

# Megger User Manual MPQSIM Power Quality Simulator



**Megger**

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**MPQSIM**  
**User Manual**

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The information presented in this manual is believed to be adequate for the intended use of the product. If the product or its individual instruments are used for purposes other than those specified herein, confirmation of their validity and suitability must be obtained from Megger. Refer to the warranty information below. Specifications are subject to change without notice.

## WARRANTY

Products supplied by Megger are warranted against defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair must be shipped prepaid and insured. Contact your MEGGER representative for instructions and a return authorization (RA) number. Please indicate all pertinent information, including problem symptoms. Also specify the serial number and the catalog number of the unit. This warranty does not include batteries, lamps or other expendable items, where the original manufacturer's warranty shall apply. We make no other warranty. The warranty is void in the event of abuse (failure to follow recommended operating procedures) or failure by the customer to perform specific maintenance as indicated in this manual.

## **Megger.**

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# 1

## INTRODUCTION

Thank you for purchasing the MPQSIM Power Quality Simulator, from Megger.

If you find any discrepancies in the product or its accessories or have any comments, please send them to Megger via fax, e-mail or phone.

Megger  
Valley Forge Corporate Center  
2621 Van Buren Avenue  
Norristown, PA, 19403  
Attn: Customer Service

Fax: (214) 331 7397  
E-mail: [USTechSupportGrp@megger.com](mailto:USTechSupportGrp@megger.com)

For Technical Support please consult the Megger Web Site at [www.megger.com](http://www.megger.com) for the local distributor near you.

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## RECEIVING INFORMATION

### *MPQ-SIM-01*

#### Contents Received:

QTY.	PART NO.	DESCRIPTION
1	1007-055	Power Quality Simulator
1	90017-548	AC Adapter
3	2008-124	Current Cables

When your Megger product arrives, check the equipment received against the packaging list to ensure that all materials are present. Notify Megger of any shortages.

Examine the contents for damage received during transit. If any damage is discovered, file a claim with the carrier at once and notify Megger or it's nearest authorized sales representative, giving a detailed description of the damage.

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# 3

## OVERVIEW

### *Intended Use*

The MPQSIM is a power quality event simulator. This simulator is intended for use with the Megger MPQ line of power quality analyzers. The MPQSIM power quality simulator box is a training tool that simulates various power quality phenomena. *The MPQSIM is not intended to be used for instrument calibration or troubleshooting.*

### *Applications*

Applications include:

- Demonstrating Power Quality Phenomenon
- Power Quality Phenomenon Locating and Identification Training.

<p><i>NOTE: If this product is to be used in an industrial location with high ambient EMI levels, some degradation of performance may occur. If this degradation is objectionable, the unit should be moved to a more benign location.</i></p>
--

## **Definitions**

<b>Term</b>	<b>Definition</b>
<b>Power Quality</b>	The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.
<b>Transient</b>	A sudden, non-power frequency change in the steady-state condition of voltage, current, or both.
<b>Amplitude</b>	In this document amplitude will refer to the percentage of change from 100% of the RMS voltage and or current value.
<b>Phase Angle</b>	In this document phase angle will refer to the number of degrees between the phase voltages as well as the number of degrees between the phase voltage and phase current.
<b>Harmonics</b>	Sinusoidal components of periodic waves that have frequencies that are multiples of the fundamental frequency. The MPQSIM product creates 3 <sup>rd</sup> and 5 <sup>th</sup> order harmonics.
<b>Flicker</b>	Flicker is a very specific problem related to human perception and incandescent light bulbs. It is not a general term for voltage variations. The MPQSIM product produces voltage variations over time that will create Flicker phenomenon in incandescent lighting.
<b>Source</b>	The source of electrical generation or supply.
<b>Load</b>	The load of an electrical generator or supply.
<b>Line Frequency</b>	The fundamental AC frequency of the power network.

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## SPECIFICATIONS

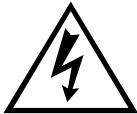
<b>DC Input Voltage:</b>	12VDC +/-0.5VDC
<b>AC Adapter:</b>	100-240VAC 50/60Hz
<b>Nominal Output Voltage:</b>	115VAC +/- 1.2VAC 230VAC +/- 2.4VAC
<b>Voltage Selections Accuracy:</b> <i>(% of nominal)</i>	85.0 % +/- 0.5% 102.0% +/- .2% 115.0% +/- 0.5%
<b>Current Ranges:</b>	10A, 100A, 1000A & 6000A
<b>Current Accuracy:</b>	+/-2% Full Scale
<b>Nominal Phase Angles:</b>	0°, 120°, 240°
<b>Phase Angle Selection</b> <i>(from nominal)</i>	-30°, -11°, 0°, +11°
<b>Phase Accuracy:</b>	+/-1.5°
<b>Voltage Transient Amplitude:</b>	1075 +/-50Vpk
<b>Voltage Transient Rise Time:</b>	18 +/-5µsec
<b>Voltage Transient Duration:</b>	35+/-10µsec
<b>Harmonic Orders:</b>	3 <sup>rd</sup> and 5 <sup>th</sup>
<b>Harmonic Amplitudes</b>	10.0 +/-3.% of fundamental
<b>Frequency Output:</b>	50Hz / 60Hz
<b>Frequency Accuracy:</b>	+/-0.05Hz
<b>Flicker:</b> <i>(Square wave modulation)</i>	2% ΔU @ 0.2Hz 2% ΔU @ 1.0Hz 2% ΔU @ 5.0Hz
<b>Physical size</b>	14.2" x 12.0" x 7.6" (36cm x 30.5cm x 19.3cm)
<b>Weight:</b>	11.5lbs (5.2kg)
<b>Operating Temperature:</b>	0C to +40C
<b>Storage Temperature:</b>	-20C to +50C
<b>Humidity:</b>	0 to 95% non-condensing

<b>Altitude:</b>	2000 meters
<b>EMF</b>	IEC 61326:2012 Class A, Basic Immunity
<b>Safety</b>	IEC61010-1
<b>IP Rating</b>	40
<b>CAT Rating</b>	CAT II @ 300V

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## SAFETY

### *Warnings and Safety Precautions*


	<b>WARNING!</b>
<b>Death, serious injury, or fire hazard could result from improper use/installation of this instrument. Read and understand this manual before installing this instrument.</b>	


- Installation of this instrument **MUST** be performed in compliance with the National Electric Code and any additional safety requirements applicable to your installation.
- Installation, operation and maintenance of this instrument **MUST** be performed by qualified personnel only. The National Electrical Code defines a qualified person as one familiar with the construction and operation of the equipment and the hazards involved.
- Do not leave the instrument connected to the system under test when not in use.
- Do not touch circuit connections or any metal that is exposed due to damaged insulation.
- Do not use the instrument or connect it to any external system if it shows any visible signs of damage, malfunction or if it has been stored in unfavorable conditions.
- Always inspect the instrument prior to use.
- Replace any defective parts or return the instrument to an authorized center for repair.
- Do not use the instrument or connect it to any external system if the enclosure is open or any parts of the enclosure are missing.
- Only use specified batteries as described by this document, if applicable.
- The instrument shall not be used if any parts are damaged.
- This instrument is not intrinsically safe and must not be used in hazardous atmospheres.

The following safety precautions **MUST** be taken whenever this product is installed.






- Wear safety glasses and insulated gloves when making connections to power circuits
- Hands, shoes, floor/ground must be dry when making any connection to a power line

These warnings and safety precautions are to be used where appropriate when following instructions in this manual.

	<p><b>CAUTION!</b></p> <p><b>If this equipment is used in the manner not specified by the manufacturer, the protection provided by the equipment may be impaired.</b></p>
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	<p><b>PROTECTIVE TERMINAL</b></p> <p><b>The Phase C RTN banana jack must be connected to Earth Ground prior to the connection of any of the other voltage output banana jacks.</b></p>
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## Safety and Warning Symbols

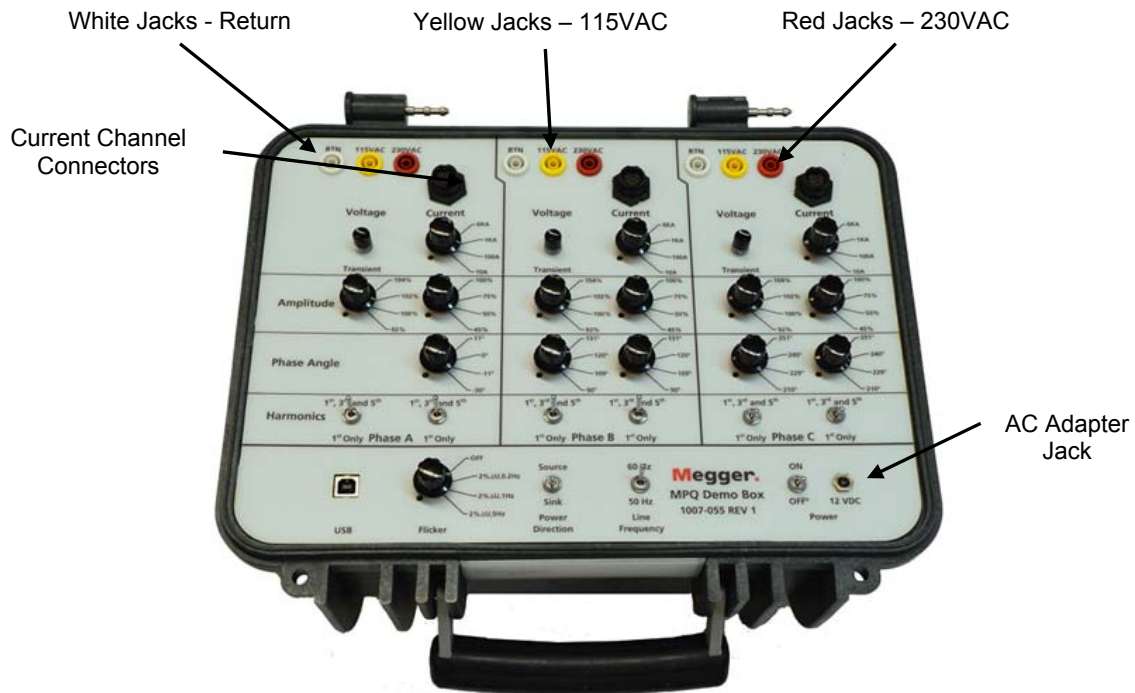
SYMBOL	REFERENCE	DESCRIPTION
	IEC 60417-5031 (2002-10)	Direct current
	IEC 60417-5019 (2006-08)	Protective conductor terminal
		Warning, possibility of electric shock
	ISO 7000-0434B (2004-01)	Caution
	WEEE	The crossed out wheeled bin placed on Megger products is a reminder not to dispose of the product at the end of its life with general waste. Megger is registered in the UK as a Producer of Electrical and Electronic Equipment. The Registration No is WEE/DJ2235XR.



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## PRODUCT INSTALLATION

### *Connector Layout / Interconnect*



Plug the AC Adapter into the AC Adapter jack of the MPQSIM product.

#### **When used with an MPQ1000:**

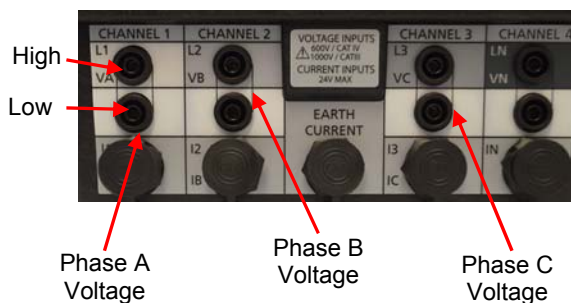
1. Connect the Phase C RTN jack on the MPQSIM to Earth Ground.
2. Connect the GND input on the MPQ1000 to Earth Ground.
3. Plug the Phase A voltage lead (supplied with the Megger PQ Product) between the Phase A 115V or 230V banana jack on the MPQ-SIM and the Phase A voltage input of the MPQ1000.
4. Plug the Phase B voltage lead (supplied with the Megger PQ Product) between the Phase B 115V or 230V banana jack on the MPQ-SIM and the Phase B voltage input of the MPQ1000.

5. Plug the Phase C voltage lead (supplied with the Megger PQ Product) between the Phase C 115V or 230V banana jack on the MPQ-SIM and the Phase C voltage input of the MPQ1000.
6. Plug the Neutral lead (supplied with the Megger PQ Product) between the Phase A RTN banana jack on the MPQ-SIM and the Neutral lead of the MPQ1000.

