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ELECTRONIC CONTROLS FOR INDUSTRY

Power Quality Design Issues for AC Drives

Keith Benson
IEEE- MCPQ
2/1/2005

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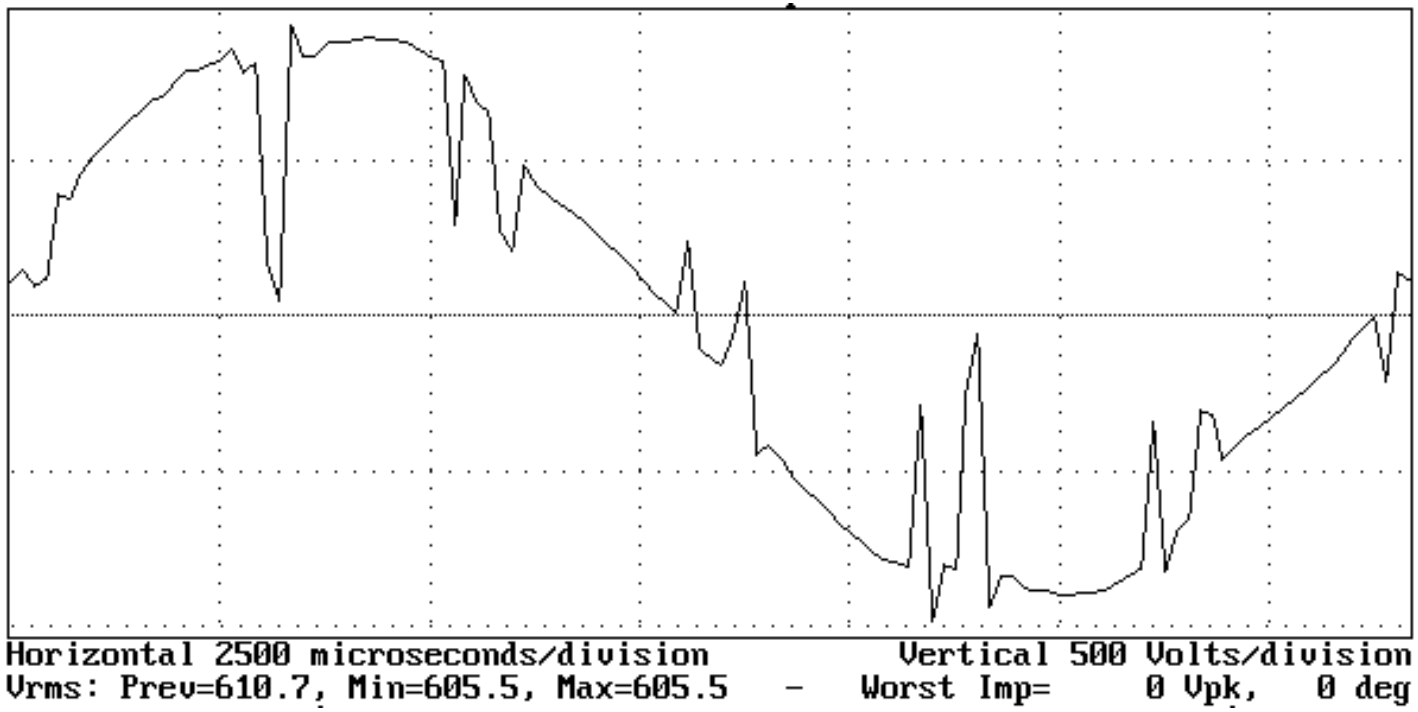
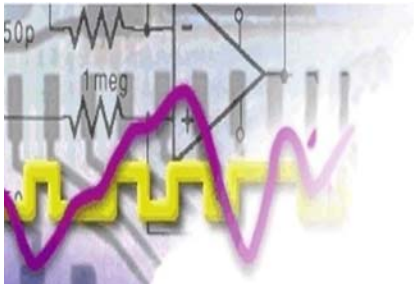
"Power Quality is not a problem for AC Drives unless it is a problem!"





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PQ Issues

Either

- **PQ creates Drive Problems**

Or

- **Drive creates PQ problems for other connected equipment**

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What is an AC Drive

Electronic Power Module

With Fixed Voltage, Fixed Frequency Input

ie 460 VAC, 3Phase, 60 Hz

And Variable Voltage, Variable Frequency Output

ie 230 VAC, 3Phase, 30 Hz

That is used to achieve Control of:

Speed, Torque, Flow, etc.

