REINHOLD ENVIRONMENTAL Ltd.

2013 APC Round Table & Expo Presentation

July 8-9, 2013, in St. Louis, MO / Hosted by Ameren

Taking the Mystery Out of Precipitator Power Supplies

2013 APC Conference

St. Louis, Missouri – July 8-9, 2013

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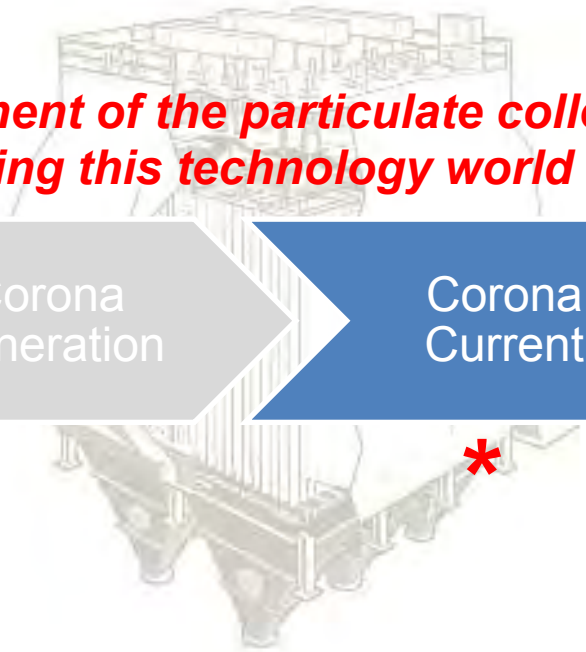
David Johnston

Service Center Manager, PrecipTech Products

An Ongoing Process of Research and Development



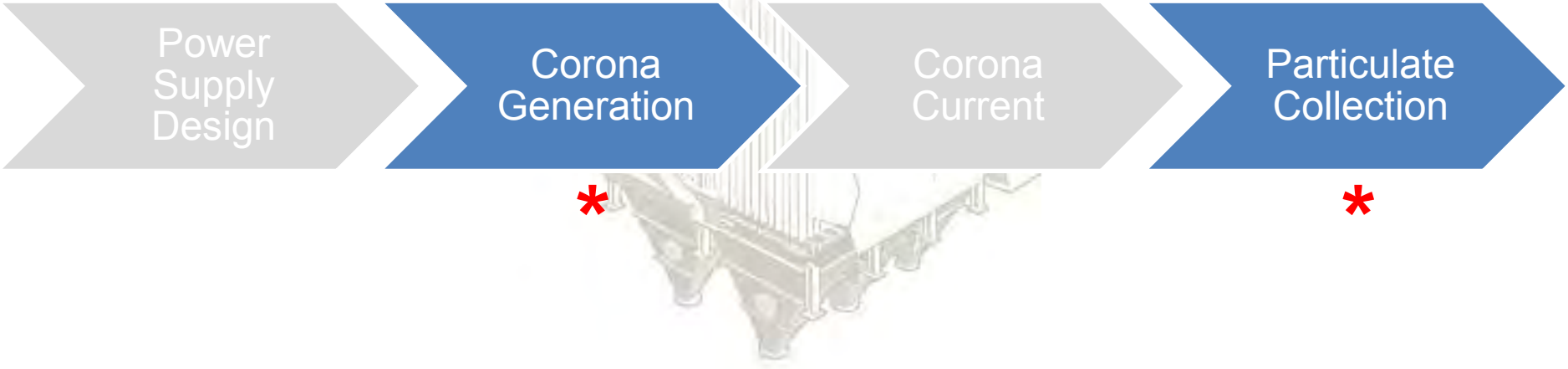
Goal: Evaluate each component of the particulate collection process so we may do a better job of applying this technology world wide.

Power Supply Design	Corona Generation	Corona Current	Particulate Collection
*		*	

*** *Discussed in this Workshop***

An Ongoing Process of Research and Development

Goal: Evaluate each component of the particulate collection process so we may do a better job of applying this technology world wide.

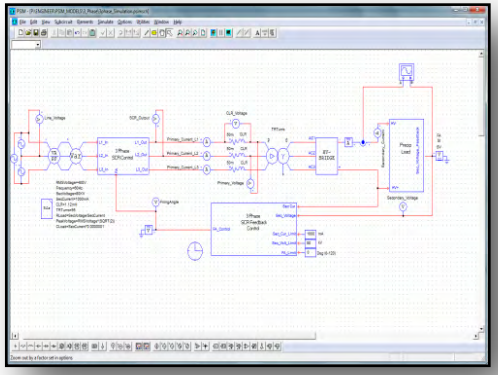


***** ***Discussed in Workshop 14: Corona Gone Bad*** ***(presented by John Knapik, Rob Hummell)***

An Ongoing Process of Research and Development

The Tools:

Software Models



Laboratory Testing

Field Verification

An Ongoing Process of Research and Development

The Facilities for Laboratory Testing:

A test ESP where we can change:

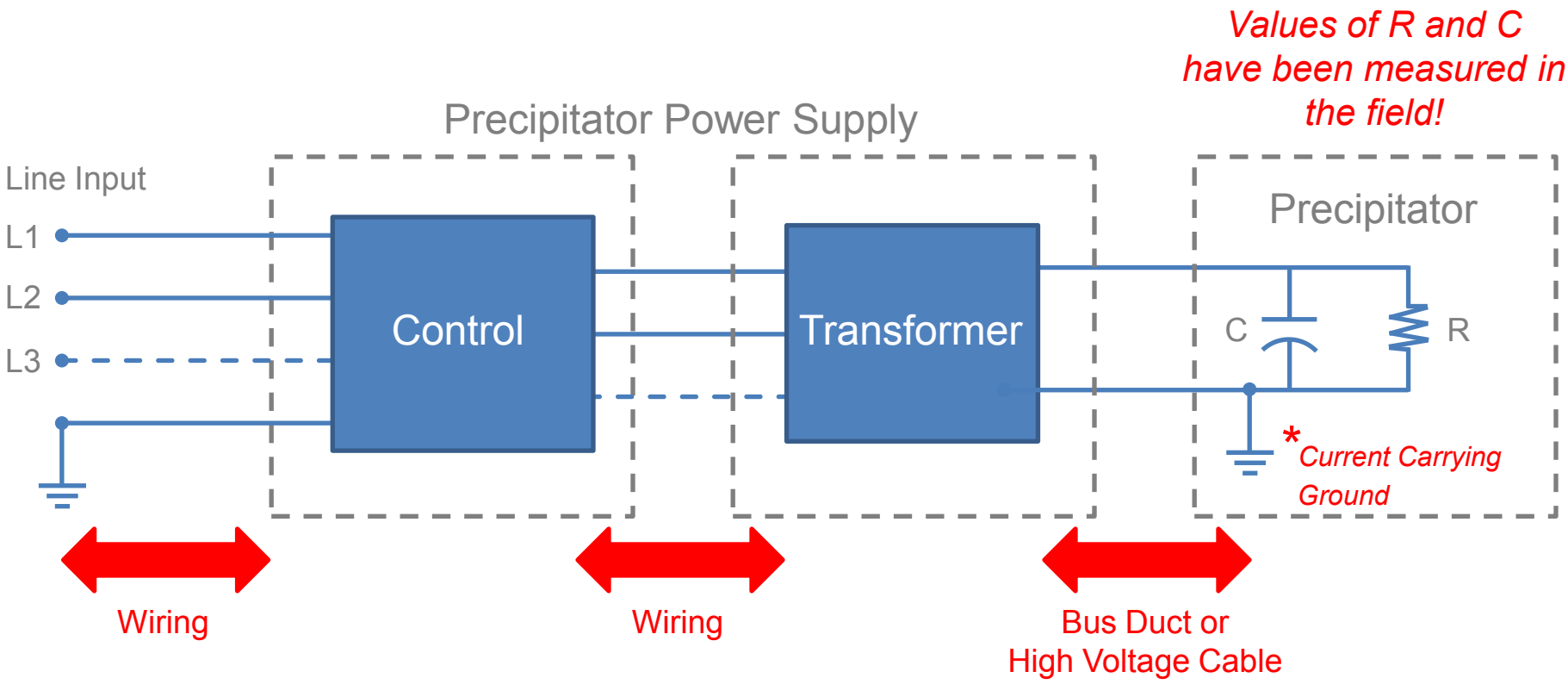
- *Power supplies*
- *Plate spacing*
- *Discharge electrodes*
- *Flow*

An Ongoing Process of Research and Development

Field Verification:

Database: • **Over 15,000 power supplies** • **In 52 countries** • **Installed in over 400 plants**

Power Supply Configuration

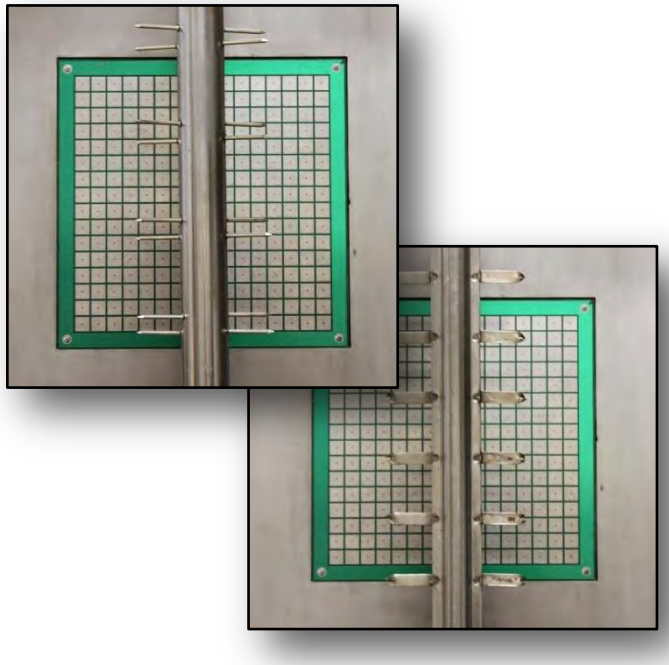


Location and distance between components may vary (which affects grounding, shielding and temperature)

Does Changing the Type of Power Supply Change the V-I Curve?