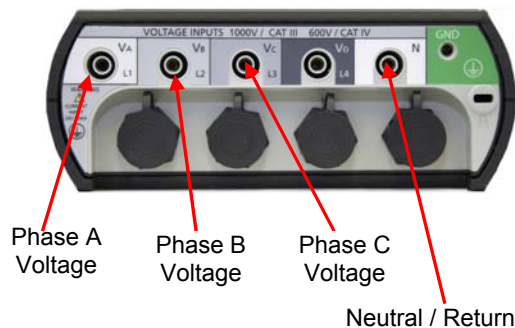
**When used with the MPQ2000:**

1. Connect the Phase C RTN jack on the MPQSIM to Earth Ground.
2. Connect the GND input on the MPQ2000 to Earth Ground.
3. Using two of the white Jumper Leads (supplied with the Megger PQ Product), connect the VA-Low, VB-Low and VC-Low banana jack inputs on the MPQ2000 together in daisy-chain fashion.
4. Using the voltage leads supplied with the Megger PQ Product connect the Phase A high input on the MPQ2000 analyzer to either the Phase A 115V or 230V banana jack on the MPQ-SIM.
5. Using the voltage leads supplied with the Megger PQ Product connect the Phase A low input to the Phase A RTN jack on the MPQ-SIM.
6. Using the voltage leads supplied with the Megger PQ Product connect the Phase B high input on the MPQ2000 analyzer to either the Phase B 115V or 230V banana jack on the MPQ-SIM.
7. Using the voltage leads supplied with the Megger PQ Product connect the Phase C high input on the MPQ2000 analyzer to either the Phase C 115V or 230V banana jack on the MPQ-SIM.

The MPQ2000 has differential voltage inputs. Using the jumpers supplied with MPQ2000 jump the voltage neutrals (lows) together. Then connect the jumped neutrals to the Phase A neutral jack on the PQ Simulator. Then plug each channel to the corresponding voltage channel on the PQ simulator.

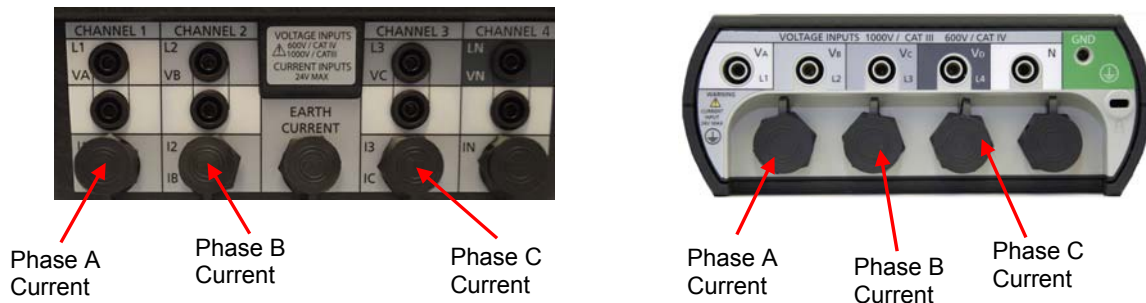


The MPQ1000 has a common neutral so no jumpers are required. Plug each channel to the corresponding voltage channel on the PQ simulator. Plug the neutral lead into the Phase A neutral jack of the simulator.



8. Plug the Phase A current lead into the MPQSIM Phase A current connector.
9. Plug the other side of the Phase A current lead into the Phase A current connector of the Megger PQ Product.
10. Plug the Phase B current lead into the MPQSIM Phase B current connector.
11. Plug the other side of the Phase B current lead into the Phase B current connector of the Megger PQ Product.
12. Plug the Phase C current lead into the MPQSIM Phase C current connector.
13. Plug the other side of the Phase A current lead into the Phase A current connector of the Megger PQ Product.

Both the MPQ1000 and MPQ2000 use the same type self-identifying current clamps. No actual current clamps are required to use the PQ Simulator with an MPQ Analyzer. Connect the MPQ Analyzer CT connector directly to the PQ Simulator using the provided current cable.



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## PRODUCT OPERATION

The following section describes the operation of the MPQSIM Power Quality Simulator. This section will describe in a step by step manner how to operate the unit.

### Operation Controls and Modes

Definitions of switch and control functions.



#### CONTROL

**Current Selector**

**Transient Button**

**Amplitude Selector  
(Voltage)**

#### FUNCTION

Sets the full scale range of the simulated current probe.

Applies a momentary transient pulse on the voltage signal.

Sets the voltage amplitude. This value is set as a percentage of the voltage output. If the voltage output being used is 230VAC then 100% = 230VAC and 80% = 184V.

CONTROL	FUNCTION
<b>Amplitude Selector (Current)</b>	Sets the current amplitude. This value is set as a percentage of the full scale current range. If the current selector is set to 6000A output then 100% = 6000AAC and 80% = 4800AAC.
<b>Phase Angle Selector (Voltage)</b>	Sets the voltage phase angles. Phase A is used as the reference.
<b>Phase Angle Selector (Current)</b>	Sets the current phase angles. The Phase A Voltage is used as the reference.
<b>Harmonics Switch</b>	Turns ON and OFF the voltage and / or current harmonics.
<b>Flicker Selector</b>	Sets the level and rate of voltage variation which causes flicker in incandescent lighting.
<b>Power Direction Switch</b>	Sets the power flow. The power flow can either be from the source or the load.
<b>Line Frequency Switch</b>	Sets the fundamental line frequency. The line frequency can be at either 50Hz or 60Hz.
<b>Power Switch</b>	Turns the MPQSIM ON and OFF.

## Initial Settings

Connect the Power Quality Simulator to the Megger MPQ Analyzer as described in *Section 6*.

Set the controls to the following initial settings.

CONTROL	SETTING
<b>PHASE A</b>	
Phase A Current Range	Desired Current Range
Phase A Voltage Amplitude	100%
Phase A Current Amplitude	100%
Phase A Current Angle	0°
Phase A Voltage Harmonics	OFF
Phase A Current Harmonics	OFF
<b>PHASE B</b>	
Phase B Current Range	Desired Current Range
Phase B Voltage Amplitude	100%
Phase B Current Amplitude	100%
Phase B Voltage Angle	120°
Phase B Current Angle	120°

CONTROL	SETTING
Phase B Voltage Harmonics	OFF
Phase B Current Harmonics	OFF
<b>PHASE C</b>	
Phase C Current Range	Desired Current Range
Phase C Voltage Amplitude	100%
Phase C Current Amplitude	100%
Phase C Voltage Angle	240°
Phase C Current Angle	240°
Phase C Voltage Harmonics	OFF
Phase C Current Harmonics	OFF
<b>GENERAL</b>	
Flicker	OFF
Power Direction	SOURCE
Line Frequency	Desired Frequency
Power	ON

## Simulations

### Power Reversal

Verify the Power Quality instrument connected to the simulator is programmed to record power in a 4-wire wye 3-wattmeter configuration.

#### **Method # 1 Real Time Demand DVM Screen**

1. Verify the controls are set to their initial settings.
2. View the real time demand (DVM screen) and note the KW is positive.
3. Set the Power Direction switch on the PQ Simulator to Sink.
4. The KW now reads negative. This indicates a reversal of power.

*NOTE: The current vectors are now 180° out of phase with the voltage. Current vectors should never exceed 90° of the voltage. If the current does exceed 90° of the voltage angle then this indicates a reverse power flow.*

## **Method # 2 Real Time Demand Scope Screen**

1. Verify the controls are set to their initial settings.
2. View the Phase A voltage and current on the scope screen.
3. Note the current is in Phase with the Voltage.
4. Set the Power Direction switch on the PQ Simulator to Sink.

*NOTE: The current is now 180° out of phase with the voltage. This indicates a reversal of power.*

## **Method # 3 Recording Data**

1. Verify the Power Quality instrument connected to the simulator has a programmed demand interval of no more than 1 minute. This simulation will require that at least 6 demand intervals are captured. The longer the demand interval the longer this test will take.
2. Verify the controls are set to their initial settings.
3. Start the unit recording.
4. Allow the unit to record for at least 2 demand intervals.
5. Set the Power Direction switch on the PQ Simulator to Sink.
6. Allow the unit to record for at least 2 demand intervals.
7. Set the Power Direction Switch back to Source.
8. Allow the unit to record for at least 2 demand intervals.
9. Stop the recording.
10. View the Active Power (KW).
11. Note that during the phase reversal the KW value went negative.



## Active Power vs. Reactive Power

Verify the Power Quality instrument connected to the simulator is programmed to record power in a 4-wire wye 3-wattmeter configuration.

### **Method # 1 Real Time Demand DVM Screen**

1. Verify the controls are set to their initial settings.
2. View the real time demand (DVM screen) and note the KW displays a value and the KVAR is near 0.
3. Set any of the Current Phase Angle selectors to  $30^\circ$  from its nominal angle. ( $-30^\circ$  for Phase A,  $90^\circ$  for Phase B or  $210^\circ$  for Phase C)

*NOTE: The KW value for the selected channel goes down while the KVAR value goes up. As inductive load is added the phase angle increases which reduces the active power and increases the reactive power.*

### **Method # 2 Recording Data**

1. Verify the Power Quality instrument connected to the simulator has a programmed demand interval of no more than 1 minute. This simulation will require that at least 6 demand intervals are captured. The longer the demand interval the longer this test will take.
2. Verify the controls are set to their initial settings.
3. Start the unit recording.
4. Allow the unit to record for at least 2 demand intervals.
5. Set any of the Current Phase Angle selectors to  $30^\circ$  from its nominal angle. ( $-30^\circ$  for Phase A,  $90^\circ$  for Phase B or  $210^\circ$  for Phase C)
6. Allow the unit to record for at least 2 demand intervals.
7. Set the Current Phase Angle Selectors back to their nominal angles ( $0^\circ$ ,  $120^\circ$  and  $240^\circ$ ).
8. Allow the unit to record for at least 2 demand intervals.
9. Stop the recording.
10. View the Active Power (KW) and Reactive Power (KVAR).

*NOTE: As the phase angle increases the reactive power increases and the active power decreases.*

## Displacement Power Factor (Leading and Lagging Current)

Verify the Power Quality instrument connected to the simulator is programmed to record power in a 4-wire wye 3-wattmeter configuration.

### **Method # 1 Real Time Demand DVM Screen**

1. Verify the controls are set to their initial settings.
2. Set the Phase A, B and C Current Phase Angle selector switches to  $-11^\circ$ .
3. View the real time demand (DVM screen) and note the DPF for each channel is positive.
4. Set the Phase A, B and C Current Phase Angle selector switches to  $11^\circ$ .
5. View the real time demand (DVM screen) and note the DPF for each channel is negative.

*NOTE: When the load is inductive (as in a motor) the current lags the voltage. This will be seen as a positive displacement power factor (DPF). When the load is capacitive (as in a cap bank) the current leads the voltage. This will be seen as a negative displacement power factor (DPF).*

*The sign of the DPF will always equal the sign of the KVAR.*

### **Method # 2 Real Time Demand Scope Screen**

1. Verify the controls are set to their initial settings.
2. Set the Phase A Phase Angle selector switch to  $-30^\circ$ .
3. View the Phase A voltage and current on the scope screen.
4. Note the current lags the voltage.
5. Set the Phase A Phase Angle selector switch to  $11^\circ$ .
6. View the Phase A voltage and current on the scope screen.

*NOTE: The current now leads the voltage.*

*NOTE: When the load is inductive (as in a motor) the current lags the voltage. This will be seen as a positive displacement power factor (DPF). When the load is capacitive (as in a cap bank) the current leads the voltage. This will be seen as a negative displacement power factor (DPF).*

*The sign of the DPF will always equal the sign of the KVAR.*

**Method # 3 Recording Data**

1. Verify the Power Quality instrument connected to the simulator has a programmed demand interval of no more than 1 minute. This simulation will require that at least 8 demand intervals are captured. The longer the demand interval the longer this test will take.
2. Verify the controls are set to their initial settings.
3. Set the Voltage Phase A, B and C Phase Angle selector switches to  $11^\circ$ .
4. Start the unit recording.
5. Allow the unit to record for at least 3 demand intervals.
6. Set the Voltage Phase A, B and C Phase Angle selector switches to  $-30^\circ$ .
7. Allow the unit to record for at least 3 demand intervals.
8. Set the Voltage Phase A, B and C Phase Angle selector switches to  $11^\circ$ .
9. Allow the unit to record for at least 2 demand intervals.
10. Stop the recording.
11. View the Displacement Power Factor (DPF).