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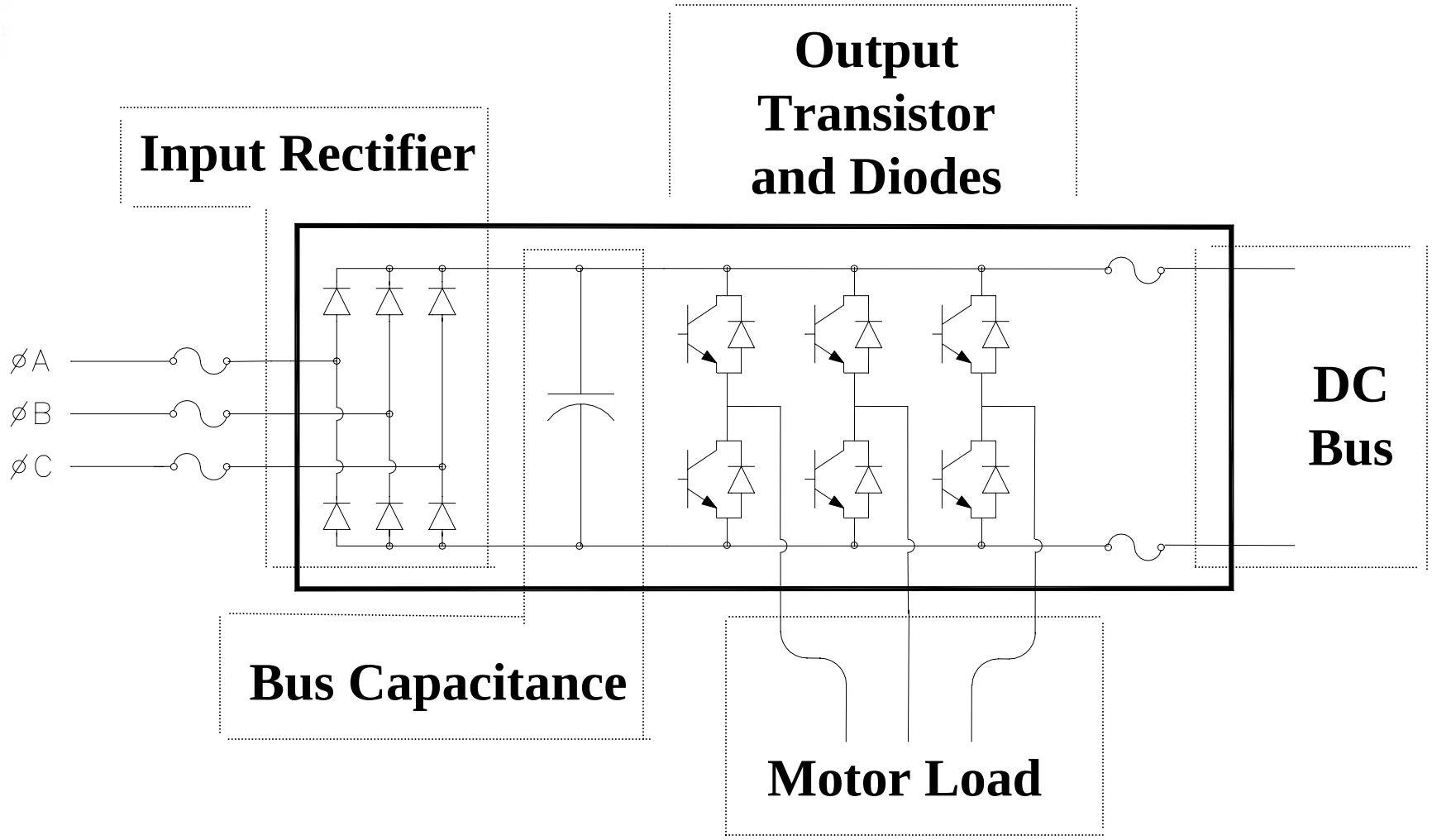
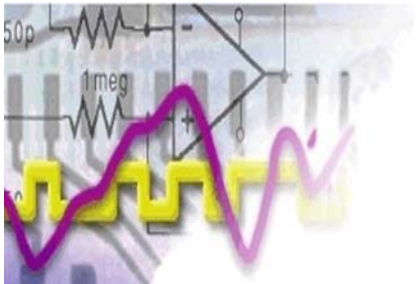
Typical PWM Drive Topology