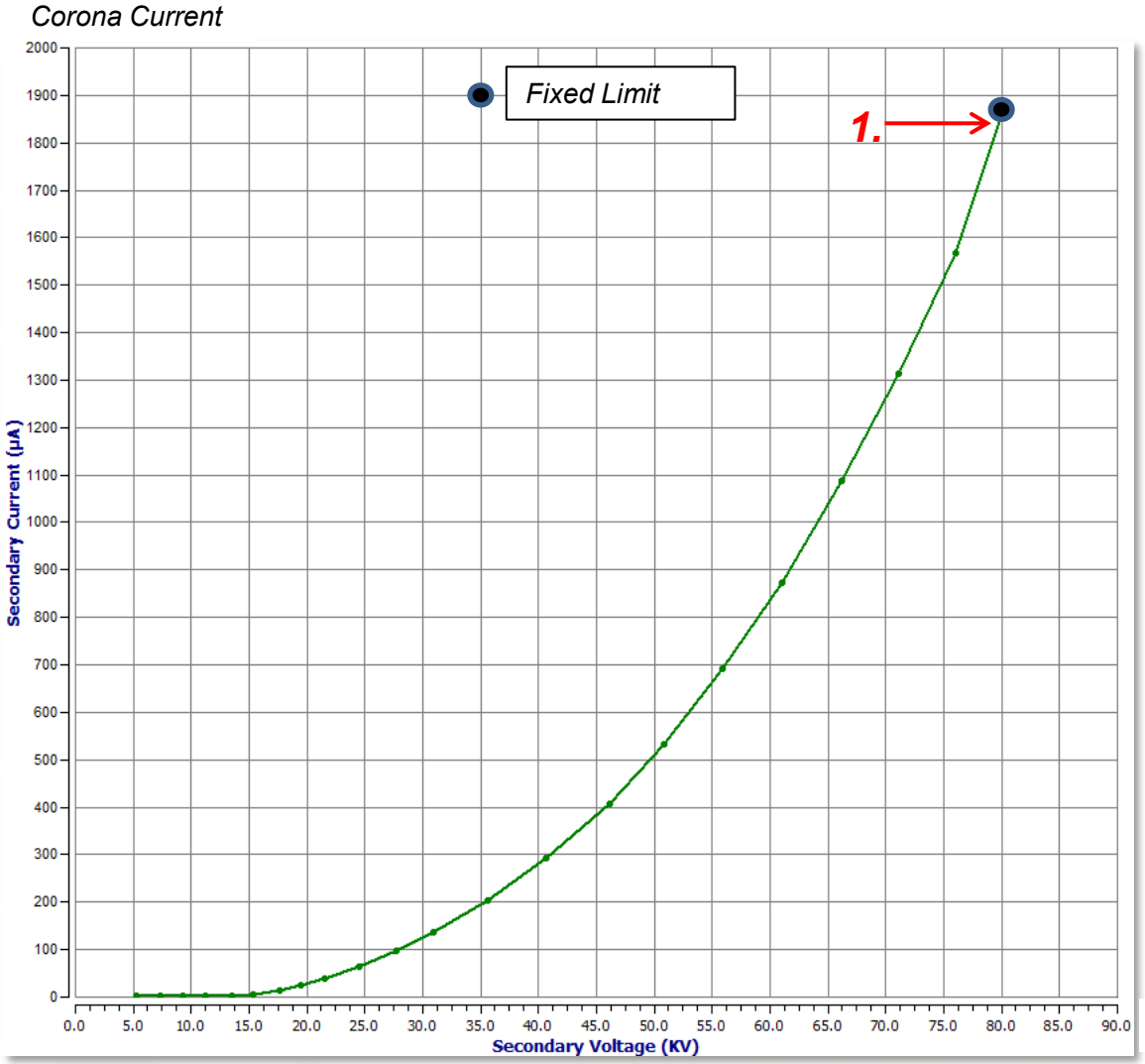
The following slides show a sample of the tests we have conducted to explore this question using:

- ***Test ESP***
- ***Multiple, popular discharge electrodes***
- ***Four different precipitator power supplies***



Without Sparking
Does changing the type of power supply change the V-I curve?

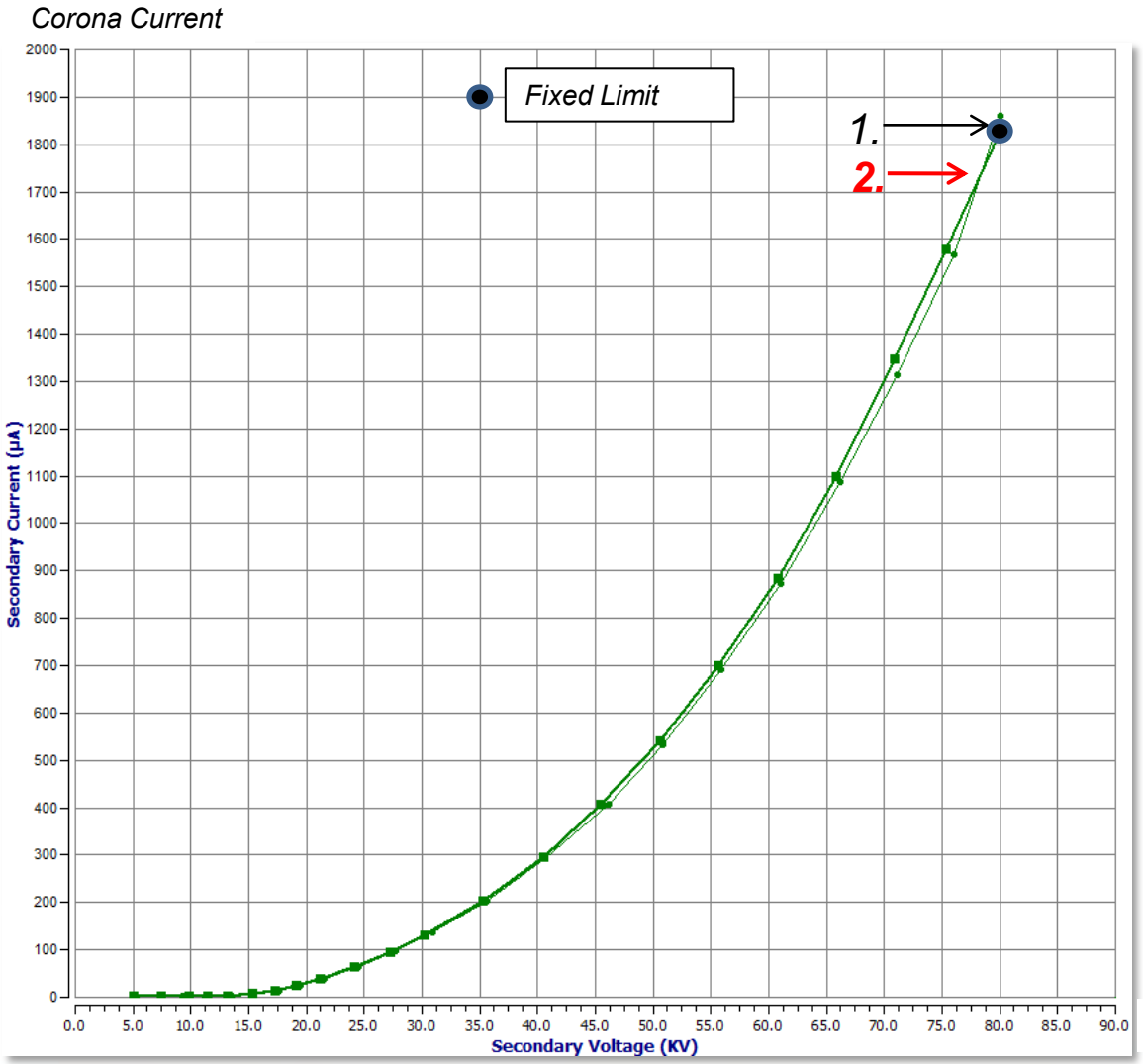
1. **True DC***
2. Single Phase
3. 3-Phase
4. High Freq.



* ***Laboratory Power Supply*** *(Not Designed for Sparking)*

Without Sparking
Does changing the type of power supply change the V-I curve?

1. *True DC**
2. ***Single Phase***
3. *3-Phase*
4. *High Freq.*



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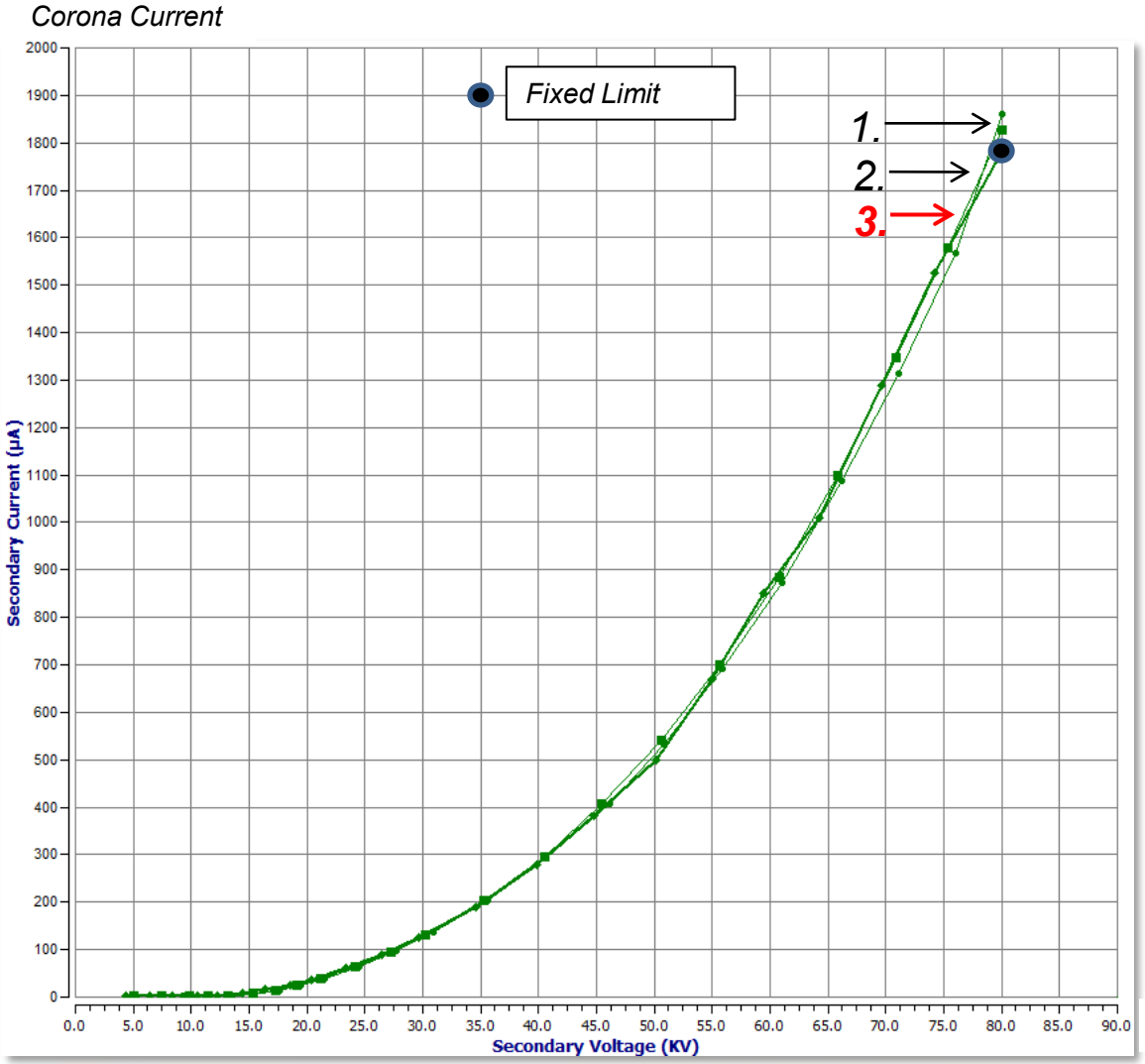