<p><i>NOTE: When the phase angle was <math>30^\circ</math> the DPF was positive. When the phase angle was <math>-30^\circ</math> the DPF was negative.</i></p>
--

<p><i>NOTE: When the load is inductive (as in a motor) the current lags the voltage. This will be seen as a positive displacement power factor (DPF). When the load is capacitive (as in a cap bank) the current leads the voltage. This will be seen as a negative displacement power factor (DPF).</i></p> <p><i>The sign of the DPF will always equal the sign of the KVAR.</i></p>
--

## Harmonic Effect on Power

Verify the Power Quality instrument connected to the simulator is programmed to record power in a 4-wire wye 3-wattmeter configuration.

### **Method # 1 Real Time Demand DVM Screen**

1. Verify the controls are set to their initial settings.
2. Set the Phase A, B and C Current Phase Angle selector switches to 30°.
3. View the real time demand (DVM screen) and note the Apparent Power (KVA), the Active Power (KW) and the Reactive Power (KVAR).

*NOTE: The Power Triangle holds true*

$$S = \sqrt{P^2 + Q^2}$$

*S = Apparent Power*

*P = Active Power*

*Q = Reactive Power*

4. Set the voltage and current harmonic switches to ON.
5. View the real time demand (DVM screen) and note the Apparent Power (KVA), the Active Power (KW) and the Reactive Power (KVAR).

*NOTE: The power triangle now has increased errors. This shows that power triangle does not hold true for non-sinusoidal waveforms.*

### **Method # 2 Recording Data**

1. Verify the Power Quality instrument connected to the simulator has a programmed demand interval of no more than 1 minute. This simulation will require that at least 6 demand intervals are captured. The longer the demand interval the longer this test will take.
2. Verify the controls are set to their initial settings.
3. Set the Phase A, B and C Phase Angle selector switches to 30°.
4. Start the unit recording.
5. Allow the unit to record for at least 3 demand intervals.
6. Set the voltage and current harmonic switches to ON.

7. Allow the unit to record for at least 3 demand intervals.
8. Stop the recording.
9. View the Apparent Power (KVA), the Active Power (KW) and the Reactive Power (KVAR).

*NOTE: The Power Triangle holds true when the harmonics are off.*

$$S = \sqrt{P^2 + Q^2}$$

*S = Apparent Power*

*P = Active Power*

*Q = Reactive Power*

The power triangle now has increased errors when the harmonics are on. This shows that power triangle does not hold true for non-sinusoidal waveforms.

## Voltage Dips / Sags

1. Verify the Power Quality instrument connected to the simulator has a programmed sag / dip limit of no more that 10% of the MPQSIM voltage output that it is connected.

*NOTE: If you wish to record RMS values as well it may be best to set the RMS storage interval to 3 seconds, so you do not need to wait a long period to acquire saved RMS intervals.*

2. Verify the controls are set to their initial settings.
3. Start the unit recording.
4. Allow the unit to record for several seconds.
5. Note there are no recorded Sags / Dip events.
6. Set one of the voltage phase Amplitude selector switches to 85%.
7. Allow the unit to record for several seconds.
8. Set the voltage phase Amplitude selector switch back to 100%.
9. Allow the unit to record for several seconds.
10. Note the unit now displays a Sag / Dip event.
11. Stop the recording.
12. The Sag event can now be viewed on the unit.

## Voltage Swells

Verify the Power Quality instrument connected to the simulator has a programmed swell limit of no more than 10% of the MPQSIM voltage output that it is connected.

*NOTE: If you wish to record RMS values as well it may be best to set the RMS storage interval to 3 seconds, so you do not need to wait a long period to acquire saved RMS intervals.*

1. Verify the controls are set to their initial settings.
2. Start the unit recording.
3. Allow the unit to record for several seconds.
4. Note there are no recorded Swell events.
5. Set one of the voltage phase Amplitude selector switches to 115%.
6. Allow the unit to record for several seconds.
7. Set the voltage phase Amplitude selector switch back to 100%.
8. Allow the unit to record for several seconds.
9. Note the unit now displays a Swell event.
10. Stop the recording.
11. The Swell event can now be viewed on the unit.

## Voltage Transients

1. Verify the Power Quality instrument connected to the simulator has a programmed with sag and swell limit of no more than 10% of the MPQSIM voltage output that it is connected.
2. Verify the Power Quality instrument connected to the simulator has a programmed with transient limit of 140.00 for a 115VAC voltage connection or a transient limit of 280.00 for a 230VAC voltage connection.

*NOTE: If you wish to record RMS values as well it may be best to set the RMS storage interval to 3 seconds, so you do not need to wait a long period to acquire saved RMS intervals.*

3. Verify the controls are set to their initial settings.

4. Start the unit recording.
5. Allow the unit to record for several seconds.
6. Note there are no recorded Transient events.
7. Depress and release one of the transient buttons.
8. Allow the unit to record for several seconds.
9. Note the unit now displays a Transient event.
10. Stop the recording.
11. The Transient event can now be viewed on the unit.

### Phase Angle Event

1. Verify the Power Quality instrument connected to the simulator has the following settings programmed.
  - a. Phase Ange Events – Enabled
  - b. Rotation – ABC
  - c. Phase A Nominal Angle = 0
  - d. Phase B Nominal Angle = 120
  - e. Phase C Nominal Angle = 240
  - f. Phase B Angle Deviation = 2.00
  - g. Phase C Angle Deviation = 2.00

*NOTE: If you wish to record RMS values as well it may be best to set the RMS storage interval to 3 seconds, so you do not need to wait a long period to acquire saved RMS intervals.*

2. Verify the controls are set to their initial settings.
3. Start the unit recording.
4. Allow the unit to record for several seconds.
5. Note there are no phase angle events.
6. Set Phase B Voltage Angle to 131°
7. Allow the unit to record for several seconds.

8. Set Phase B Voltage Angle to  $120^\circ$
9. Allow the unit to record for several seconds.
10. Note the unit now displays a Phase Angle Event.
11. Set Phase C Voltage Angle to  $251^\circ$
12. Allow the unit to record for several seconds.
13. Set Phase C Voltage Angle to  $240^\circ$
14. Allow the unit to record for several seconds.
15. Note the unit now displays another Phase Angle Event.
16. Stop the recording.
17. The Phase Angle events can now be viewed on the unit

## **Voltage and Current Harmonics**

Verify the Power Quality instrument connected to the simulator is programmed to record power in a 4-wire wye 3-wattmeter configuration.

### **Method # 1 Real Time Harmonics DMM Screen**

1. Verify the controls are set to their initial settings.
2. Verify the Voltage and Current Harmonic switches are set to OFF.
3. View the real time harmonics in the units real time DMM screen and note the harmonic content is near 0.
4. Set the Phase A, B and C Voltage Harmonics to ON.
5. View the real time harmonics in the units real time DMM screen and note the 3<sup>rd</sup> order and 5<sup>th</sup> order voltage harmonics now display

### **Method # 2 Real Time Harmonics Scope Screen**

1. Verify the controls are set to their initial settings.
2. Verify the Voltage and Current Harmonic switches are set to OFF.
3. View the real time harmonics in the units real time Scope screen and note the harmonic content is near 0.
4. Set the Phase A, B and C Current Harmonics to ON.



5. View the real time harmonics in the unit's real time Scope screen and note the 3rd order and 5th order current harmonics now display.
6. Set the Phase A, B and C Voltage Harmonics to ON.
7. View the real time harmonics in the units real time Scope screen and note the 3rd order and 5th order voltage harmonics now display.

### **Method # 3 Recording Data**

1. Verify the Power Quality instrument connected to the simulator is programmed to record power in a 4-wire wye 3-wattmeter configuration and has the following settings programmed.
  - a. RMS Storage Interval – 3 Seconds
  - b. Timed Waveform Capture – Enabled
  - c. Timed Capture Rate = 1 Minute
  - d. Timed Capture Duration in Cycles = 6
  - e. Enable THD Recording = Enabled
  - f. Enable IEC Harmonics Recording = Enabled
  - g. THD / Harmonic Storage Interval = 3 Seconds
2. Verify the controls are set to their initial settings.
3. Verify the Voltage and Current Harmonic switches are set to OFF.
4. Start the unit recording.
5. Allow the unit to record for at least 30 seconds to 1 minute.
6. Set the Phase A, B and C Current Harmonics to ON.
7. Allow the unit to record for at least 30 seconds to 1 minute.
8. Set the Phase A, B and C Voltage Harmonics to ON.
9. Allow the unit to record for at least 30 seconds to 1 minute.
10. Set the Phase A, B and C Voltage and Current Harmonics to OFF.
11. Allow the unit to record for at least 30 seconds to 1 minute.
12. Stop the recording.
13. You can now view the recorded harmonic on the unit.

**NOTE:** *You can transfer the data to the PC for a more advanced analysis.*

## Flicker

### **Method # 1 Real Time Flicker DVM Screen**

1. Verify the controls are set to their initial settings.
2. Load a setup file into the MPQ Analyzer that has flicker recording enabled. (Pst and Plt)
3. Verify the flicker knob on the unit Power Quality Simulator is set to OFF.
4. View the real time flicker on the flicker portion of the DVM screen and note the flicker content is near 0.
5. Set the flicker knob on the Power Quality Simulator to one of the flicker settings.
6. Note the instantaneous flicker value on the MPQ DVM screen is now showing a value.
7. Wait one minute for the Pst 1 Minute value to display.

### **Method # 2 Recording Data**

1. Verify the Power Quality instrument connected to the simulator is programmed to record power in a 4 wire wye 3 wattmeter configuration and has the flicker capture enabled. (Pst and Plt)
2. Verify the controls are set to their initial settings.
3. Set the flicker knob on the Power Quality Simulator to one of the flicker settings.
4. Start the MPQ Analyzer recording.
5. Let the unit record for 30 minutes, in order to record several flicker intervals.
6. Stop the recording and view the flicker data on the unit or download the data to the Megger PQ PC software.

# 8

## UNIT MAINTENANCE

This unit has no field serviceable parts within it.

### ***Instructions for Cleaning and Decontamination***

The unit should not be cleaned with anything more than a clean dry cloth.

**Megger.**

# 9

## SPARE PARTS

<b>PART NO.</b>	<b>DESCRIPTION</b>
2008-124	Current Cable
90017-548	AC Adapter

**Megger.**

# ADDENDUM A

## SAMPLE QUICK TRAINING

This Addendum is meant to offer a possible sample training routine for the MPQ line of power quality analyzers.

### 1. Initial PQ Simulator Configuration

Configure the PQ Simulator as shown in *Section 7 Initial Settings* of this manual

### 2. Program the MPQ Analyzer

<b>Programming the MPQ Analyzer for 115V input from simulator.</b>	
<b>Voltage sag / dip limit</b>	108.00
<b>Voltage swell limit</b>	132.00
<b>Fast transient limit</b>	400.00
<b>THD limit</b>	5.0
<b>RMS storage interval</b>	3 Seconds
See <i>Addendum D - Complete 115V MPQ Setup File</i> for full setup file.	

<b>Programming the MPQ Analyzer for 230V input from simulator.</b>	
<b>Voltage sag / dip limit</b>	207.00
<b>Voltage swell limit</b>	262.00
<b>Fast transient limit</b>	600.00
<b>THD limit</b>	5.0
<b>RMS storage interval</b>	3 Seconds
See <i>Addendum E - Complete 230V MPQ Setup File</i> for full setup file.	

Connect the unit to the simulator as shown in *Section 6 Product Installation* of this manual.

### 3. Operation of Scope Mode and DVM Mode

- a. View the voltages and demand values on the DVM screen of the MPQ Analyzer.
- b. View the waveforms on the Scope screen of the MPQ Analyzer. Scroll through the phases.

## 4. Harmonic Bar Chart

- a. View the waveforms on the Scope screen of the MPQ Analyzer. *Scroll through the phases.*
- b. Turn ON the Voltage Harmonics switch on the PQ Simulator. *The harmonics are displayed.*
- c. Turn OFF the Voltage Harmonics switch ON the PQ Simulator.

## 5. Phase Angles

- a. View the Vectors on the Unbalance screen of the MPQ Analyzer.
- b. Change the Current phase angles on the PQ Simulator. *View the changes on the vector diagram.*
- c. Set the Current phase angles on the PQ Simulator back to nominal.

## 6. Source Reversal

- a. View the demand values on the DVM screen of the MPQ Analyzer.
- b. Set the Power Direction Switch on the PQ Simulator to SINK. *The KW values are now negative, indicating reversed power flow.*

<p><i>NOTE: This can also be viewed in the scope mode and in the unbalance vectors as currents being 180° out of phase.</i></p>
---

- c. Set the Power Direction Switch on the PQ Simulator to SOURCE.