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AC Drive Input/Output

Equal

- **Kw**

Not Equal

- **KVA, Current, Power Factor, Harmonics, etc.**

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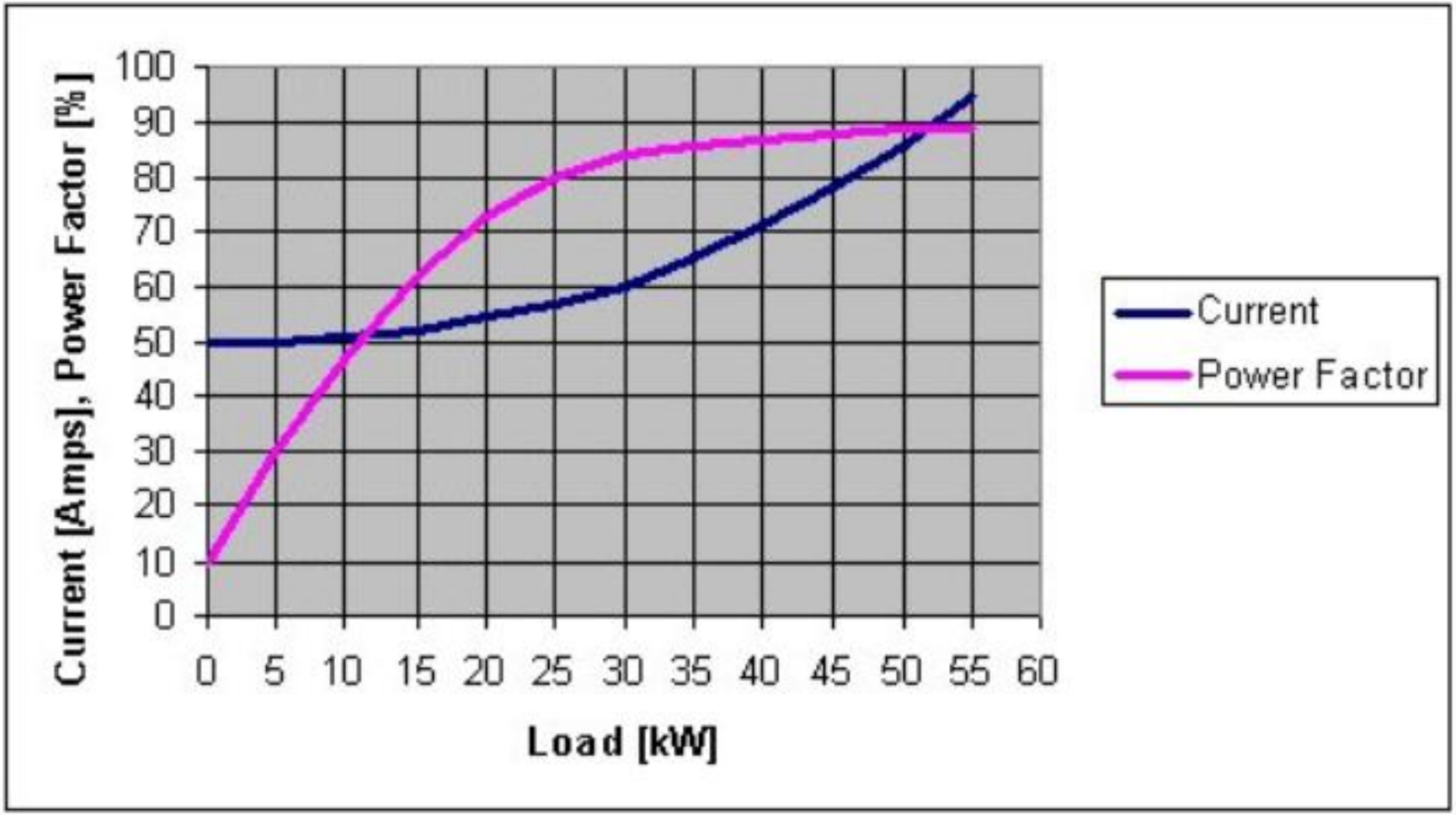
AC Motor Power Factor