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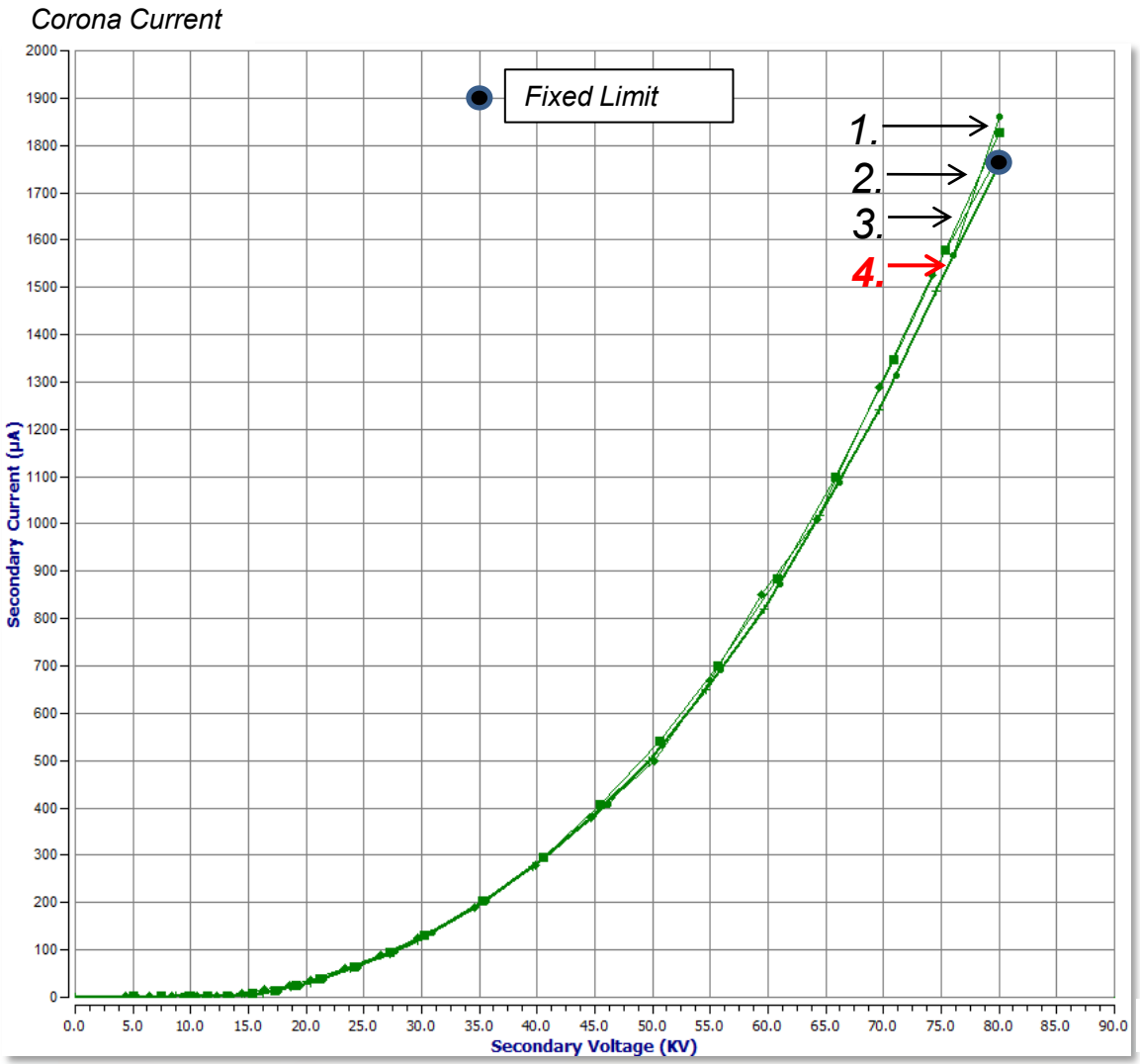


Without sparking, changing the power supply did not show a significant change in the V-I curve.

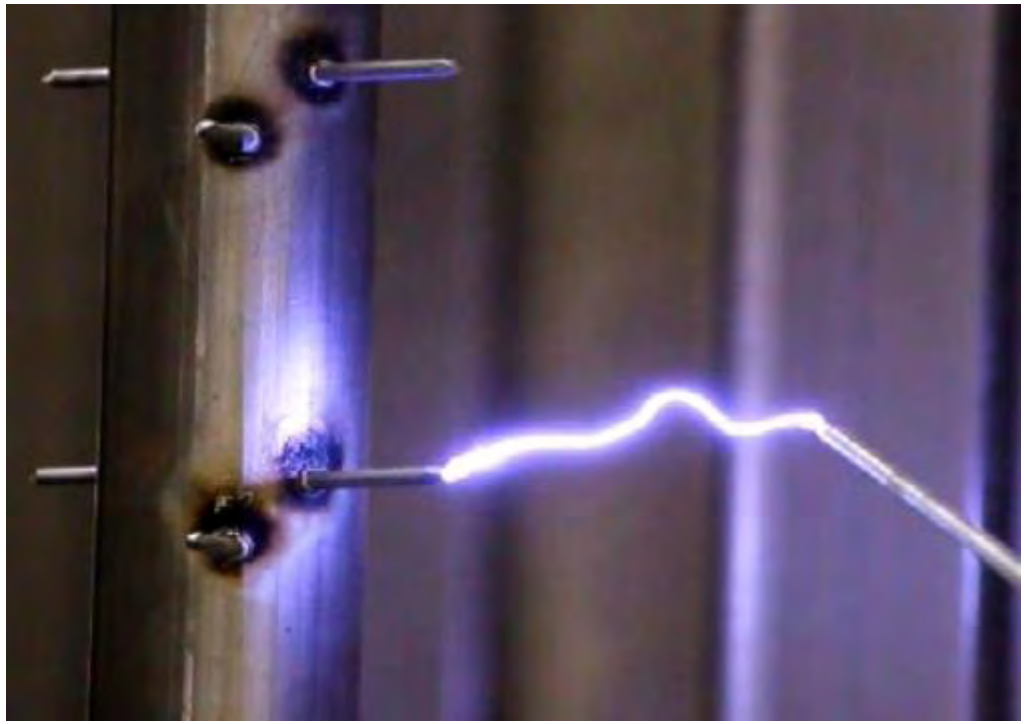
* ***Laboratory Power Supply*** *(Not Designed for Sparking)*

With Sparking
Does changing the type of power supply change the V-I curve?

When a Spark Occurs:

- ***The energy stored in the field is consumed by the spark.***
- ***The ionized gas is removed by the flow.***

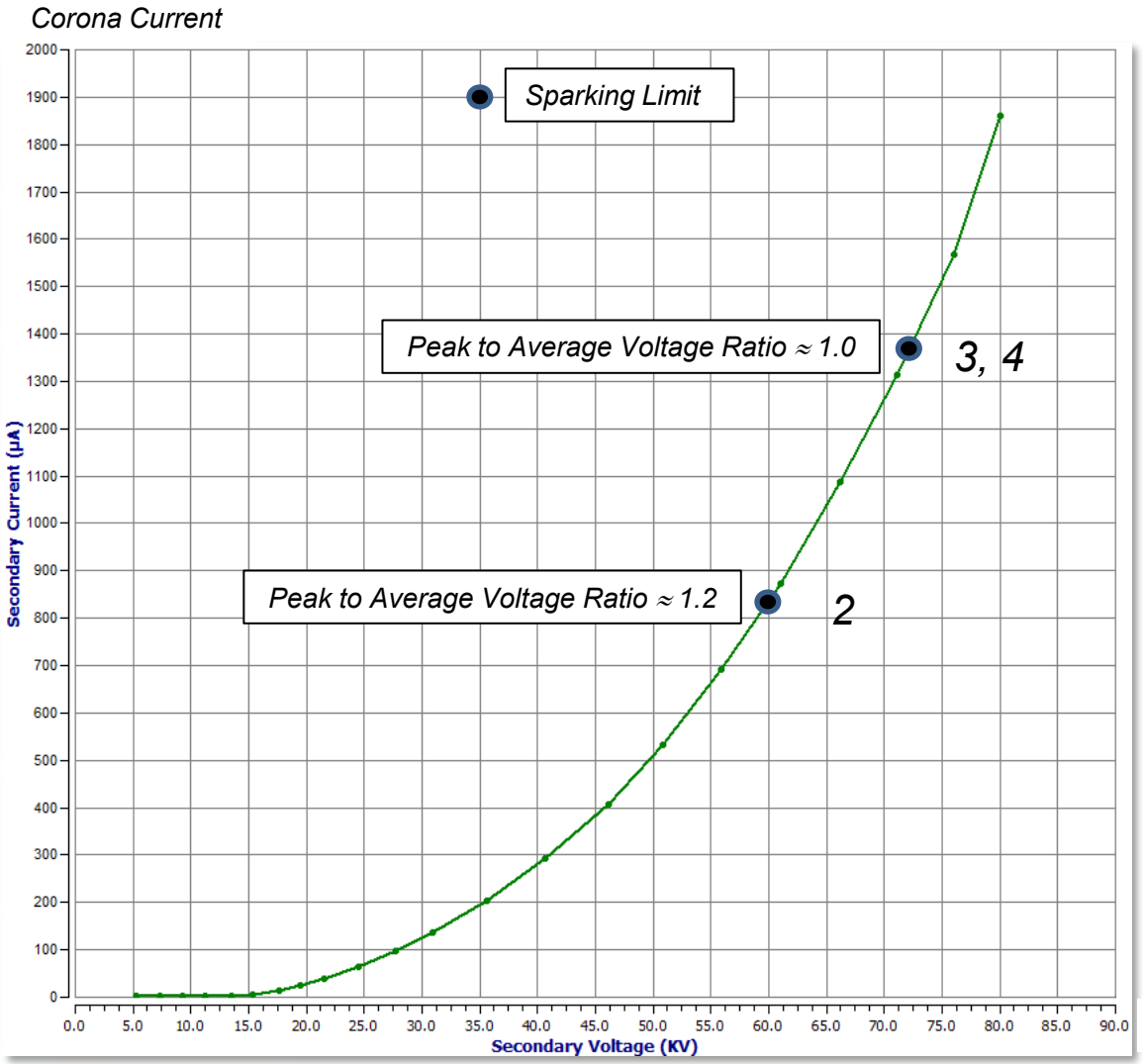
Independent of power supply type, this process can take several milliseconds.



Spark current can exceed a peak of 20,000 Amps!

With Sparking
Does changing the type of power supply change the V-I curve?

1. True DC*
2. Single Phase
3. 3-Phase
4. High Freq.



With sparking, a power supply that had a peak to average voltage ratio near 1.0 (True DC) provided for operation higher on the V-I curve.

This explains the importance of True DC power supplies!