## 7. Leading/Lagging Current

- a. View the Waveforms on the Scope screen of the MPQ Analyzer.
- b. Change the Current phase angle on the PQ Simulator to -30°. *The current now lags the voltage. This is indicative of an inductive load, such as a motor.*
- c. View the Vectors on the Unbalance screen of the MPQ Analyzer.
- d. View the phase rotation caused by a lagging current.
- e. Change the Current phase angle on the PQ Simulator to +11°.
- f. View the Waveforms on the Scope screen of the MPQ Analyzer. *The current now leads the voltage. This is indicative of a capacitive load, such as a cap bank.*
- g. View the Vectors on the Unbalance screen of the MPQ Analyzer.

<p><i>NOTE: The phase rotation caused by a leading current.</i></p>
---

- h. Set the Current phase angles on the PQ Simulator back to nominal.



### 8. Start a Recording

Start the MPQ Recording.

### 9. Create a SAG / DIP

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Start a SAG / DIP on one of the voltage phases by setting the voltage selector to 85%.
- c. Wait about 1 second.
- d. Stop the SAG / DIP by setting the voltage selector back to 100%. *The record screen now will register a sag.*

### 10. Create a Swell

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Start a SWELL on one of the voltage phases by setting the voltage selector to 115%.
- c. Wait about 1 second.
- d. Stop the SWELL by setting the voltage selector back to 100%. *The record screen now will register a swell.*

### 11. Create a Transient

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Create a transient by depressing and releasing one of the transient switched on the PQ Simulator. *The record screen now will register a transient.*

### 12. Create THD Event

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Start a THD Event by turning ON one of the voltage harmonic switches.
- c. Wait about 2 second.
- d. Stop the THD Event by turning OFF one of the voltage harmonic switches. *The record screen now will register a THD Event.*

### 13. Create a Phase Event

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Start a Phase Event by setting one of the Voltage Phase switches to +11°.
- c. Wait about 1 second.
- d. Stop the Phase Event by setting the voltage phase switch selector back to nominal. *The record screen now will register a Phase Event.*

## 14. Turn on Harmonics

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Turn ON one of the voltage and current harmonic switches.
- c. Let the unit record for about 1 minute.
- d. Turn OFF the voltage and current harmonic switches.
- e. Let the unit record for about another 15 seconds then stop the recording.

## 15. View the data on the MPQ Analyzer

- a. View the RMS Charts.
- b. View the Power Charts.
- c. View the Harmonic Charts.
- d. View the Event Data Charts.

*NOTE: This data can also be transferred and viewed in the Megger PQ software.*

# ADDENDUM B

## SAMPLE DEMAND TRAINING

This Addendum is meant to offer a possible sample training to illustrate power and energy parameters.

### 1. Initial PQ Simulator Configuration

Configure the PQ Simulator as shown in *Section 7: Initial Settings* of this manual.

### 2. Program the MPQ Analyzer

<b>Programming the MPQ Analyzer for 115V input from simulator.</b>	
<b>Voltage sag / dip limit</b>	108.00
<b>Voltage swell limit</b>	132.00
<b>Fast transient limit</b>	400.00
<b>THD limit</b>	5.0
<b>RMS storage interval</b>	3 Seconds
<b>Demand Configuration</b>	4-Wire Wye 3-Wattmeter
<b>Demand Storage Interval</b>	5 Minutes
See <i>Addendum 4 - Complete 115V MPQ Setup File</i> for full setup file.	

<b>Programming the MPQ Analyzer for 230V input from simulator.</b>	
<b>Voltage sag / dip limit</b>	207.00
<b>Voltage swell limit</b>	262.00
<b>Fast transient limit</b>	600.00
<b>THD limit</b>	5.0
<b>RMS storage interval</b>	3 Seconds
<b>Demand Configuration</b>	4-Wire Wye 3-Wattmeter
<b>Demand Storage Interval</b>	5 Minutes
See <i>Addendum 5 - Complete 230V MPQ Setup File</i> for full setup file.	

Connect the unit to the simulator as shown in Section 6 *Product Installation* of this manual.

### 3. RMS and Demand Values

- a. View the voltages and demand values on the DVM screen of the MPQ Analyzer.

*NOTE: The phase angles of the voltage and current. Voltages and current are at 0, 120 and 240. This is true under purely resistive loads only.*

Confirm the following:

- The KW is positive. This indicates the power is flowing from the source to the load.
- The KVAR is near zero. This indicates there is minimal phase shifting due to reactive loads.
- The DPF is 1.0 and is positive. This is a sign of a resistive load.

The Displacement Power Factor (DPF) is the power factor of the fundamental value. (COS of the phase angle between the voltage and current)

- b. View the waveforms on the Scope screen of the MPQ Analyzer. Scroll through the phases. *The currents are in phase with the voltages.*

### 4. Phase Rotation

- a. View the Vectors and Power Factor on the DVM Power screen of the MPQ Analyzer.

The phase rotation is as follows:

- Phase A Voltage =  $0^\circ$
- Phase B Voltage =  $120^\circ$
- Phase C Voltage =  $240^\circ$

*This is an ABC Phase rotation.*

- b. Swap Phase B and C voltage inputs.

The phase rotation is as follows:

- Phase A Voltage =  $0^\circ$
- Phase B Voltage =  $240^\circ$
- Phase C Voltage =  $120^\circ$

*This is an ACB phase rotation*

Notice the currents are still in an ABC Phase rotation. The Phase B and C current phase angles now have a phase angle difference of greater than  $90^\circ$  from their voltages.

## ADDENDUM B - SAMPLE DEMAND TRAINING

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Different phase rotations can be used however the current phase angle can never be more than  $90^\circ$  away from the phase voltage. This is a sign that something is not connected properly.

- c. Swap Phase B and C voltage inputs back to normal.

### 5. Phase Angles and Power Factor

- a. View the Phase A Voltage and Current Waveforms on the Scope screen of the MPQ Analyzer.
- b. Change the Phase A Current phase angle on the PQ Simulator to  $-30^\circ$ .

This simulates an inductive load, such as a motor.

*The current now lags the voltage. This is because the coil is resistant to the change in ac current, per Lenz's law.*

Lenz's law states that when an *electromagnetic field* (EMF) is generated by a change in magnetic flux. The polarity of the induced EMF is such, that it produces a current that's magnetic field opposes the change which produces it.

- c. View the Vectors and Power Factor on the DVM Power screen of the MPQ Analyzer. The phase rotation due to the lagging current moves the current vector clockwise.

<p><i>NOTE: The DPF is now less than 1.0 and is positive. A positive DPF is a sign of a lagging current (Inductive load).</i></p>
---

- d. Change the Phase A Current phase angle on the PQ Simulator to  $+11^\circ$ . *This simulates a capacitive load such as a cap bank.*
- e. View the Waveforms on the Scope screen of the MPQ Analyzer. The current now leads the voltage. This is because the capacitors will charge and discharge as the voltage changes. This creates a phase shift.
- f. View the Vectors and Power Factor on the DVM Power screen of the MPQ Analyzer. The phase rotation due to the leading current moves the current vector counter-clockwise.

<p><i>NOTE: The DPF is now less than 1.0 and is negative. A negative DPF is a sign of a leading current (Capacitive load).</i></p>
--

- g. Set the Current phase angles on the PQ Simulator back to nominal.

## 6. Source Reversal

- View the demand values on the DVM screen of the MPQ Analyzer.
- Set the Power Direction Switch on the PQ Simulator to SINK. *The KW values are now negative, indicating reversed power flow. The power is now flowing from the load to the source. This can be due to local sources such as solar power locations, distributed generation devices.*

If the KW is *negative* when the power quality device is connected this can be an indication that the current probes are backwards. Verify the arrows on the current probes point toward the load.

NOTE: *This can also be viewed in the scope mode and in the unbalance vectors as currents being 180° out of phase.*

- Set the Power Direction Switch on the PQ Simulator to SOURCE.

## 7. Power Triangle

- View the demand values on the DVM screen of the MPQ Analyzer.

NOTE:

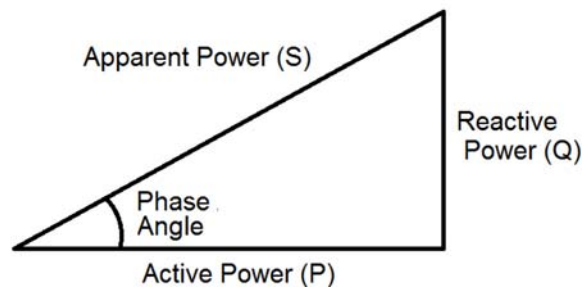
$$KVA = \sqrt{KW^2 + KVAR^2}$$

**Active Power (P):** *measured in W / (KW): Performs real work*

**Reactive Power (Q):** *measured in VAR / (KVAR): Out of phase power, does not perform real work.*

**Apparent Power (S):** *measured in VA / (KVA)*

### POWER TRIANGLE



$$S = \sqrt{P^2 + Q^2}$$

- Change the Phase A Current phase angle on the PQ Simulator to -30°. *The KVAR on Phase A increased due to the increase in reactive current caused by the added inductive load.*

## ADDENDUM B - SAMPLE DEMAND TRAINING

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However the power triangle still holds true.  $KVA = \sqrt{KW^2 + KVAR^2}$

The more reactive power in a system the greater the amount of apparent power (KVA) is required. As inductive loads are added to a network they increase the lag in the current. This increases the amount of reactive power in that network. The energy provider needs to create larger amounts of apparent power to carry that burden. By switching in a capacitive load such as a capacitor bank, this compensates for the lagging current and therefore reduces the reactive power in the network. This means the energy provider can produce less apparent power to run the network. This makes the energy provider more efficient.

c. Set the Current phase angles on the PQ Simulator back to nominal.

### 8. Harmonic Effects on the Power Triangle

a. View the demand values on the DVM screen of the MPQ Analyzer.

<i>NOTE:</i> <i>the</i> $KVA = \sqrt{KW^2 + KVAR^2}$
--

b. Change the Phase A Current phase angle on the PQ Simulator to  $-30^\circ$ . The KVAR on Phase A increased due to the increase in reactive current caused by the added inductive load.

c. Turn ON the Phase A Voltage and Current Harmonics on the PQ Simulator. *The power triangle does NOT hold true  $\neq \sqrt{KW^2 + KVAR^2}$ .*

The power triangle only holds true for sinusoidal waveforms. Once harmonics are introduced the waveform is no longer sinusoidal, therefore the power triangle will have errors. In the real world virtually all power will have some amount of harmonics. This means that calculating a single power parameter based on the other two will always have some error. In a PQ Instrument these values need to be measured values not calculated values.

*There is now a difference between the DPF and the TPF.*

This is because the Displacement Power Factor (DPF) is the power factor of the fundamental value only (COS of the phase angle between the voltage and current). The True Power Factor (TPF) is the power factor of the fundamental plus the harmonics (TPF = KW/KVA).

The greater the difference between the TPF and DPF, the greater the harmonic content.

d. Set the Current phase angles on the PQ Simulator back to nominal.

## 9. Start a recording

- a. Change the Phase A Current phase angle on the PQ Simulator to  $-30^\circ$ .
- b. Change the Phase B Current phase angle on the PQ Simulator to  $-30^\circ$ .
- c. Change the Phase C Current phase angle on the PQ Simulator to  $-30^\circ$ .

*NOTE: The KW, KVA and KVA values on the DVM Demand screen.*

- d. Start the MPQ Recording.

Allow the unit to record for 20 minutes.

## 10. Energy

- a. Stop the recording.
- b. View the recorded energy graph on the unit.

Confirm the following:

- Each KWH 5 minute interval =  $KW/12$
- Each KVAR 5 minute interval =  $KVAR/12$
- Each KVA 5 minute interval =  $KVA/12$

This is because the demand interval was set to 5 minutes. There are 12 (5 minute) intervals in an hour. So the power is aggregated over a 5 minute interval to calculate energy. If the demand interval was set to 15 minutes then the energy would be aggregated 4 times every hour. So if the active power draw was constant the over the 15 minute demand interval then the  $KWH = KW/4$ .

When verifying revenue meters the demand aggregation should be set to the same value as the revenue meter.

*NOTE: This data can also be transferred and viewed in the Megger PQ software.*



# ADDENDUM C

## SAMPLE POWER QUALITY TRAINING

This Addendum is meant to offer a possible sample training to illustrate power quality phenomenon.

