works

See Figure 1, TSC-WVR™ Simplified Block Diagram. The incoming surge first encounters the input transformer. Transformers augmented with magnetic materials are normally avoided since such transformers tend to "saturate" at the higher currents, just when the transformer inductance is most required. Since a series connected transformer has the property of inhibiting higher frequencies more than lower frequencies, the most dangerous, fastest surge components are most severely restricted. This current transformer must be designed to handle the large surge current linearly and high voltage without arcing.

For small surges and noise within the power wave voltage envelope, the transformer series inductance works in conjunction with a first filter capacitor in a low pass filter configuration to attenuate surges and noise above 5 kHz, with 26 dB minimum attenuation typical at 100 kHz.

Incoming surges which exceed the power wave peak voltage must overcome the much larger capacitor within the diode bridge. The capacitor within the bridge integrates the incoming surge voltage, controlling the peak let-through voltage, dv/dt, and offering a measurement of the residual surge energy ($1/2C\Delta V^2$) passing through the transformer. A very large dv/dt developed across this large capacitor indicates a large surge.

A signal from the capacitor is fed to the sense circuits, and should the signal pass through the selective filter indicating a large surge is present, the surge inverter activates. This effectively restricts the surge duration.

Now that the surge voltage, current and duration have been diminished to very low levels, the surge voltage from the current transformer is subtracted from the output to totally cancel the residual surge voltage!

We can therefore see that the circuit acts to reduce surge current di/dt, reduce the peak surge current and duration and totally cancels the residual surge voltage attacking ALL dangerous surge energy components. The waveforms in the Appendix show examples of performance available from practical production products at 6 kV, 3kA and 3 kV, 1.5 kA.

Although some of the parts used for higher voltage operation at 240 Volts rms are more expensive than those for 120 Volts, there is no inherent voltage sensitivity to performance. The circuits work just as effectively during brown-out conditions, and even over the entire 85 Volts rms to 265 Volts rms powerline voltage range due to dynamic operation.

Mode 1 Operation

Further compounding the power quality protection situation generally is the ever decreasing low voltages and low noise voltage thresholds being used by computer ICs, making surge and noise protection more critical to reliable operation, especially in an interconnected environment where noise on the ground system is so important.

Audio and video products have even lower noise susceptibility thresholds than computers and greatly benefit from this new technology. The technology operates in US government Mode 1 (L-N suppression- no ground wire surge contamination), eliminating this source of noise for these sensitive applications.

TSC-WVR™ Technology:

Voltage range: 85-265VRMS. No thermal runaway, as fixed clamping is not used.

Endurance: 1,000 ANSI C62.41 worst case (6kV, 3kA) surges, certified by an independent lab. No sacrificial components are used. At least 10 year life is assured even in worst-case surge environments.

Surge Suppression: Current limiting, total surge voltage cancellation, di/dt reduction -- complete suppression.

Catastrophic shut-down: Not required; 1,000 surge endurance is assured. Eliminates a source of equipment "down time".

Summary

A new surge suppression technology has been described. This filter technology was developed to totally cancel residual surge voltage while maintaining a very wide effective voltage operating range. It offers this unsurpassed protection while eliminating the unfortunate down time characteristic of many SPDs which depend on fixed clamping voltage, sacrificial components that are designed to fail with use.

By totally canceling residual surge voltage, performance and endurance levels have been established that make this advanced series-mode filter technology the logical choice for important applications.

References:

¹ ANSI C62.41 -2002 defines a Category B surge as 6,000 Volts open circuit, 50 microseconds duration, 3,000 Amps short circuit current, 20 microseconds duration.

² US government CID A-A-55818 (commercial SPD purchase specification- can be downloaded from www.zerosurge.com).

³ Wide Voltage Range Surge Protection Break-through. (PQ 2002)