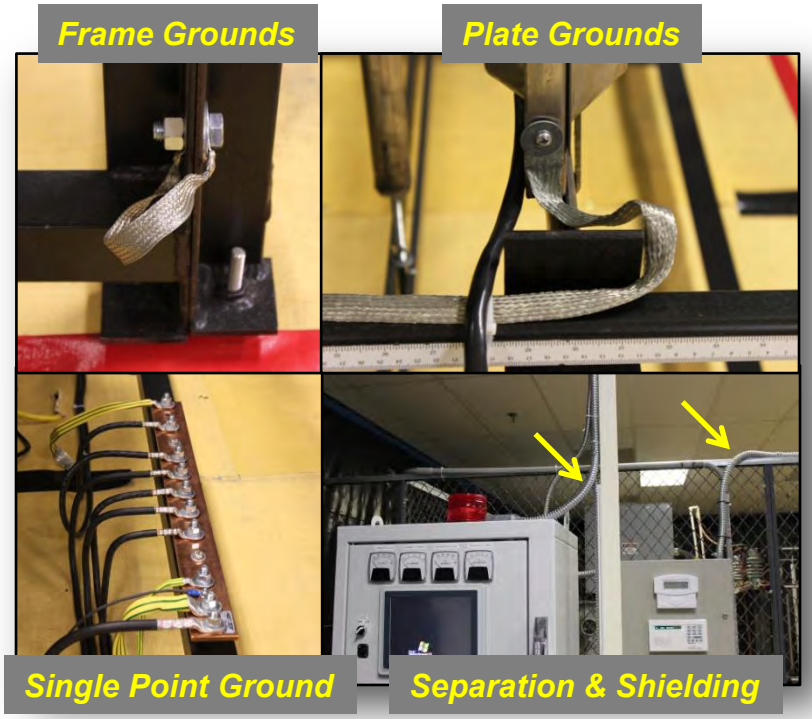
* ***Laboratory Power Supply*** *(Not Designed for Sparking)*

Unexpected Test Results

As the frequency of the power supply increased, we experienced problems with the Test ESP:

- ***Interference and power quality.***
- ***Shielding and connections that were not an issue at lower frequencies became a problem at higher frequencies and resulted in equipment failure.***

As frequency goes up, more attention is required in these areas for reliable operation!



Power Supply Comparison - Design

- ***Seven power supply software models were evaluated under identical test conditions and compared to an "Ideal" True DC model:***

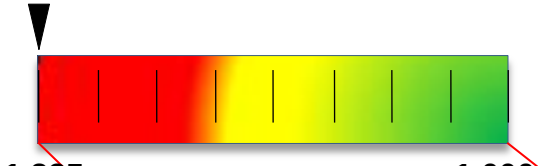
"Ideal" True DC	Mid-Freq – Amp Control
Single Phase	Mid-Freq – Phase Control
Single Phase + JuiceCan	HF – Frequency Control
3-Phase	HF – Phase Control

Power Supply Comparison

Sample Scorecard

The arrow indicates how the *peak to avg. voltage ratio* for this power supply stacks up against the other power supplies.

Peak to avg. voltage ratio:

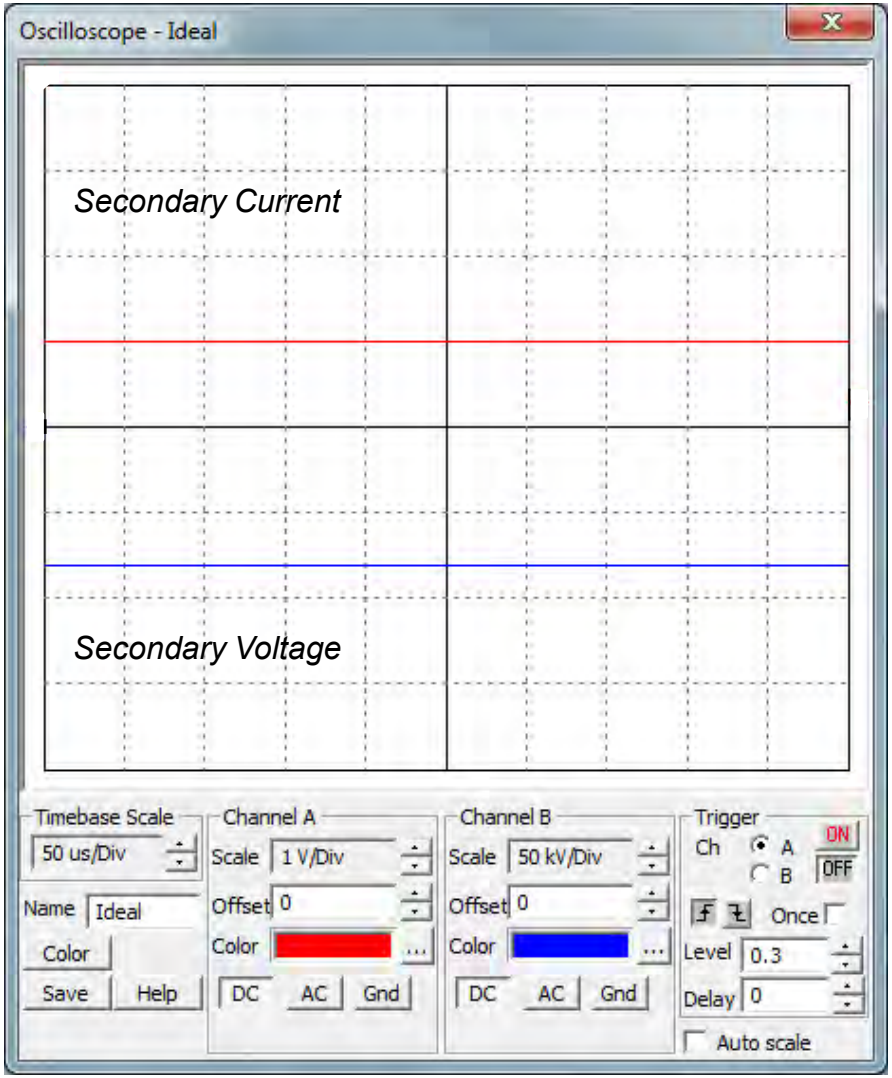


1.235 **1.000**

Of the power supplies compared, this was the least favorable value recorded.

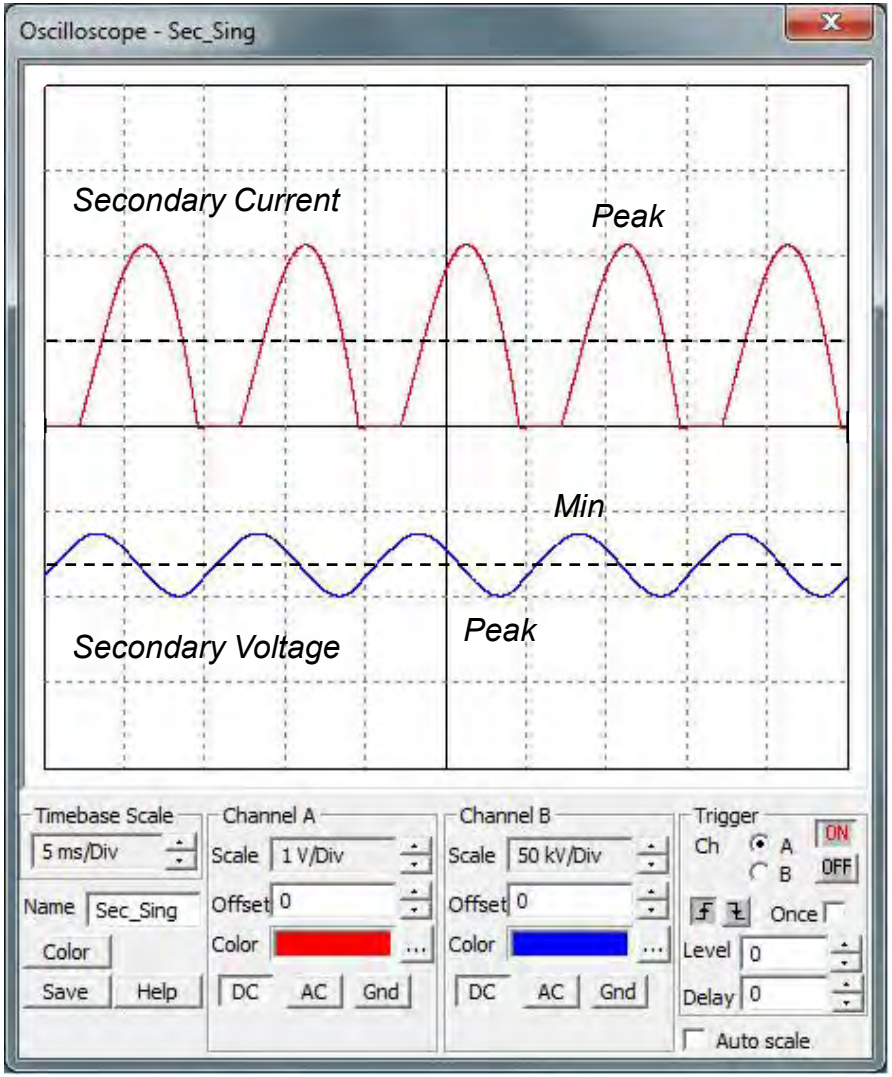
Of the power supplies compared, this was the most favorable value recorded.

"Ideal" True DC



Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (3-Phase):	96.3 A	96.3
Power factor:	1.000	1.000
Apparent power:	80.00 KVA	80.00
Reactive power:	0.00 KVAR	0.00
Total Harmonic Distortion	0%	0.00
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.000	1.000
Peak to avg. current ratio:	1.000	1.000
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	100.00%	100.00
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	YES
Heat Loss (Control Element):	0 W	0
Reliability Ranking:	1	1

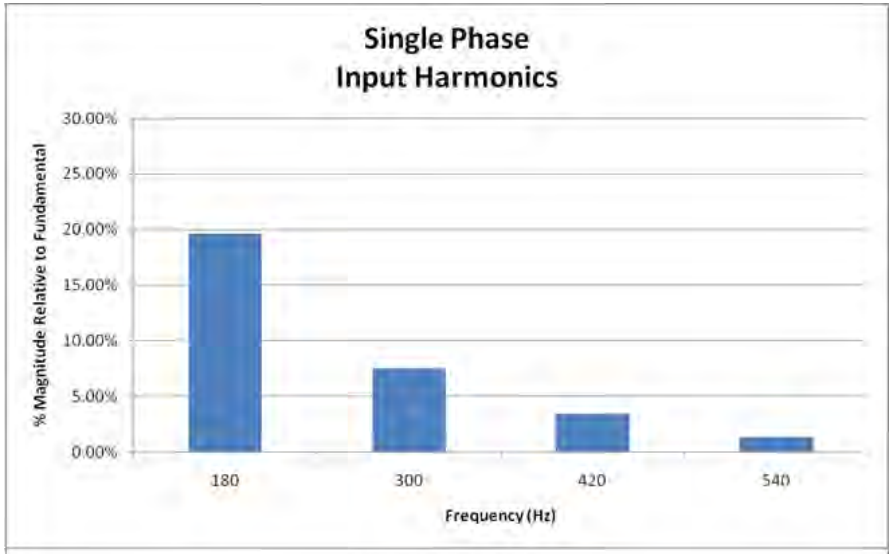
Single Phase

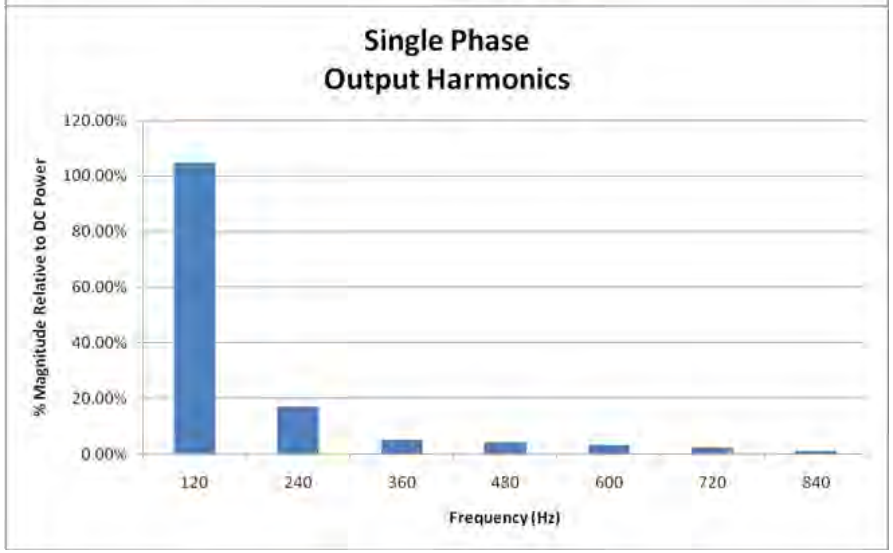


True DC: ----------

Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (Single Phase):	308.3 A	308.3 — 100.9
Power factor:	0.566	.566 — .926
Apparent power:	146.70 KVA	146.70 — 87.18
Reactive power:	121.42 KVAR	121.42 — 31.02
Total Harmonic Distortion	21.40%	36.25 — 13.01
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.235	1.235 — 1.000
Peak to avg. current ratio:	2.132	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	54.53%	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO — YES
Heat Loss (SCRs):	462 W	3311 — 455
Reliability Ranking:	1	7 — 1