### 1. Initial PQ Simulator configuration

Configure the PQ Simulator as shown in *Section 7 Initial Settings* of this manual.

### 2. Program the MPQ Analyzer

<b>Programming the MPQ Analyzer for 115V input from simulator.</b>	
<b>Voltage sag / dip limit</b>	108.00
<b>Voltage swell limit</b>	132.00
<b>Fast transient limit</b>	400.00
<b>THD limit</b>	5.0
<b>RMS storage interval</b>	3 Seconds
See <i>Addendum 4 Complete 115V MPQ Setup File</i> for full setup file.	

<b>Programming the MPQ Analyzer for 230V input from simulator.</b>	
<b>Voltage sag / dip limit</b>	207.00
<b>Voltage swell limit</b>	262.00
<b>Fast transient limit</b>	600.00
<b>THD limit</b>	5.0
<b>RMS storage interval</b>	3 Seconds
See <i>Addendum 5 Complete 230V MPQ Setup File</i> for full setup file.	

Connect the unit to the simulator as shown in *Section 6 Product Installation* of this manual.

### 3. RMS, Phases and THD

- a. View the voltages and current values on the DVM screen of the MPQ Analyzer. Verify RMS voltages and currents are correct. This should always be done prior to performing a power quality investigation.
- b. View the phase angles of the voltage and current on the DVM screen of the MPQ Analyzer.

*NOTE: Always verify the voltage phase angles are correct per the power configuration.*

*Always verify the current angles are less than 90° from their respective voltage angles.*

*Current phase angle can never be more than 90° away from the phase voltage. This is a sign that something is not connected properly.*

- c. View the scope screen of the MPQ Analyzer.

Examinations of voltage waveforms can indicate power quality problem. These can include harmonic distortion, notching and noise.

- d. View the scope harmonics screen of the MPQ Analyzer.

Examinations of the harmonics can indicate power quality problems without the need of doing a recording.

*NOTE: Harmonics can cause various problems, including beating of transformers, and motors, reduced efficiency in motors, neutral line overheating, capacitor bank failures, as well as equipment failure.*

*Even harmonics (2, 4, 6...etc) are indications of a faulty rectifier.*

*Negative sequence harmonics (5, 11, 17...etc) have magnetic fields that rotate opposite the fundamental. This creates inefficiencies in motors.*

*Odd Zero Sequence harmonics also known as triplens (3, 9, 15...etc) do not cancel out. They add together. This can create high neutral currents.*

## ADDENDUM C - SAMPLE POWER QUALITY TRAINING

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### 4. Unbalance

- a. View the Vectors and Unbalance on the SCOPE/UNBALANCE screen of the MPQ analyzer.
- b. Change the Phase A Current phase angle on the PQ Simulator to  $-30^{\circ}$ .
- c. Change the Phase A Voltage to 85% on the PQ Simulator. *Note the change in the unbalance.*

**NOTE:** *Voltage unbalance causes heating in neutral lines, motors, unbalanced currents and uncharacteristic harmonics for electronic equipment such as adjustable speed drives.*

*High-efficiency motors can be more susceptible to negative sequence unbalance.*

*Negative sequence harmonics have a magnetic field that rotate opposite of the fundamental.*

*This can lead to loss of efficiency as it resists the rotation of the motor.*

*The negative sequence factor [(negative sequence / positive sequence) \* 100] is most the key unbalance value to reference when working with motor loads.*

*Negative sequence unbalance is the basis of most international standards for unbalance.*

*It is recommended that the voltage unbalance be within 2% for 95% of the time measured over a period of a week at 10 minute intervals. For systems with large single-phase loads, the unbalance can be as high as 3%.*

- d. Use the UP/DOWN button on the MPQ analyzer to change from an IEC Unbalance measurement to an ANSI unbalance measurement.

*The ANSI method of measuring unbalance compares the individual line-to-line voltage to the average of the sum of all the line to line voltages. This value can be influenced by the zero sequence voltage as well as by the negative sequence voltage.*

*ANSI C84.1-2006 recommends that voltage unbalance be limited to 3%.*

- e. Change the Phase A Current phase angle on the PQ Simulator to  $0^{\circ}$ .
- f. Change the Phase A Voltage to 100% on the PQ Simulator.

## 5. Harmonics

- a. View the Harmonics Bar Chart on the SCOPE / HARMONICS screen of the MPQ analyzer.
- b. Turn on the voltage and current harmonics on the PQ simulator. Note the change in the harmonic bar chart as the harmonics are applied.
- c. View the waveform on the SCOPE screen of the MPQ analyzer. *Note the distortion.*

Immediate effects of harmonics can include the misoperation of electronic controls or uninterruptible power supplies. Over time harmonic distortion can result in increased heating in transformers, motors, capacitors and conductors. In addition voltage distortion can excite resonances overloading customer power factor correction equipment.

AC current flowing through coils creates eddy currents. These eddy currents create magnetic fields in opposition of the flow of current. This causes the current to be pushed out to the edge of the wire. This is known as "skin effect". As the skin effect increases the usable cross-sectional area of the wire decreases. This increases the impedance of the wire which in turn increases the heat. The higher the harmonic order the greater this effect. Eddy current losses increase with approximately the square of the frequency.

IEC 61000-2-2 specifies harmonic distortion compatibility levels dependent on the harmonic order. The compatibility level for the voltage THD is 8% for 95% of the time measured over a period of a week at 10 minute intervals.

IEEE 519 recommends voltage distortion limits of 8% for the total harmonic distortion (THD). IEEE 519 recommends individual harmonic components limits be at 5%. The compatibility level is for 95% of the time measured over a period of a week at 10 minute intervals.

- d. Turn off the voltage and current harmonics on the PQ simulator.

## 6. Start a Recording

Before starting a recording it is always recommended to verify several parameters.

- a. Go to the DVM screen of the MPQ Analyzer. Verify the voltages and currents look correct.
- b. Go to the DVM / POWER screen of the MPQ Analyzer
  - Verify the KW is positive. If it is not then the power flow is reversed. This can be demonstrated by placing the SOURCE / LOAD switch on the PQ Simulator in the SOURCE position.
  - Verify the voltage phase angles are correct per the programmed power configuration. This can be demonstrated by reversing the cable connection of one of the voltage lead cables.

## ADDENDUM C - SAMPLE POWER QUALITY TRAINING

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- Verify the current phases angles are correct. Each phase current should be within  $90^\circ$  of its phase voltage. If it is not within  $90^\circ$  then the current clamp may be backwards.

Once these parameters are verified, start the recording by pressing the record button on the MPQ Analyzer.

### 7. Create a Sag/Dip

- Allow the unit to record for approximately 15 seconds (minimum).
- Start a SAG / DIP on one of the voltage phases by setting the voltage selector to 85%.
- Wait about 1 second.
- Stop the SAG / DIP by setting the voltage selector back to 100%. *Note the record screen now will register a sag.*

Facility operations can be affected by both long and short duration dips (sags). Momentary voltage dips (sags) lasting less than 100 ms are often sufficient to cause disruptions to equipment and operations. Momentary or short duration dips (sags) can occur more frequently. Dips (sags) can be generated from either the load side of the source side. Large loads turning on this can create high inrush currents that create momentary dips (sags) on the voltage. Dips (sags) can also result from faults on distribution circuits and transmission circuits.

Short duration dips (sags) are defined as a decrease in rms voltage between 0.1 pu and 0.9 pu for durations from 0.5 cycles to 1 min. Under-voltages with durations exceeding 1 minute are considered to be long term duration events.

A dip (sag) event can either be a single phase event or a poly-phase phase event.

A dip (sag) is initiated when the  $\frac{1}{2}$  cycle RMS voltage of a single phase falls below the dip (sag) threshold. The event ends when all phases are within above the dip (sag) threshold plus any hysteresis programmed by the user.

The recommended thresholds for dip (sag) detection is 0.9pu the RMS value aggregated every  $\frac{1}{2}$  cycle.

*For example:*

A 230V system the dip (sag) limit would be 228V.

A 120V system the dip (sag) limit would be 108V.

## 8. Create a Swell

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Start a SWELL on one of the voltage phases by setting the voltage selector to 115%.
- c. Wait about 1 second.
- d. Stop the SWELL by setting the voltage selector back to 100%. *Note the record screen now will register a swell.*

Facility operation can be affected by swells. Swells can cause systems and operations to trip off line. Swells can be caused by switching off a large load, load shedding, or switching on a large capacitor bank. Swells can also be caused by system fault conditions.

*For example:* a single line to ground (SLG) fault can cause a temporary voltage rise (swell) on the un-faulted phases.

A swell is defined as an increase in rms voltage above 1.1 pu for durations from 0.5 cycle to 1 min.

A swell is initiated when the 1/2 cycle RMS voltage of a single phase rises above the swell threshold. The event ends when all phases are below the swell threshold minus any hysteresis programmed by the user.

The recommended thresholds for swell detection is 1.1pu the the RMS value aggregated every 1/2 cycle.

*For example:*

A 230V system the dip (sag) limit would be 253V.

A 120V system the dip (sag) limit would be 132V.

## 9. Create a Transient (Low Frequency / High Frequency / EFT)

- a. Allow the unit to record for approximately 15 seconds (minimum)
- b. Create a transient by depressing and releasing one of the transient switched on the PQ Simulator. *Note the record screen now will register a transient.*

Transient over-voltages can result in degradation or immediate dielectric failure in all classes of equipment. Repetitive lower magnitude application of transients decreases equipment mean time between failures. High magnitude and fast rise time of transient over-voltages contribute to insulation breakdown in electrical equipment. This equipment can include rotating machinery, transformers, capacitors, cables, current and potential transformers (CTs and PTs), as wells as switchgear. In electronic equipment, power supply component failures can result from transients. Transients can also cause tripping of Adjustable Speed Drives due to the dc link overvoltage protection circuitry.

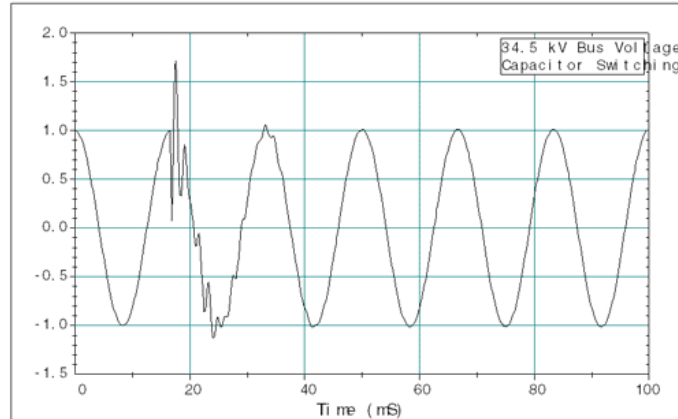
## ADDENDUM C - SAMPLE POWER QUALITY TRAINING

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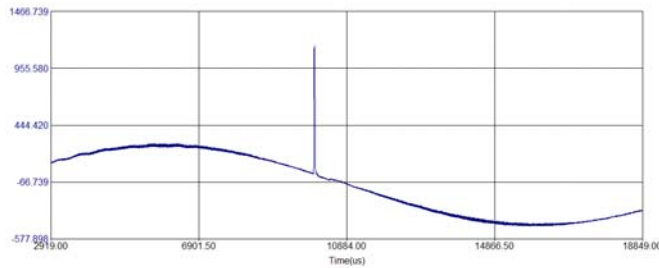
Transients are caused by lightning or almost any switching event on the power system.

Transients can be categorized into several categories.

**Oscillatory transients:** These are typically low frequency transients in the few hundred Hz range. They are caused by capacitor bank switching.



**Impulse transients:** These are typically high frequency transients in the few hundred KHz range. They are caused by lightning or equipment switching operations. They can be either uni-directional or bi-directional.



Impulsive transients can pass through transformers and appear on the low side of the transformer. They are not reduced by the turns ratio. This can cause damage on equipment connected to the low side of the transformer.

**Extremely Fast Transients (EFT):** These typically have rise times in the nano-seconds. The EFT has limited energy and is typically dampened out by just a few meters of wire.

These only become an issue in locations with short cable runs, such as off shore platforms or mines.

## 10. Create a THD Event

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Turn ON one of the voltage and current harmonic switches.
- c. Let the unit record for about 1 minutes.
- d. Turn OFF the voltage and current harmonic switches.
- e. Let the unit record for about another 15 seconds then stop the recording.

The MPQ PQ Analyzer will record harmonics as a trended value. It will also record Total Harmonic Distortion (THD) as a PQ event.