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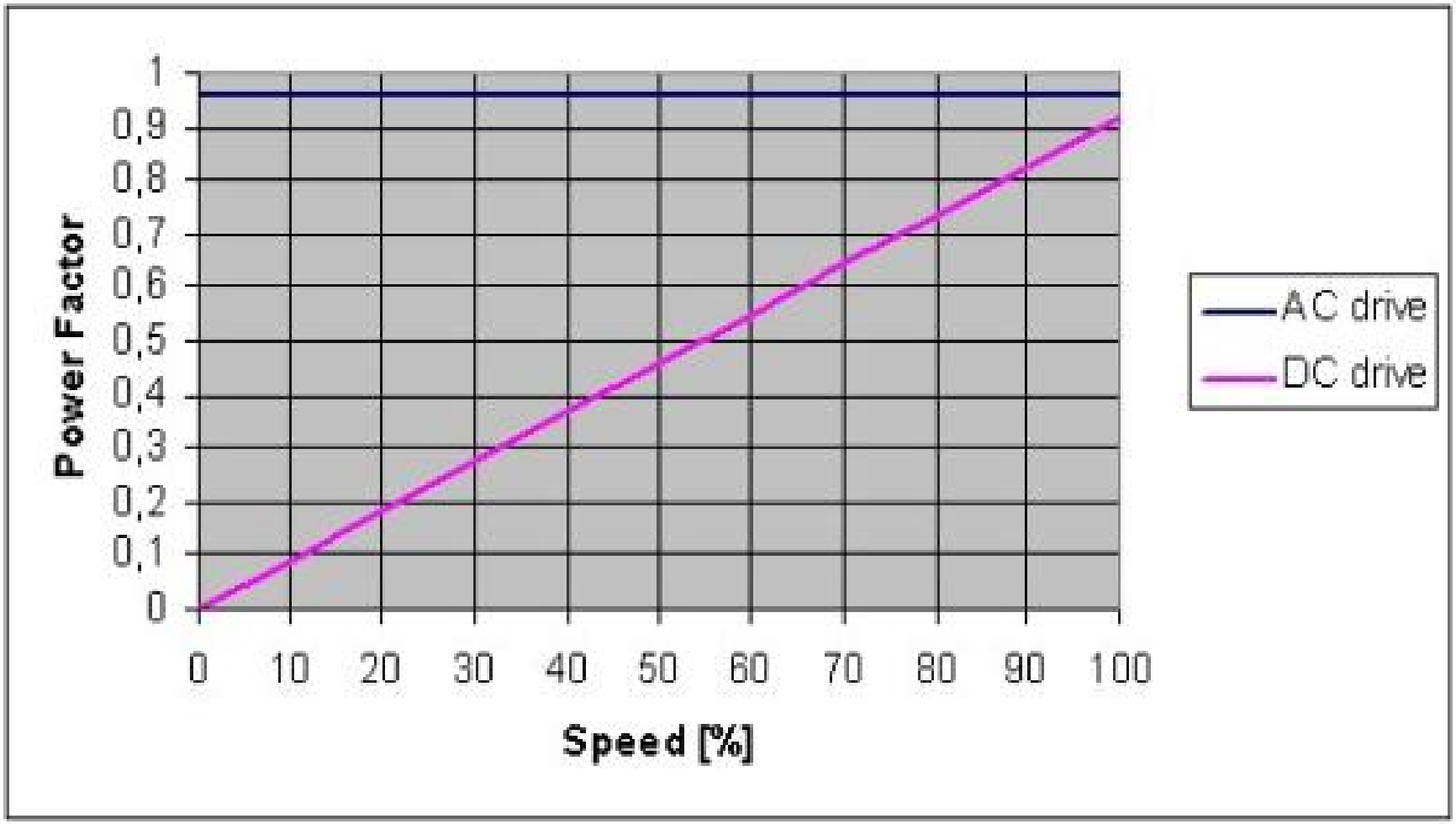
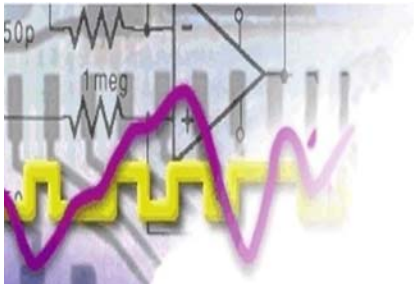
AC / DC Drive Power Factor





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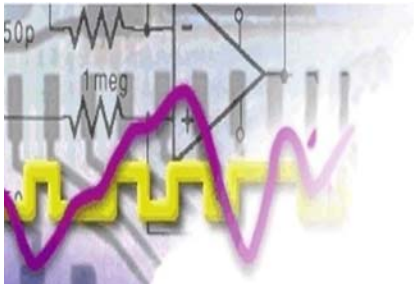
Drive PQ Problems

- Loss of Drive Enable
- Component Failure
- Over Voltage
- Under Voltage



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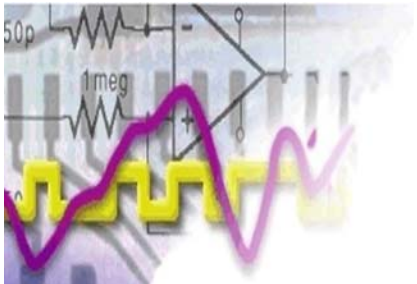
Loss of Drive Enable