Single Phase





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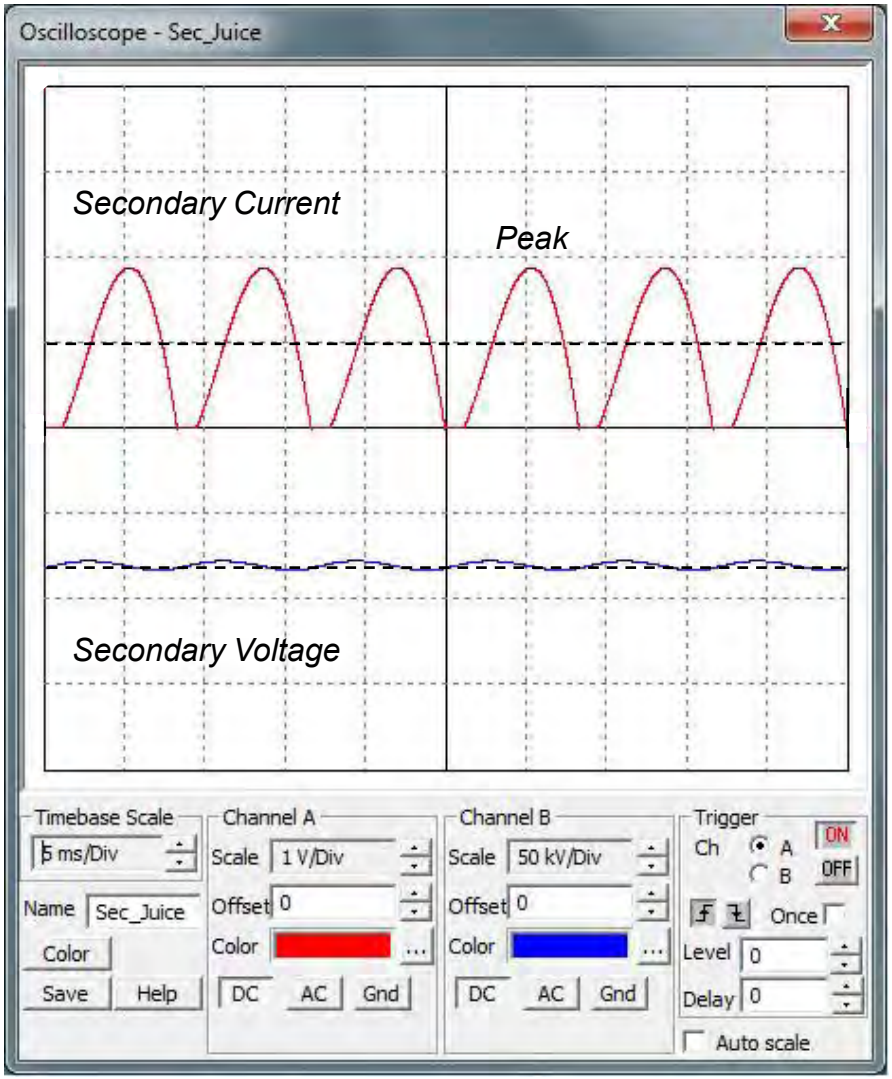
Ability to Separate the Control and Transformer:	Yes	NO … YES
Heat Loss (SCRs):	462 W	3311 … 455
Reliability Ranking:	1	7 … 1

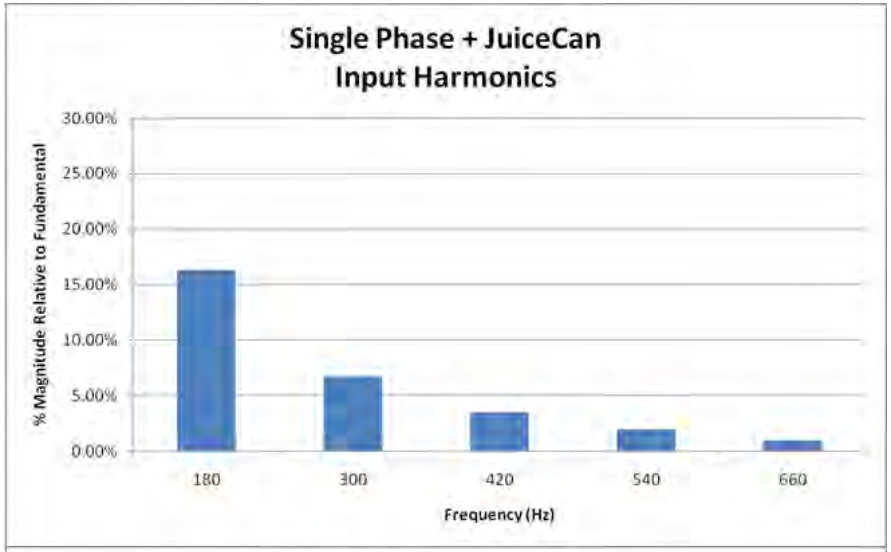
Single Phase + JuiceCan

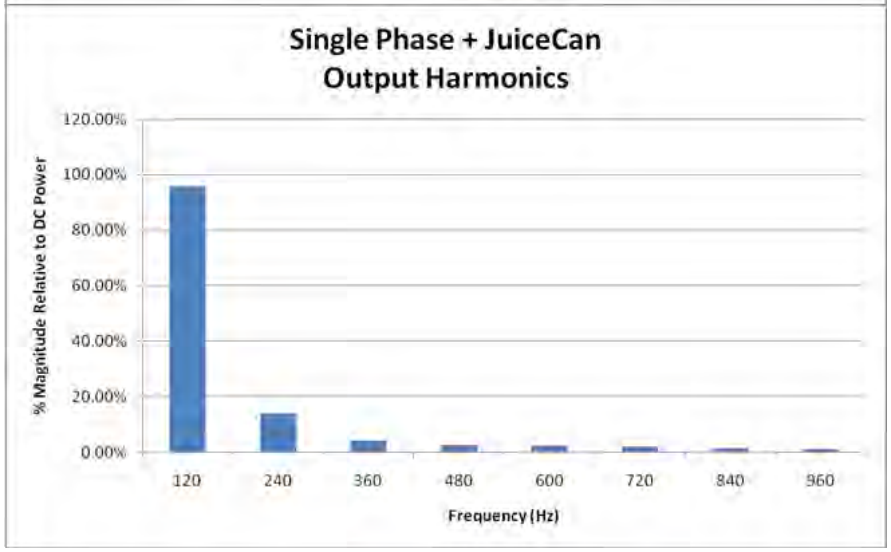


True DC: ----------

Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (Single Phase):	288.9 A	308.3 — 100.9
Power factor:	0.580	.566 — .926
Apparent power:	138.68 KVA	146.70 — 87.18
Reactive power:	112.97 KVAR	121.42 — 31.02
Total Harmonic Distortion	18.15%	36.25 — 13.01
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.036	1.235 — 1.000
Peak to avg. current ratio:	1.883	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	57.68%	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO — YES
Heat Loss (SCRs):	455 W	3311 — 455
Reliability Ranking:	3	7 — 1

Single Phase + JuiceCan





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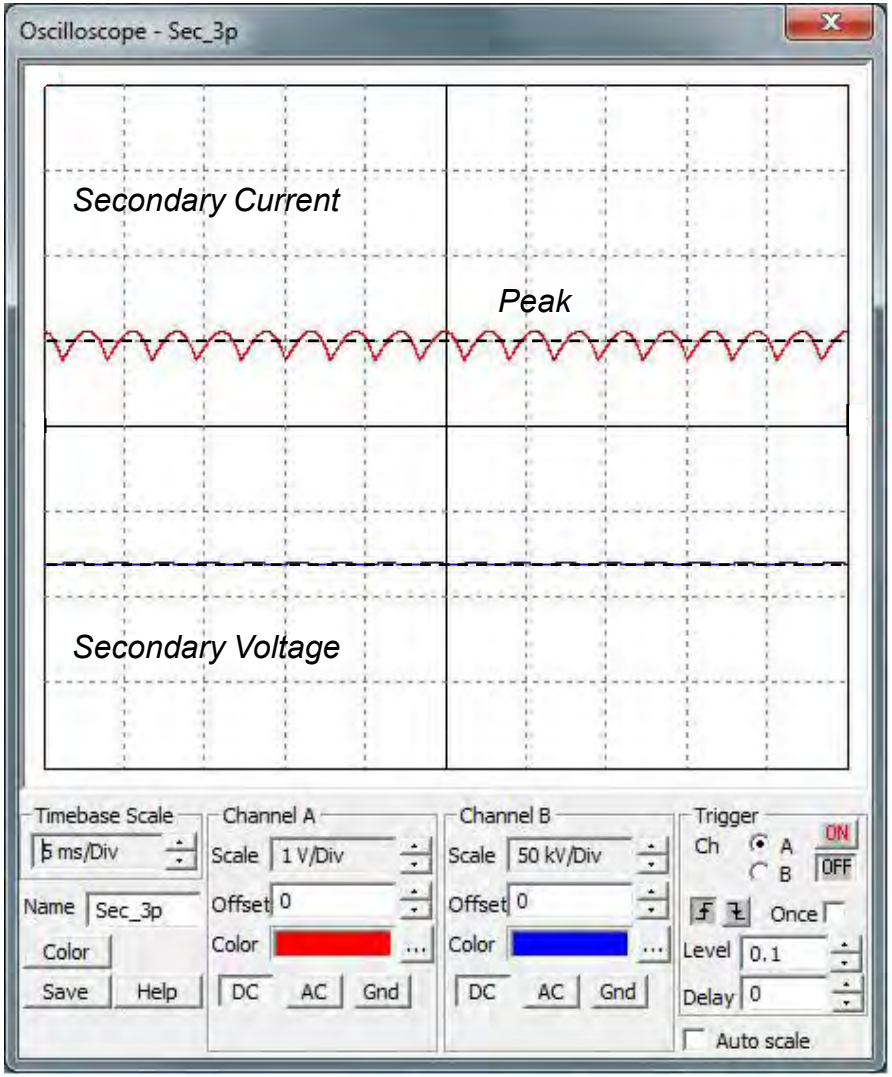
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	57.68%	54.53 / 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO / YES
Heat Loss (SCRs):	455 W	3311 / 455
Reliability Ranking:	3	7 / 1