A THD event is initiated when the THD value (aggregated over a 200msec period) of a single channel rises above the THD threshold. The event ends when the THD value (aggregated over a 200msec period) of a single channel drops below the THD threshold.

Note THD value for current channels can be misleading. THD is represented as a percentage of the fundamental value. The voltage fundamental value is a constant value. The current fundamental value can fluctuate based on the changing load impedance. This make THD evaluation on current channel difficult. IEEE 519 recommends using Total Demand Distortion (TDD) to analyze current distortion. TDD references the harmonic content of the current channels to the maximum average current drawn within the test interval. This can be analyzed in the PC software provided the unit is programmed to capture periodic waveforms.

## 11. Create a Phase Event (Loss of phase)

- a. Allow the unit to record for approximately 15 seconds (minimum).
- b. Start a Phase Event by setting one of the Voltage Phase switches to  $+11^\circ$ .
- c. Wait about 1 second.
- d. Stop the Phase Event by setting the voltage phase switch selector back to nominal. *Note the record screen now will register a Phase Event.*

The phase angle shift (jump) manifests itself as a shift in zero crossing of the instantaneous voltage. Change in the phase angle of the voltage can affect power-electronics converter and relays that use phase angle information for their firing instant. The inconsistent nature of renewable energy such as wind and solar can lead to inverters turning on and off leading to phase shift phenomenon. These can also be caused by system faults.

The phase angle is referenced from Phase A voltage. The phase angle of the Phase B Voltage and Phase C voltage are measured relative to Phase A voltage. If the Phase B or C voltage deviated by more than the programmed amount from nominal then a phase shift event occurs.



## ADDENDUM C - SAMPLE POWER QUALITY TRAINING

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### 12. View the Data on the Unit

- a. Allow the unit to record for at least 10 minutes to obtain enough data for adequate charts.
- b. Stop the unit recording.
- c. Press the HOME button.
- d. Select VIEW DATA.

**View the RMS Charts:** Scroll through the phase and note the RMS variation throughout the test period. The RMS variation should not exceed 10% of nominal for 95% of the test interval. It is recommended that this value is measured in 10 minute intervals over a period of 1 week.

**View the Unbalance Charts:** View the Unbalance data and note the unbalance deviation throughout the test period. It is recommended that the voltage unbalance does not exceed 2% of nominal for 95% of the test interval. It is recommended that this value is measured in 10 minute intervals over a period of 1 week.

**View the THD Chart:** View the THD data for the various channels and note the deviation throughout the test period. It is recommended that the voltage THD does not exceed 8% of nominal for 95% of the test interval. It is recommended that this value is measured in 10 minute intervals over a period of 1 week.

**View the Harmonic Charts:** View the Zero Sequence harmonics and Negative Sequence Harmonics. The PQ simulator will generate 3rd and 5th order harmonic. The third harmonic is a zero sequence harmonic. The 5th harmonic is a negative sequence harmonic. Per EN50160 standards 3rd harmonic should not exceed 5% of the declared value. The 5th harmonic should not exceed 6% of the declared value.

IEEE519 recommends that the individual harmonics do not exceed 5% of the fundamental value.

### 13. View the Event Data Charts

**View the Dip/Sag events:** Note the start and stop times as well as the duration and the channel that triggered the event.

**View the Swell events:** Note the start and stop times as well as the duration and the channel that triggered the event.

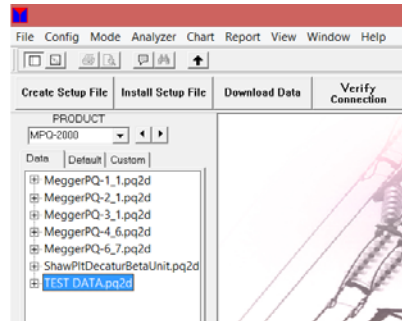
**View the THD events:** Note the start and stop times as well as the duration and the channel that triggered the event.

## 14. Transfer the Data to a PC

For the MPQ series of Power Quality Analyzers this can be done using the SD card, the USB stick or a direct link to the PC using the USB cable or Ethernet cable.

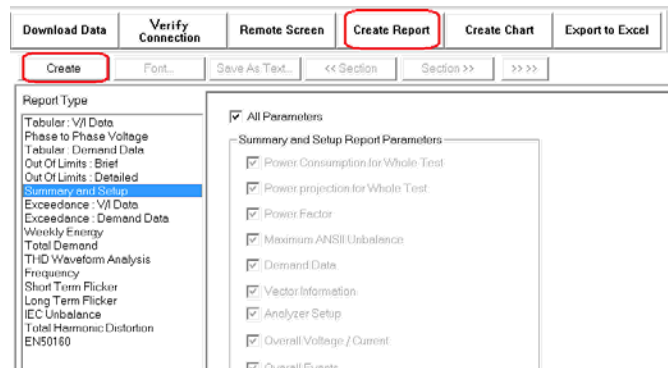
## 15. Analyze the Data on the PC

Highlight the name of the data file in the data file bar.



## 16. Create a Summary and Setup report

Click on the CREATE REPORT button then select the "Summary and Setup" report and click CREATE.



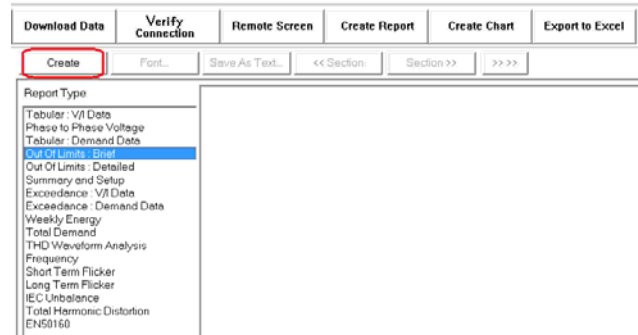
This report provides data on the following.

- Test duration
- Unit configuration
- Overall demand and power projections
- The maximum and minimum voltages & current recorded during the test interval
- A breakdown of the total number of events recorded during the test interval

## ADDENDUM C - SAMPLE POWER QUALITY TRAINING

### 17. Create an Out Of Limits-Brief report

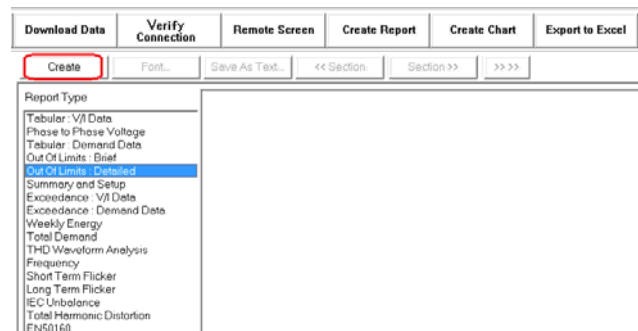
Click on the SETUP button to return to the report screen. Select the "Out Of Limits - Brief" report and click CREATE.



This report provides a brief view of the out of limits data. The report only shows the data for the channel that triggered the out of limits event.

### 18. Create an Out Of Limits-Detailed report

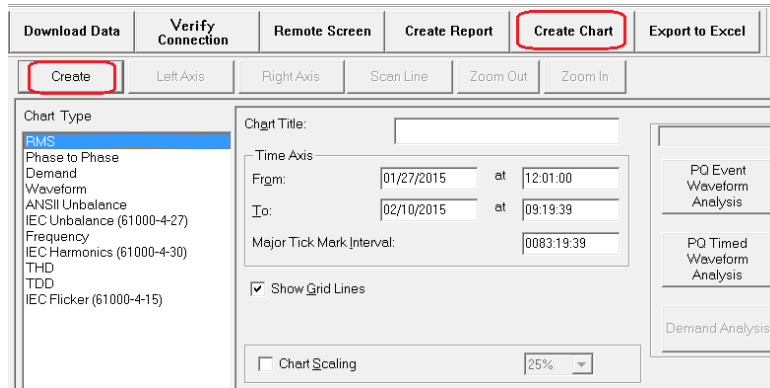
Click on the SETUP button to return to the report screen then select the "Out Of Limits-Detailed" report and click CREATE.



*This report provides a full report of the out of limits data. The report shows the data for all the channels for each out of limits event.*

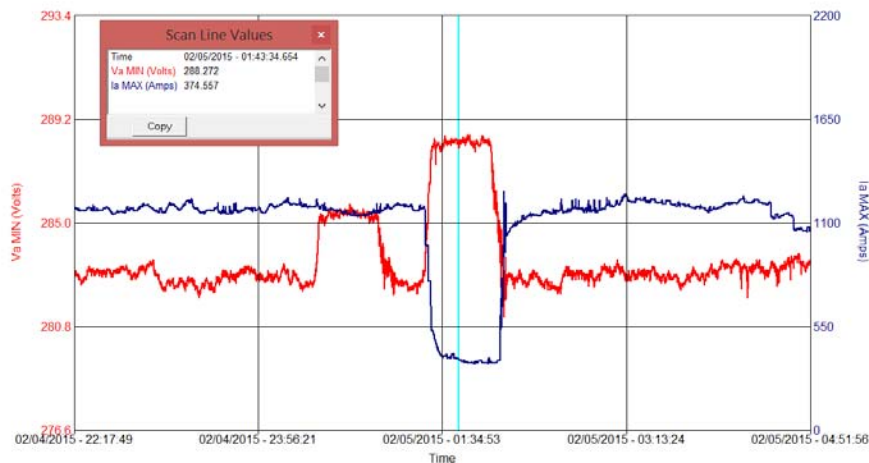
## 19. Create an RMS chart

Click on the CREATE CHART button then select the "RMS" chart and click CREATE.



**NOTE:** *The ability to zoom and create scan lines to examine individual intervals. When analyzing dip (sag) and swell events one method is to examine the direction of the voltage event and the current. If the voltage dips while the current swells this an indication that the event was on the load side. If the voltage and current are in the same direction this is a sign that the event was on the source side. Minimum voltage and maximum current should be plotted together when performing this analysis.*

*Please note" this is only an indication, it does not holds true in all cases.*



# ADDENDUM C - SAMPLE POWER QUALITY TRAINING

## 20. Create an Unbalance chart

Click on the SETUP button to return to the chart selection screen then select the "IEC Unbalance" chart and click CREATE.

Download Data   Verify Connection   Remote Screen   Create Report   Create Chart   Export to Excel

Create   Left Axis   Right Axis   Scan Line   Zoom Out   Zoom In

Chart Type

- RMS
- Phase to Phase
- Demand
- Waveform
- ANSI Unbalance
- IEC Unbalance (61000-4-27)**
- Frequency
- IEC Harmonics (61000-4-30)
- THD
- TDD
- IEC Flicker (61000-4-15)

Chart Title: \_\_\_\_\_

Time Axis

From: 01/27/2015 at 12:01:00

To: 02/10/2015 at 09:19:39

Major Tick Mark Interval: 0083:19:39

Show Grid Lines

Factors Display

Ratio

Percent

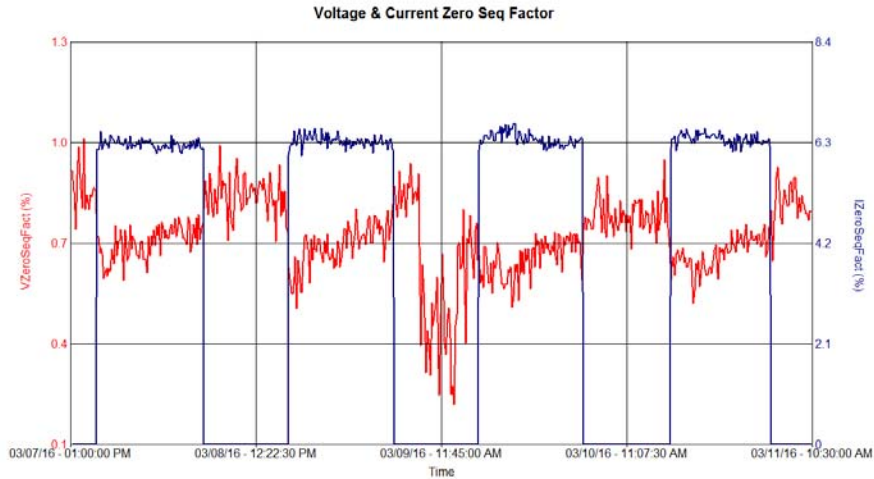
Chart Scaling   25%

PQ Event Waveform Analysis

PQ Timed Waveform Analysis

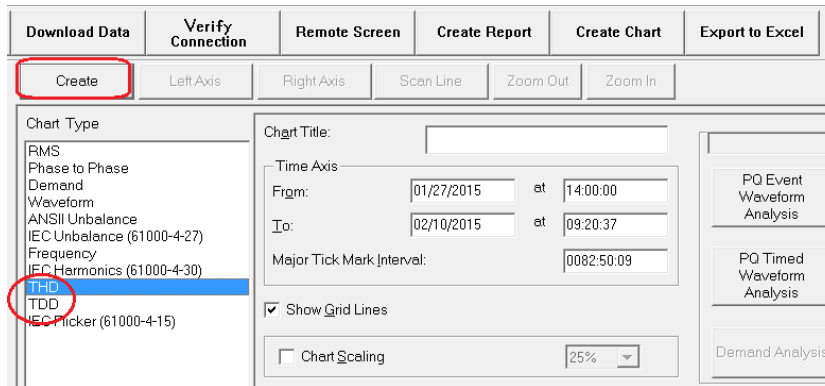
Demand Analysis

**NOTE:** *The unbalance can be shown as negative and zero sequence unbalance in the IEC unbalance chart and in an ANSI configuration in the ANSI unbalance chart.*