What

- Initiates drive shutdown command

When

- Loss of 24 VDC I/O supply
- Loss of Interlock Contactor



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Component PQ Failures

- **Fuse**
- **Capacitor**
- **Transistor**
- **Precharge**
- **MOV**

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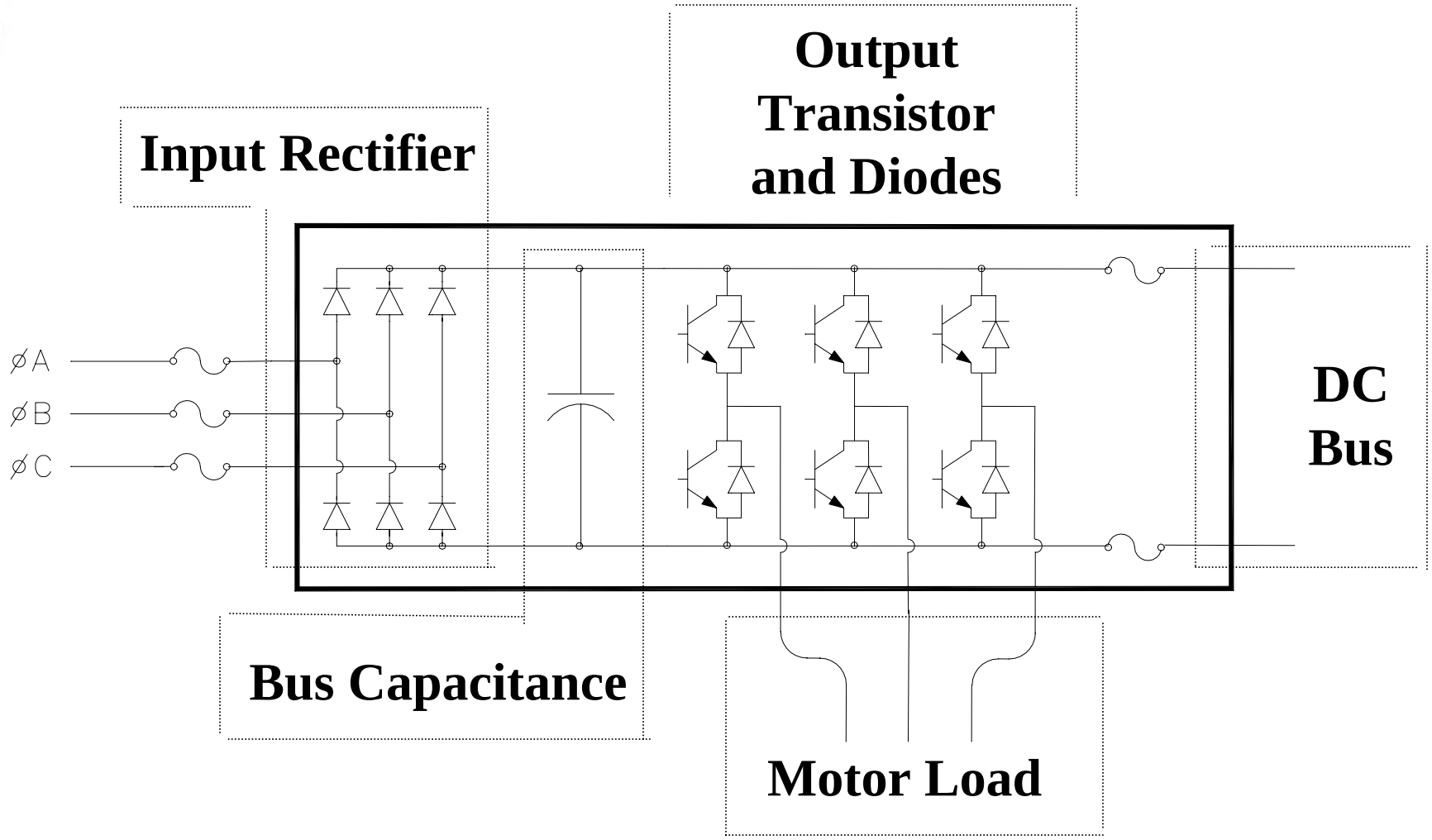
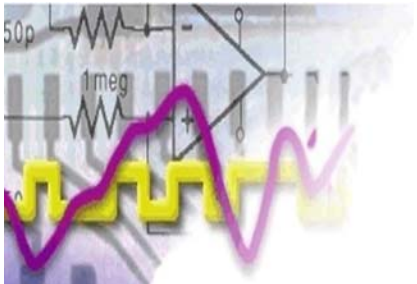
Typical PWM Drive Topology