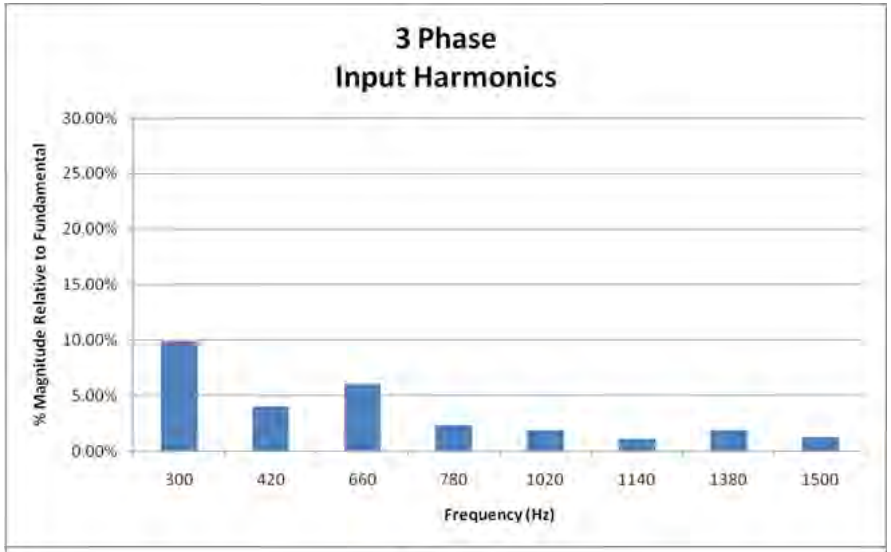
3-Phase

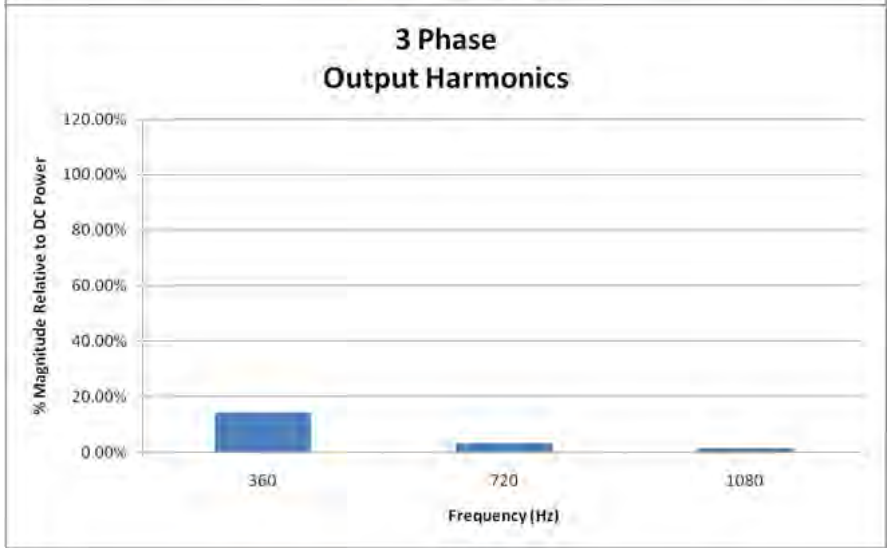


True DC: ----------

Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (3-Phase):	121.7 A	308.3 — 100.9
Power factor:	0.826	.566 — .926
Apparent power:	101.22 KVA	146.70 — 87.18
Reactive power:	57.09 KVAR	121.42 — 31.02
Total Harmonic Distortion	13.01%	36.25 — 13.01
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.009	1.235 — 1.000
Peak to avg. current ratio:	1.126	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	79.02%	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO — YES
Heat Loss (SCRs):	468 W	3311 — 455
Reliability Ranking:	2	7 — 1

3-Phase





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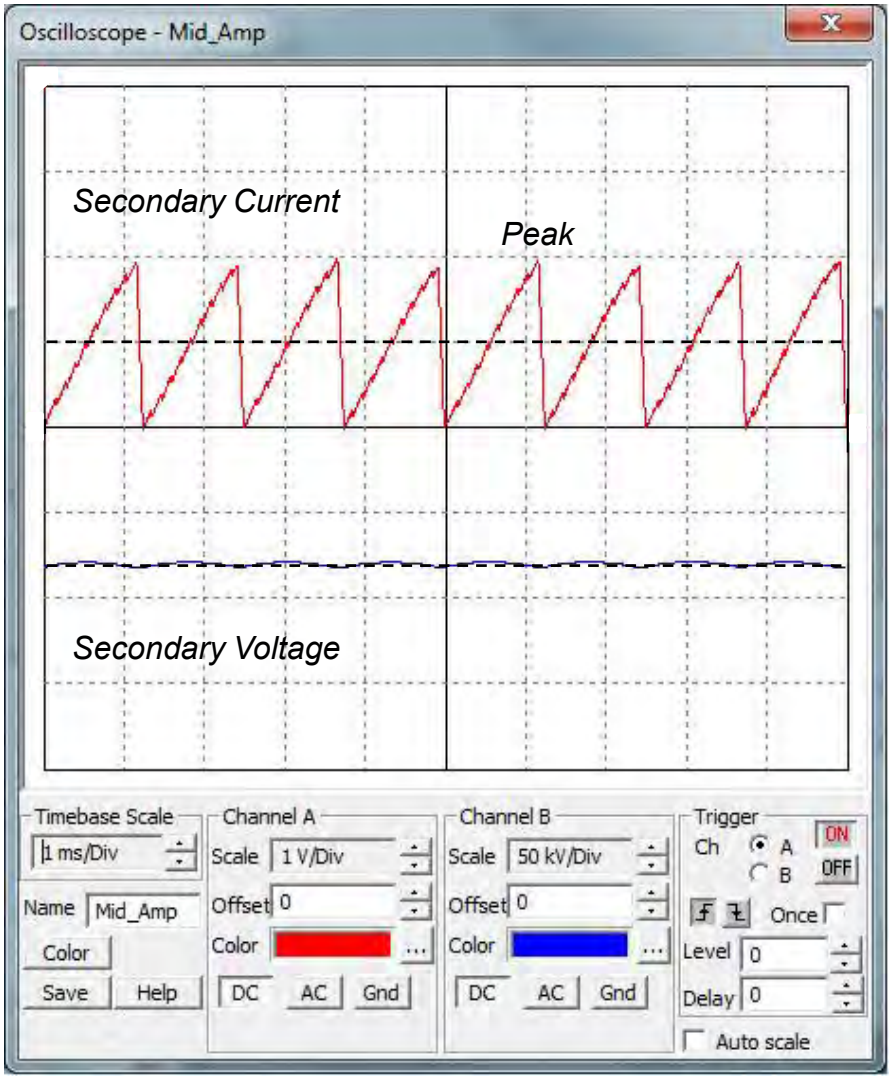
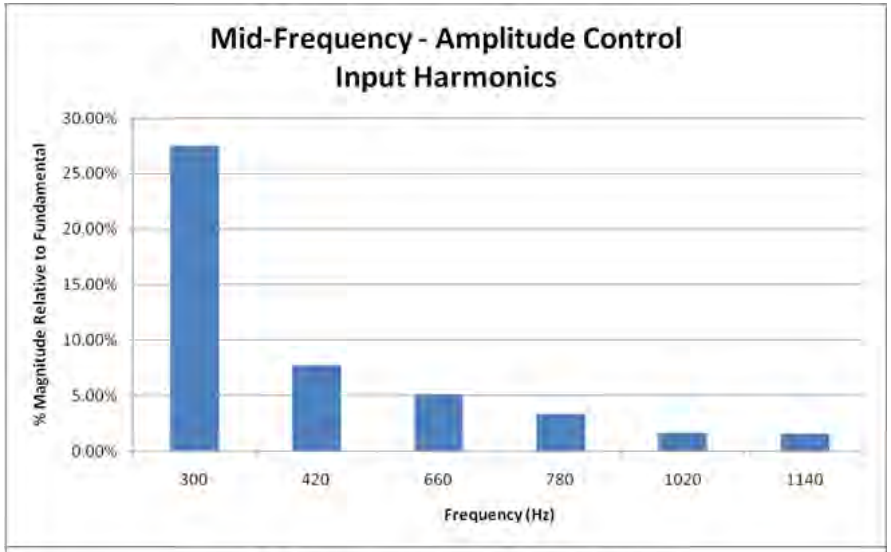
Mid-Frequency - Amplitude Control

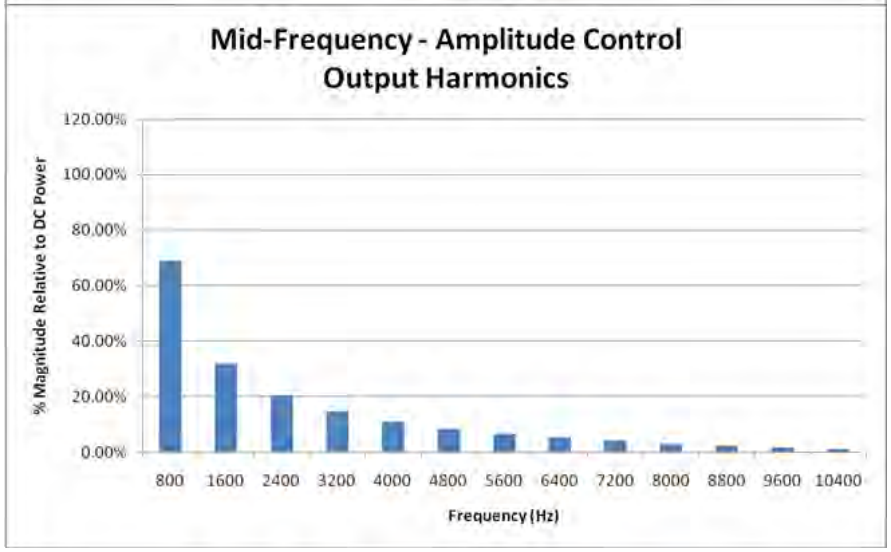


True DC: ----------

Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (3-Phase):	106.8 A	308.3 — 100.9
Power factor:	0.917	.566 — .926
Apparent power:	88.24 KVA	146.70 — 87.18
Reactive power:	35.25 KVAR	121.42 — 31.02
Total Harmonic Distortion	29.43%	36.25 — 13.01
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.032	1.235 — 1.000
Peak to avg. current ratio:	2.050	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	90.61%	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO — YES
Heat Loss (IGBTs):	930 W	3311 — 455
Reliability Ranking:	5	7 — 1