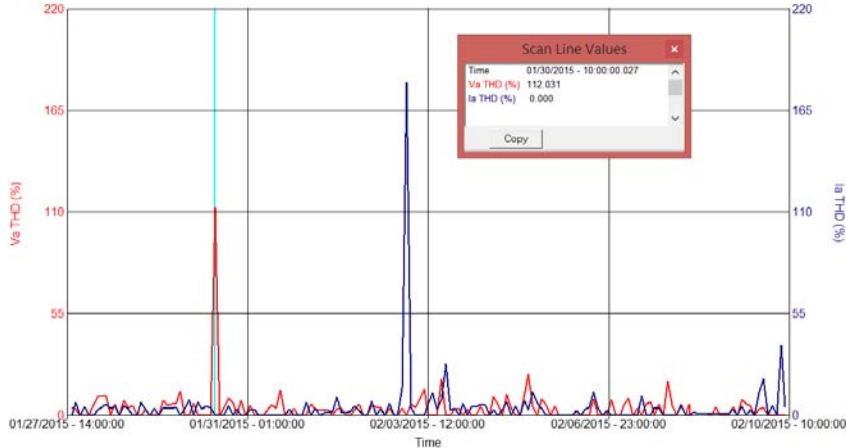


## 21. Create a THD chart

Click on the SETUP button to return to the chart selection screen then select the "THD" chart and click CREATE.



You can create THD charts to view the total harmonic distortion on the voltage channels and the current channels if you wish. However you can also create TDD total demand distortion charts to view the harmonic distortion on the current channels. TDD provides a better method for viewing current waveform distortion since the reference value is not changing.



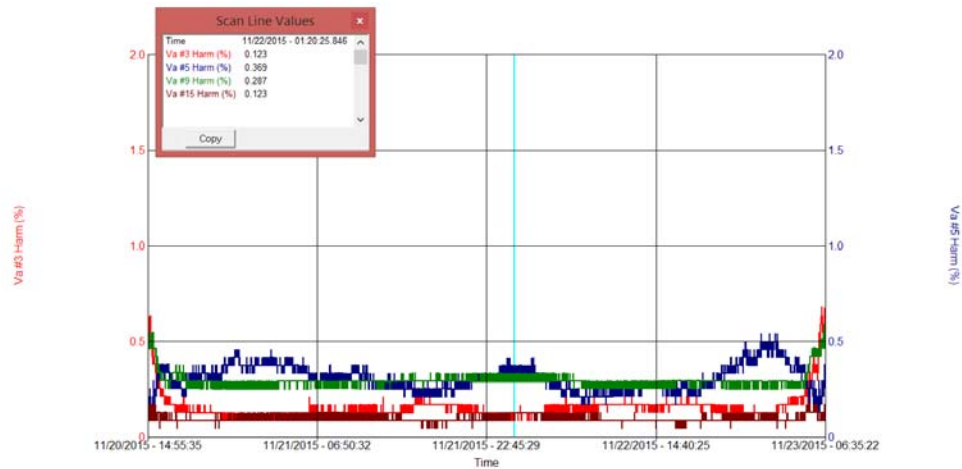
# ADDENDUM C - SAMPLE POWER QUALITY TRAINING

## 22. Create a Harmonics chart

Click on the SETUP button to return to the chart selection screen then select the "IEC Harmonics" chart and click CREATE.

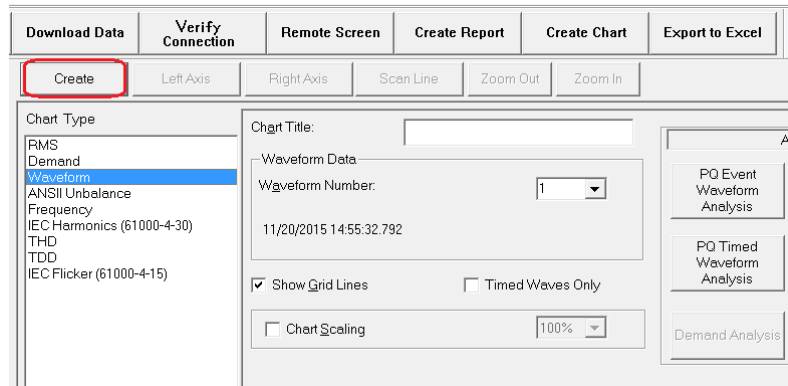
Trace	Y Axis MIN	Y Axis MAX	Line Color	Line Type	Line Color	Line Type	Line Color	Line Type	Line Color
<input checked="" type="checkbox"/> Va Harm (%)	<input type="checkbox"/> 000000	<input type="checkbox"/> 000000	Red	Solid	Red	Solid	Red	Solid	Red
<input type="checkbox"/> Ia Harm (%)	<input type="checkbox"/> 000000	<input type="checkbox"/> 000000	Red	Solid	Red	Solid	Red	Solid	Red
<input checked="" type="checkbox"/> Vb Harm (%)	<input type="checkbox"/> 000000	<input type="checkbox"/> 000000	Blue	Solid	Blue	Solid	Blue	Solid	Blue
<input type="checkbox"/> Ib Harm (%)	<input type="checkbox"/> 000000	<input type="checkbox"/> 000000	Blue	Solid	Blue	Solid	Blue	Solid	Blue
<input checked="" type="checkbox"/> Vc Harm (%)	<input type="checkbox"/> 000000	<input type="checkbox"/> 000000	Yellow	Solid	Yellow	Solid	Yellow	Solid	Yellow
<input type="checkbox"/> Ic Harm (%)	<input type="checkbox"/> 000000	<input type="checkbox"/> 000000	Yellow	Solid	Yellow	Solid	Yellow	Solid	Yellow

You can view both harmonics and inter-harmonics. You can select which harmonic orders you wish to view. You can also view the harmonics as a percentage of the fundamental or as an RMS value.

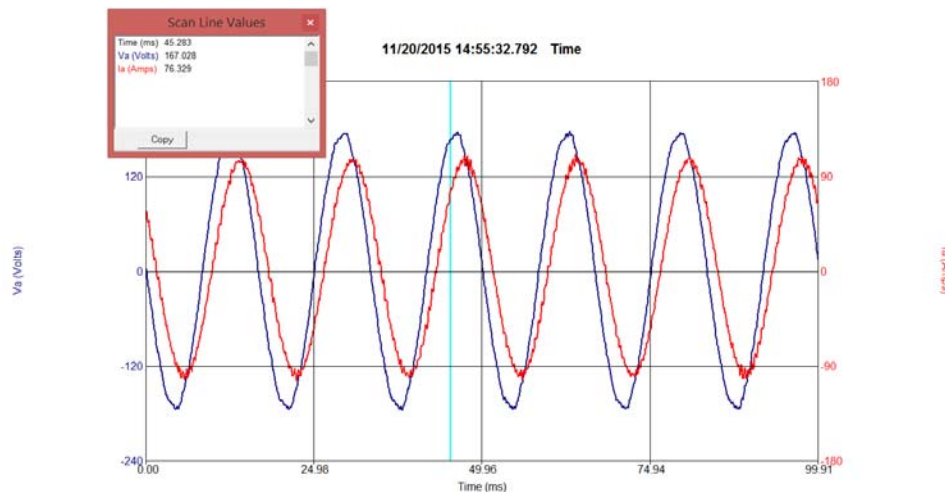


## 23. Create a Waveform Chart

Click on the SETUP button to return to the chart selection screen. Then select the "Waveforms" chart and click CREATE.



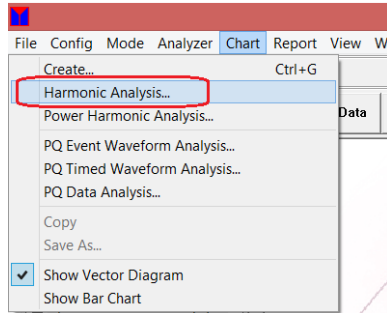
On all charts you can double click on the trace. This will open a window that will allow you to alter the trace parameters or view the values of each data point. You can change the line weight. This is a nice feature when you want to copy the chart into a report. A thicker trace is easier to view. You can view the data points, then copy and paste them into Excel for further analysis or data-basing. This way you can view the waveforms in Excel.



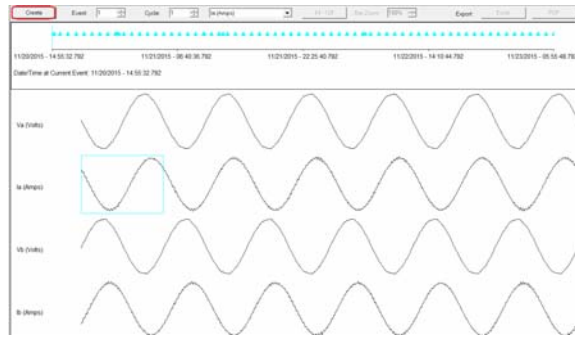


## 24. Create a Detailed Harmonic Analysis

Click on CHART/HARMONIC ANALYSIS.

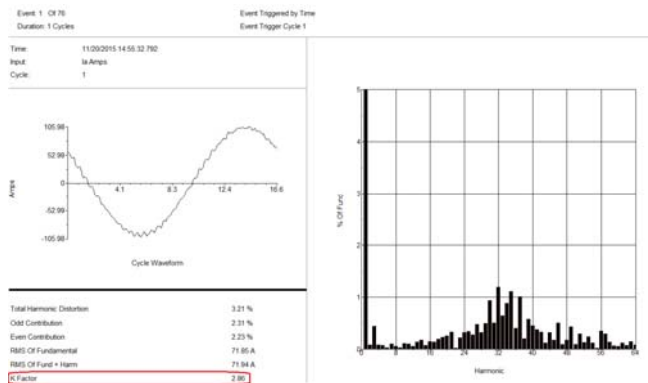


Then select the cycle of the waveform to be analyzed and click CREATE.



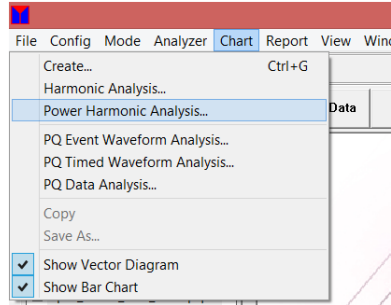
This chart will allow you to select the waveform of interest, the cycle of interest and create a detailed harmonic analysis of the waveform. It can be viewed as either text or as a bar chart. The user can also zoom into the bar chart. Using the detailed harmonic analysis helps characterize waveforms. For example a 6 pulse converter can be identified by the predominate level of 5th and 7th harmonics.

When analyzing current waveform harmonics the K factor can be viewed. This value is used to select de-rated transformers. This verifies a transformer is selected that will not overheat due to actual harmonic content.