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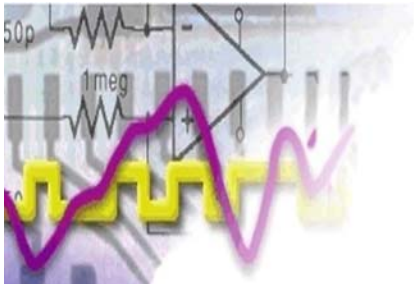
Fuse PQ Failures

Why

- High RMS Currents

When

- Single Phasing
- Line Unbalance



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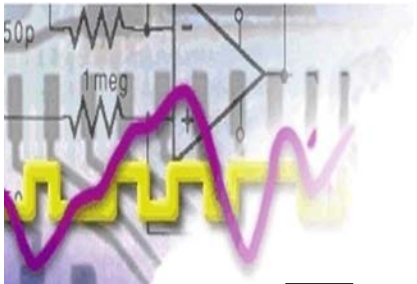
Capacitor PQ Failures

Why

- **High Ripple Currents**

When

- **Single Phasing**
- **Line Unbalance**



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Transistor PQ Failure Causes

Why

- VDC > 2x Nominal
- High Frequency Transients

When

- Power factor Capacitor Switching
- SCR Ringing

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Precharge Circuit PQ Failures

What

- Contacts welding

When

- On Power Dip Recovery

  High surge Currents

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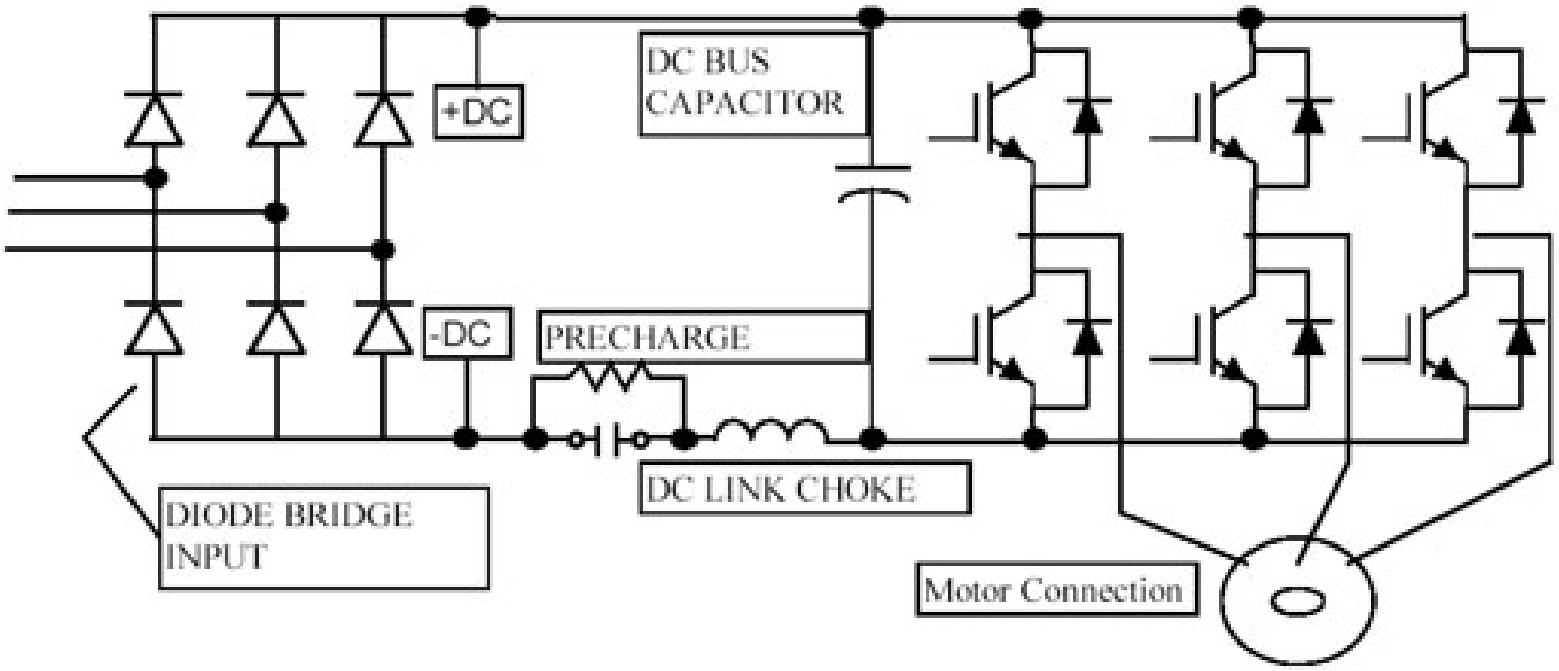
Drive Precharge with Resistor