Mid-Frequency - Amplitude Control





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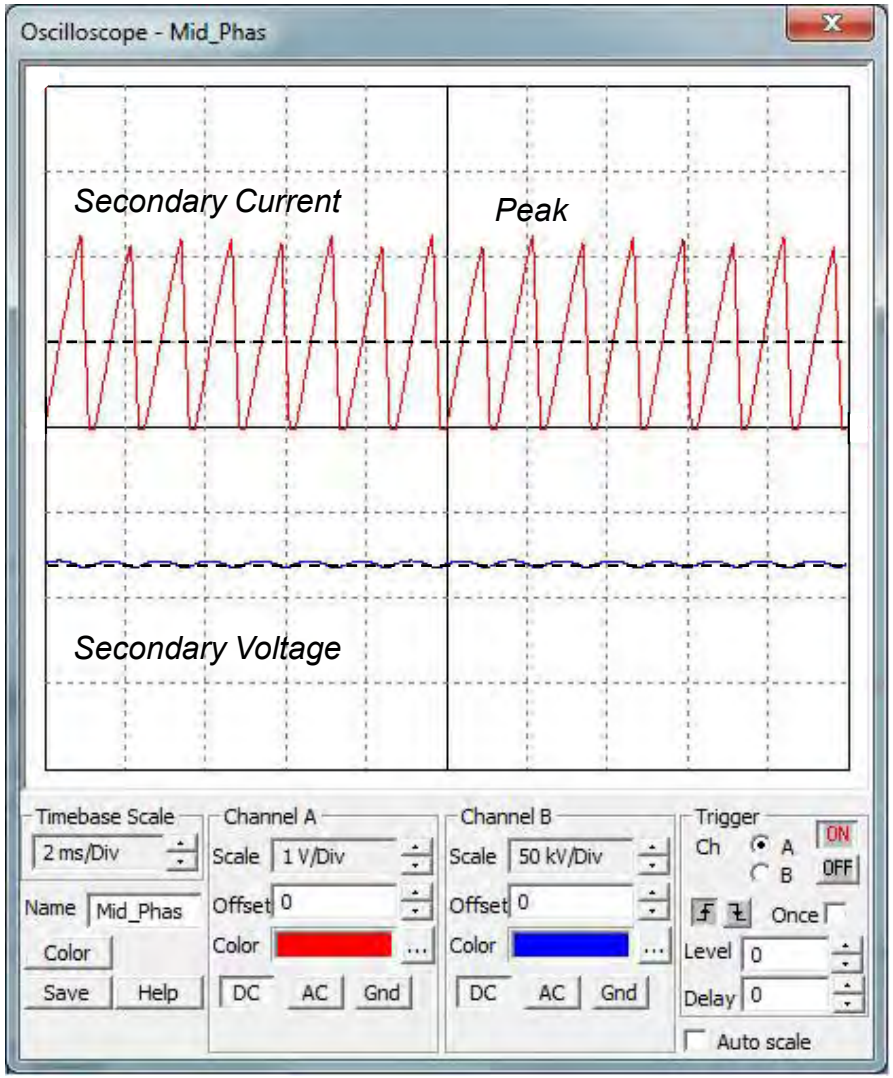
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO — YES
Heat Loss (IGBTs):	930 W	3311 — 455
Reliability Ranking:	5	7 — 1

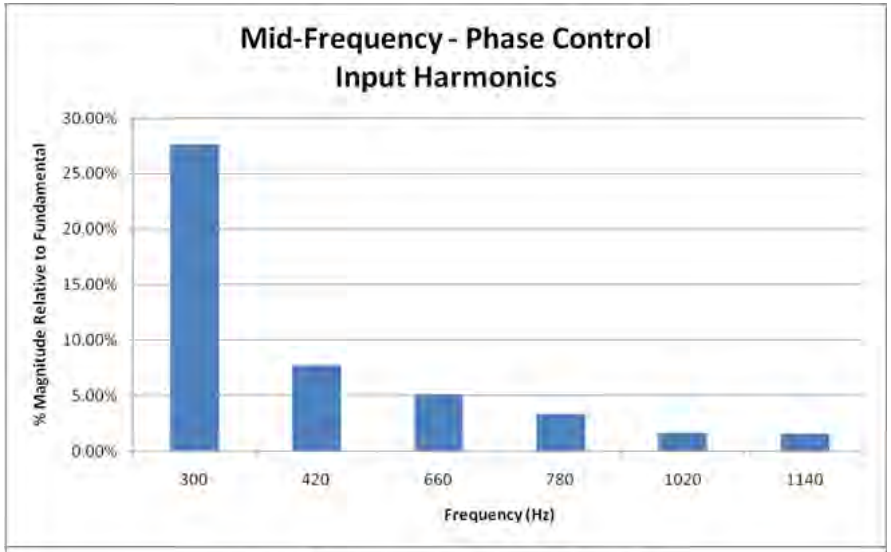
Mid-Frequency - Phase Control

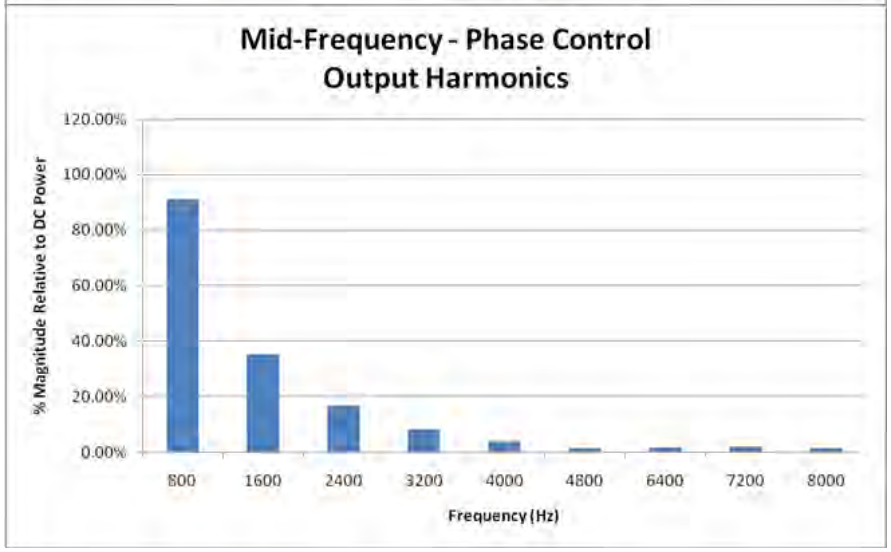


True DC: ----------

Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (3-Phase):	105.9 A	308.3 — 100.9
Power factor:	0.917	.566 — .926
Apparent power:	87.45 KVA	146.70 — 87.18
Reactive power:	34.97 KVAR	121.42 — 31.02
Total Harmonic Distortion	29.61%	36.25 — 13.01
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.033	1.235 — 1.000
Peak to avg. current ratio:	2.281	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	90.66%	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO — YES
Heat Loss (IGBTs):	591 W	3311 — 455
Reliability Ranking:	4	7 — 1

Mid-Frequency - Phase Control





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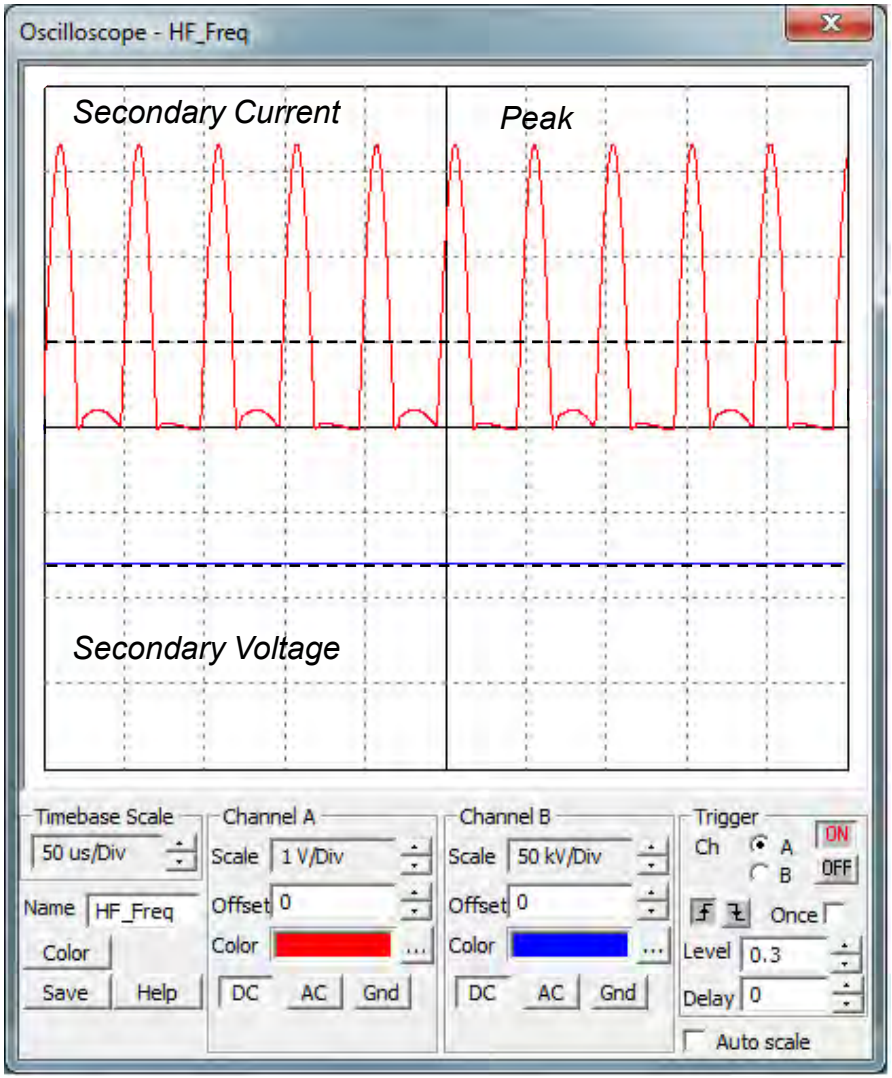
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.033	1.235 — 1.000
Peak to avg. current ratio:	2.281	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	90.66%	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	Yes	NO — YES
Heat Loss (IGBTs):	591 W	3311 — 455
Reliability Ranking:	4	7 — 1