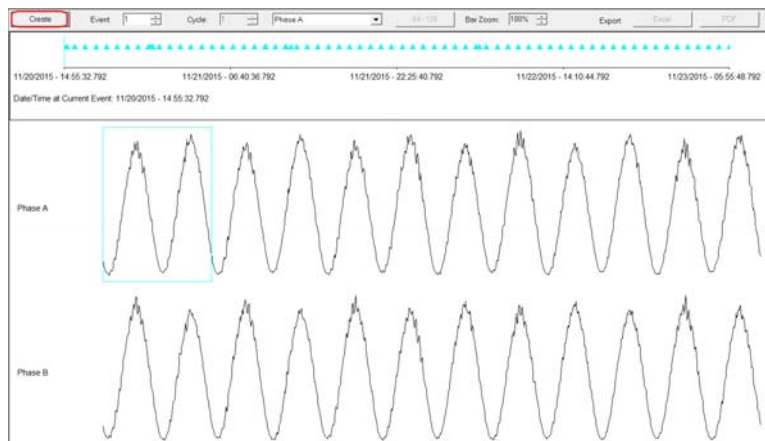


## 25. Create a Power Harmonic Analysis

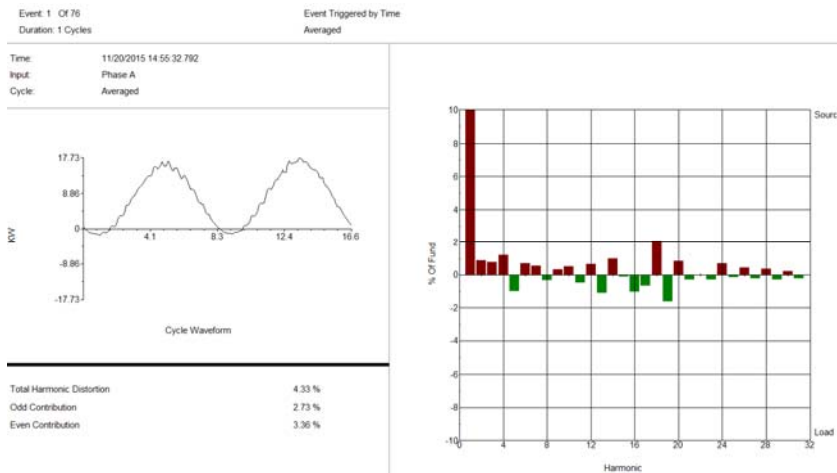
Click on CHART/POWER HARMONIC ANALYSIS.



Then select the *Cycle of the Waveform* to be analyzed and click CREATE.



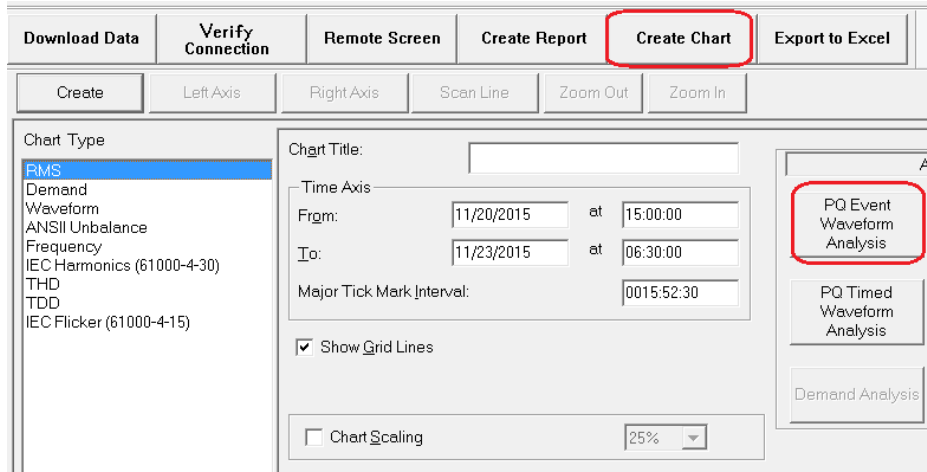
This chart will allow you to see which direction the different harmonic orders are coming from. This can be viewed as text or as a bar chart.



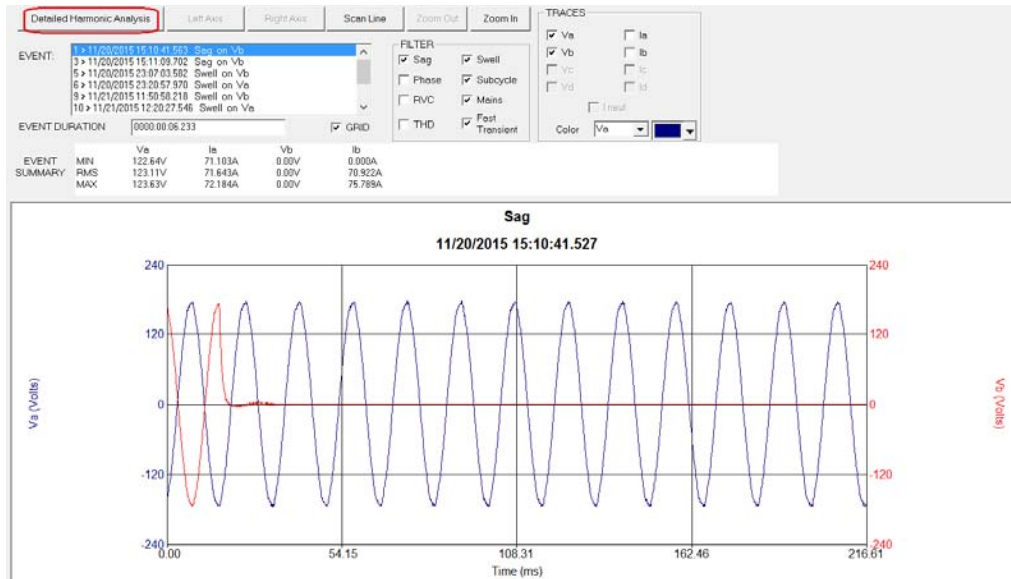
# ADDENDUM C - SAMPLE POWER QUALITY TRAINING

## 26. Create a PQ Event Waveform Analysis

Click on CREATE CHART/ PQ EVENT WAVEFORM ANALYSIS.



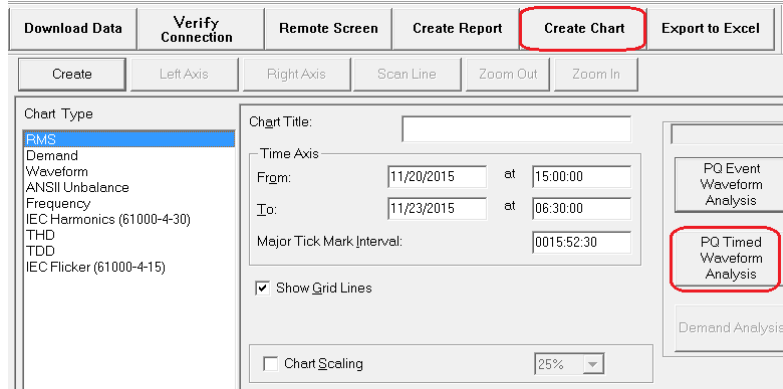
This chart allows you to view all the out of limits event data. You will also see the traces associated with those events. In addition you can filter the events you wish to view.



This chart also allows you to create a detailed harmonic analysis of the event.

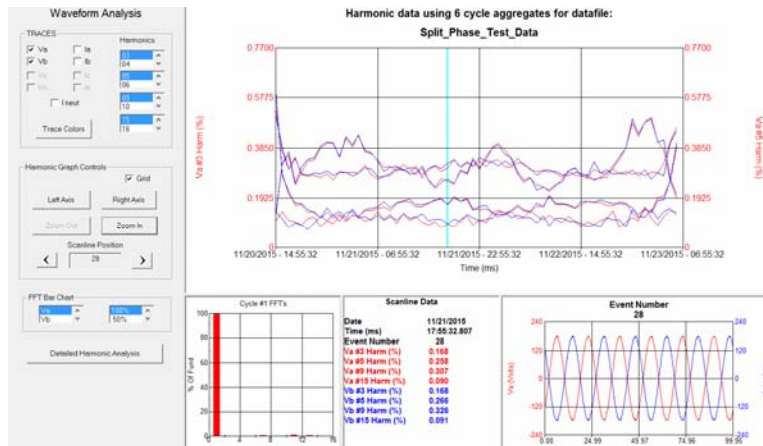
27. Create a PQ Timed Waveform Analysis

Click on CREATE CHART/PQ TIMED WAVEFORM ANALYSIS.



This chart allows you to analyze all the timed waveforms that were recorded. The MPQ unit can take waveform snap shots throughout the test interval. This screen allows you to analyze that data.

This screen will average together each cycle of each individual waveform capture then perform an FFT on that averaged cycle. It will then plot the individual harmonics orders of the waveform captures.



A scan line can then be moved back and forth through the chart. The actual waveform for that interval can be viewed. In addition a harmonic bar chart of that waveform can be viewed.

This is different from IEC Harmonic recording. The IEC Harmonic recording is a continuous value that is aggregated over a periodic interval, typically 10 minutes.

The PQ timed waveform analysis chart shows the FFT analysis of the waveform snapshots. So this data may not match the IEC Harmonic data, since it is not aggregated over a periodic interval.

# ADDENDUM D

## COMPLETE 115V MPQ SETUP FILE

DESCRIPTION	SETUP	COMMENTS
Power Wiring Connection	4 Wire Wye 3 Wattmeter	
Enable Power Calculations	Enabled	
Demand Interval	5 Minute	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
Enable RMS Recording	Enabled	
Record	MIN, MAX, RMS	
RMS Storage Interval	3 Seconds	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
Enable IEC Unbalance Recording	Enabled	
Clock Hour Orientation	Enabled	
Enable IEC Flicker Recording	Not Enabled	This test takes some time to perform and is not suitable for a short demonstration.
Enable Frequency Recording	Enabled	
Enable Instant Flicker Recording	Disabled	This is a special test used for troubleshooting of flicker failures and factory testing.
Hysteresis Value	2%	Standard value
Enable Sub-cycle event capture	Enabled	
Enable Phase Events	Enabled	
Enable RVC Events	Disabled	
Rotation	ACB	
Voltage Sag / Dip Limits	108.00	
Voltage Swell Limits	132.00	

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DESCRIPTION	SETUP	COMMENTS
Current Limits	Disabled	
Sub-cycle Limit	240.00	
Ratio	1.0	
CT Full Scale	6000.0	
Nominal Angle	0, 120, 240	
Angle Deviation	2.0	
Fast Transient	400.00	
THD Limit	5.00	
Timed Waveform Capture	Enabled at 1 Minute	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
Timed Capture Duration	6 Cycles	
Exceedance Capture Pre-Triggers	9	
Exceedance Capture Post Triggers	20	
THD / Harmonics	Enabled	
THD / Harmonic Interval	3 Seconds	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
Voltage for RVC and Mains Signaling	Auto	
Declared Voltage	NA	
Memory Mode	Stop When Full	
Default Frequency	60	
Mains Signaling	Disabled	

# ADDENDUM E

## COMPLETE 230V MPQ SETUP FILE

DESCRIPTION	SETUP	COMMENTS
<b>Power Wiring Connection</b>	4 Wire Wye 3 Wattmeter	
<b>Enable Power Calculations</b>	Enabled	
<b>Demand Interval</b>	5 Minute	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
<b>Enable RMS Recording</b>	Enabled	
<b>Record</b>	MIN, MAX, RMS	
<b>RMS Storage Interval</b>	3 Seconds	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
<b>Enable IEC Unbalance Recording</b>	Enabled	
<b>Clock Hour Orientation</b>	Enabled	
<b>Enable IEC Flicker Recording</b>	Not Enabled	This test takes some time to perform and is not suitable for a short demonstration.
<b>Enable Frequency Recording</b>	Enabled	
<b>Enable Instant Flicker Recording</b>	Disabled	This is a special test used for troubleshooting of flicker failures and factory testing.
<b>Hysteresis Value</b>	2%	Standard value
<b>Enable Sub-cycle event capture</b>	Enabled	
<b>Enable Phase Events</b>	Enabled	
<b>Enable RVC Events</b>	Disabled	
<b>Rotation</b>	ACB	
<b>Voltage Sag / Dip Limits</b>	207.00	

DESCRIPTION	SETUP	COMMENTS
Voltage Swell Limits	262.00	
Current Limits	Disabled	
Sub-cycle Limit	400.00	
Ratio	1.0	
CT Full Scale	6000.0	
Nominal Angle	0, 120, 240	
Angle Deviation	2.0	
Fast Transient	600.00	
THD Limit	5.00	
Timed Waveform Capture	Enabled at 1 Minute	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
Timed Capture Duration	6 Cycles	
Exceedance Capture Pre-Triggers	9	
Exceedance Capture Post Triggers	20	
THD / Harmonics	Enabled	
THD / Harmonic Interval	3 Seconds	This is not a normal interval used in the real world. This is just a short interval to accumulate data quickly for demonstration.
Voltage for RVC and Mains Signaling	Auto	
Declared Voltage	NA	
Memory Mode	Stop When Full	
Default Frequency	50	
Mains Signaling	Disabled	