Smaller Drives < 25 Hp

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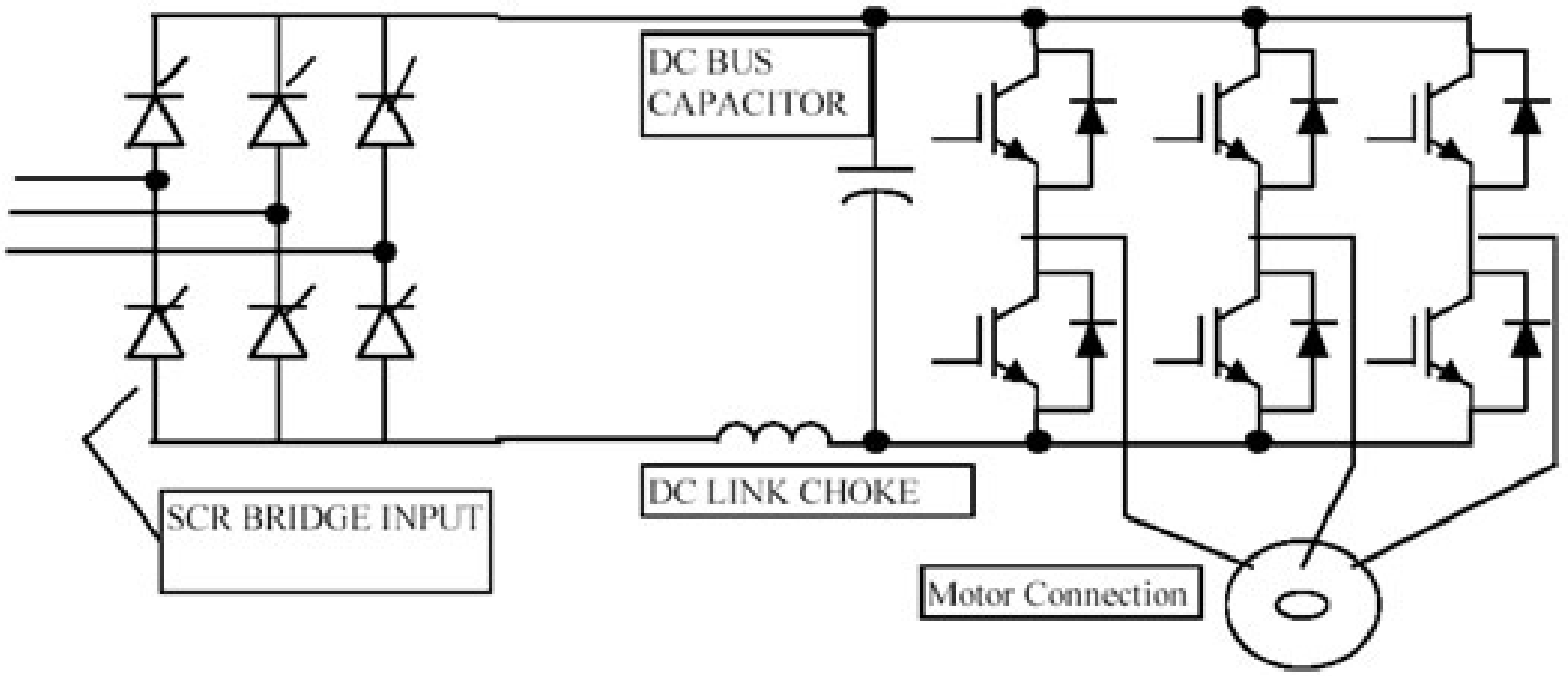
Drive Precharge with SCR's



Bigger Drives > 25 Hp

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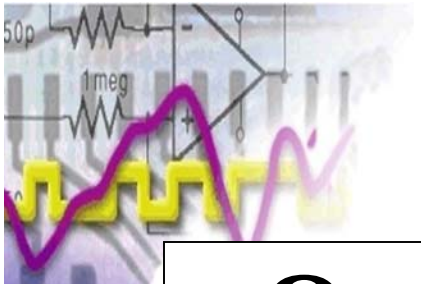
MOV PQ Failures

Why

- High Peak Over Voltage

When

- Line Surges and Swells
- Repetitive Transients
- Ring Waves



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Over and Under Voltage Faults