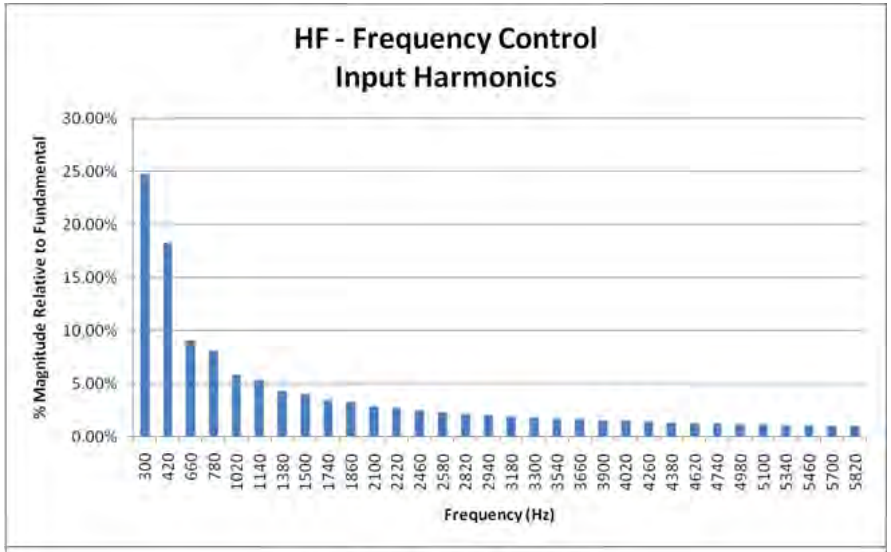
HF – Frequency Control

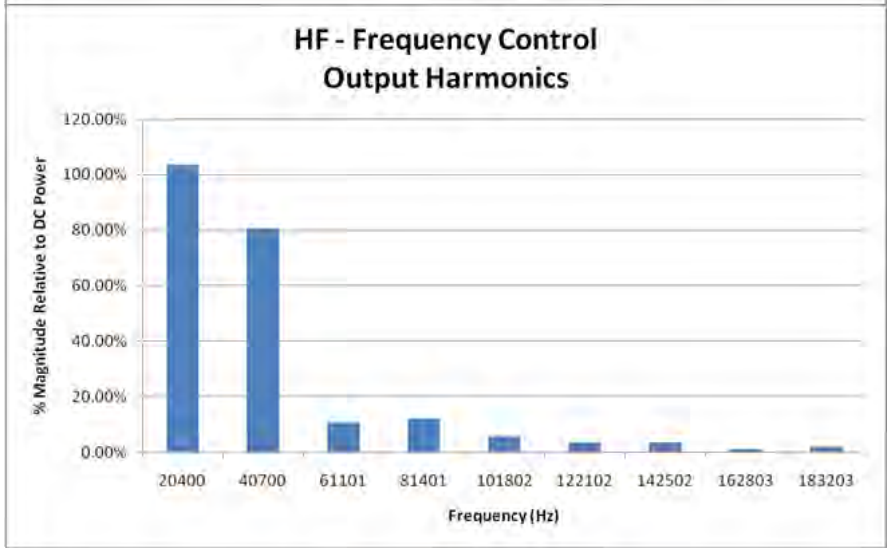


True DC: ----------

Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (3-Phase):	104.0 A	308.3 — 100.9
Power factor:	0.926	.566 — .926
Apparent power:	88.97 KVA	146.70 — 87.18
Reactive power:	31.02 KVAR	121.42 — 31.02
Total Harmonic Distortion	35.17%	36.25 — 13.01
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.002	1.235 — 1.000
Peak to avg. current ratio:	3.324	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	89.19 %	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	No	NO — YES
Heat Loss (IGBTs):	1414 W	3311 — 455
Reliability Ranking:	6	7 — 1

HF – Frequency Control





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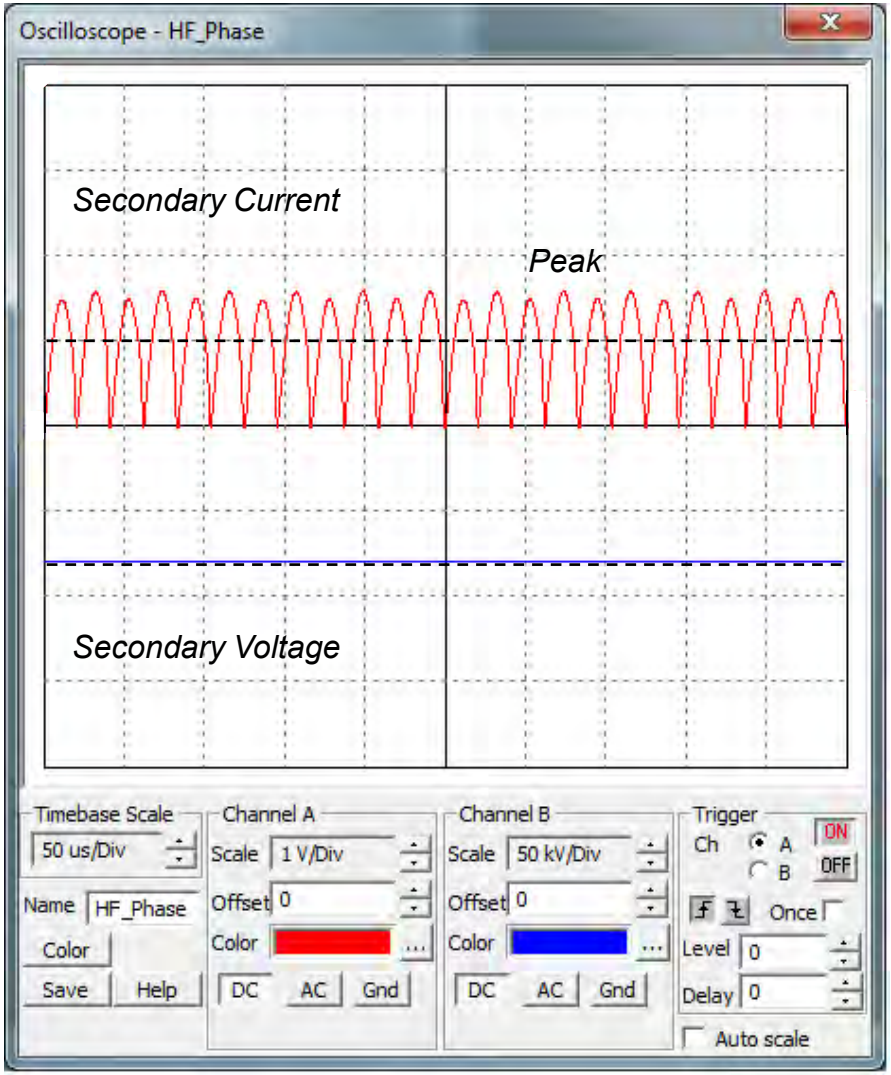
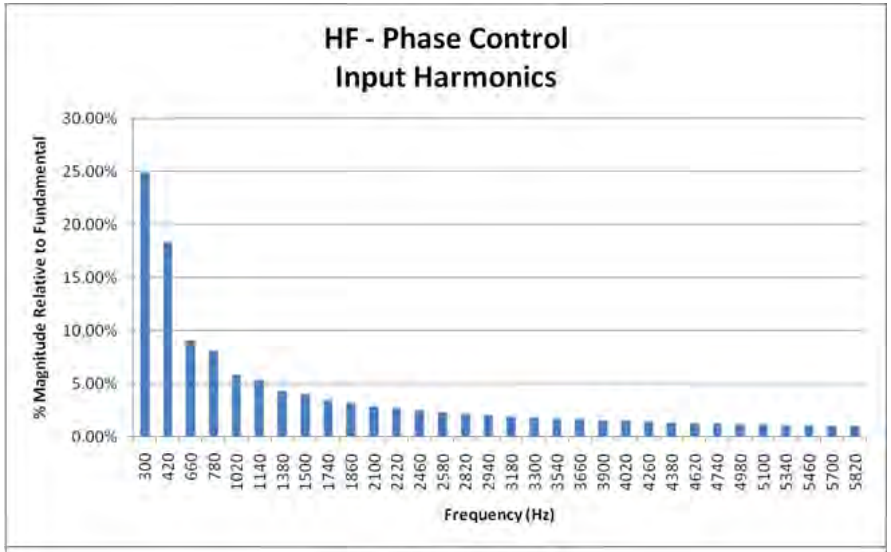
HF – Phase Control

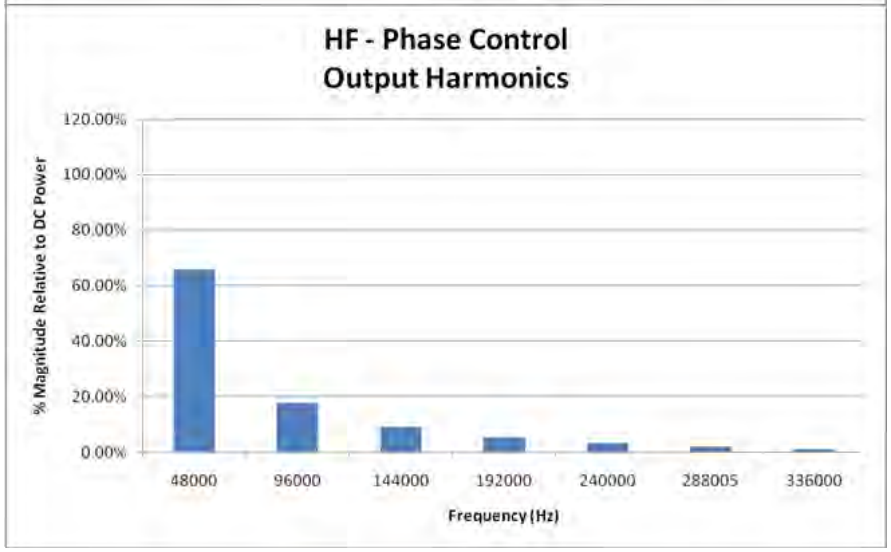


True DC: ----------

Input (480.0 Volts RMS, 60 Hz)		**Score Card**
Line current (3-Phase):	100.9 A	308.3 — 100.9
Power factor:	0.914	.566 — .926
Apparent power:	87.18 KVA	146.70 — 87.18
Reactive power:	31.78 KVAR	121.42 — 31.02
Total Harmonic Distortion	36.25%	36.25 — 13.01
Output (Set point: 80 KV, 1000 mA DC Avg)		**Score Card**
Peak to avg. voltage ratio:	1.000	1.235 — 1.000
Peak to avg. current ratio:	1.589	3.324 — 1.126
Efficiency (Output power/Apparent power)		**Score Card**
Efficiency:	91.05 %	54.53 — 91.05
Design Capability		**Score Card**
Ability to Separate the Control and Transformer:	No	NO — YES
Heat Loss (IGBTs):	3311 W	3311 — 455
Reliability Ranking:	7	7 — 1

HF – Phase Control





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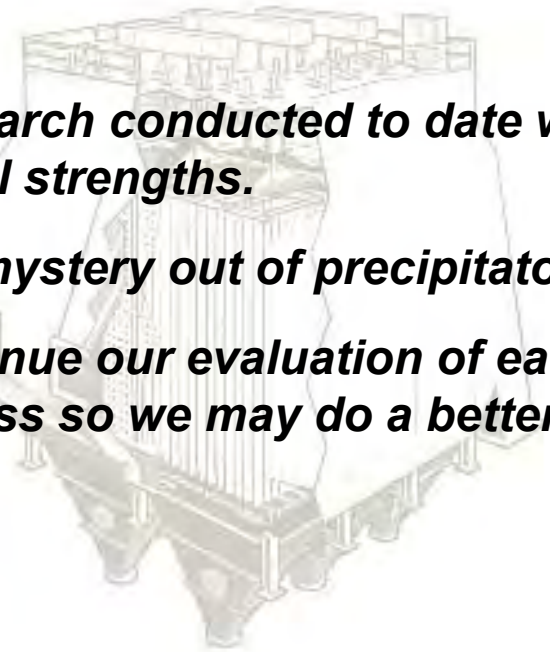
Taking the Mystery Out of Precipitator Power Supplies

An Ongoing Process of Research and Development



Summary:

- ***This is a sample of the research conducted to date which shows that each power supply has individual strengths.***
- ***This process is taking the mystery out of precipitator power supplies.***
- ***The path forward is to continue our evaluation of each component of the particulate collection process so we may do a better job of applying this technology world wide.***

The Path Forward:

Power Supply Design → Corona Generation → Corona Current → Particulate Collection

Taking the Mystery Out of Precipitator Power Supplies

2013 APC Conference

St. Louis, Missouri – July 8-9, 2013

THANK YOU. QUESTIONS?

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