What

- **PQ shutdowns are Voltage related, not Current Related**

How Sensed

- **DC Bus**

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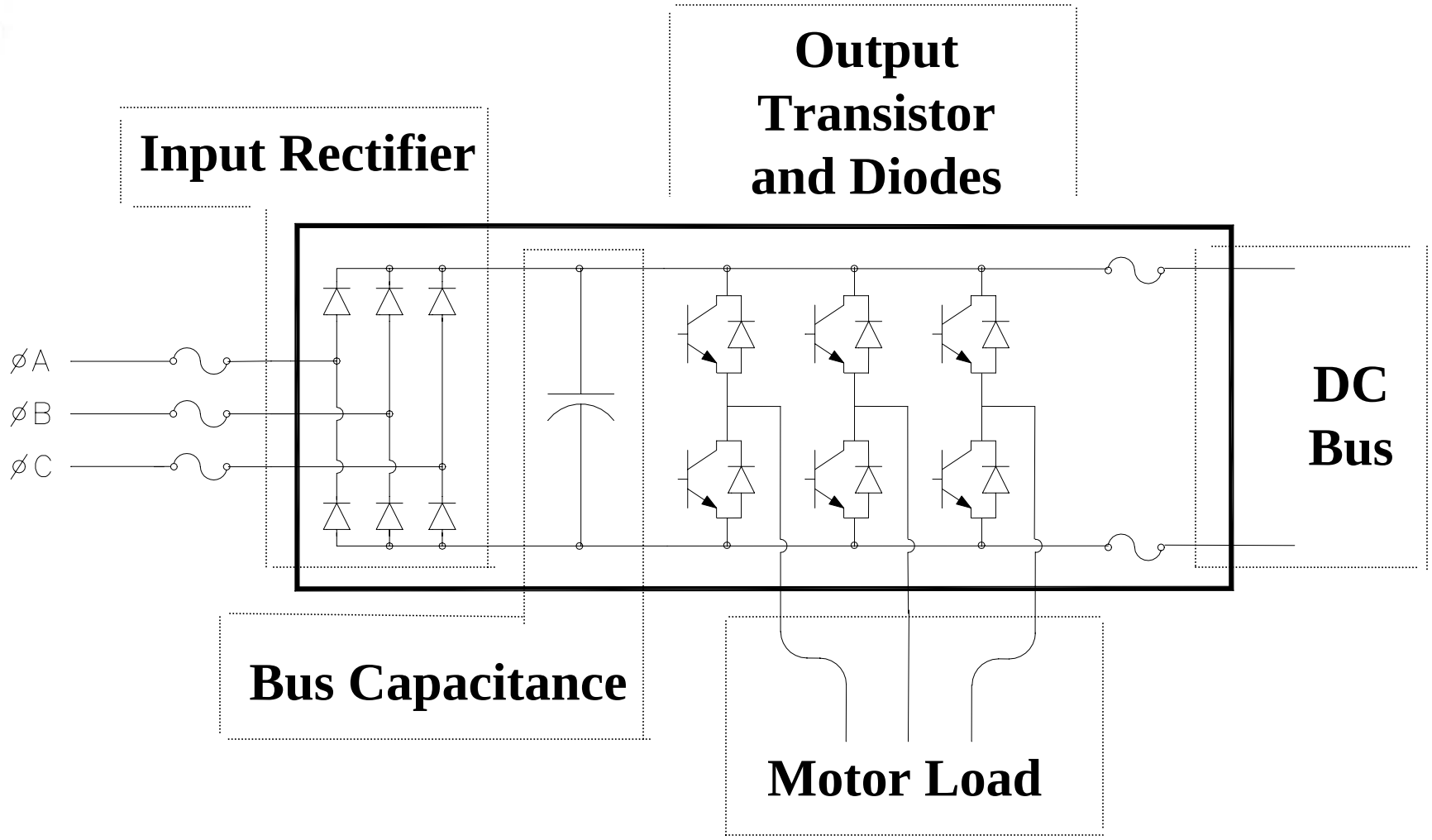
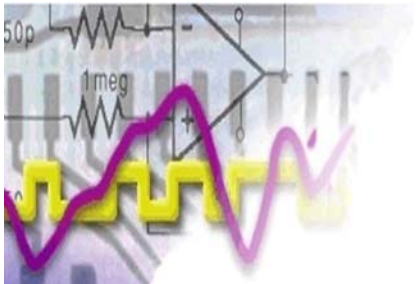
Typical PWM Drive Topology





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Typical Parameters for 460/480 VAC Drives

DC Bus = 640 VDC (460 VAC), 670 VDC (480 VAC).

DC Bus + 10% = 740VDC (480 VAC).

Over Voltage

Drive Over Voltage Trip at 800 VDC.

Under Voltage

DC Bus * 85% = 544 VDC (460 VAC).

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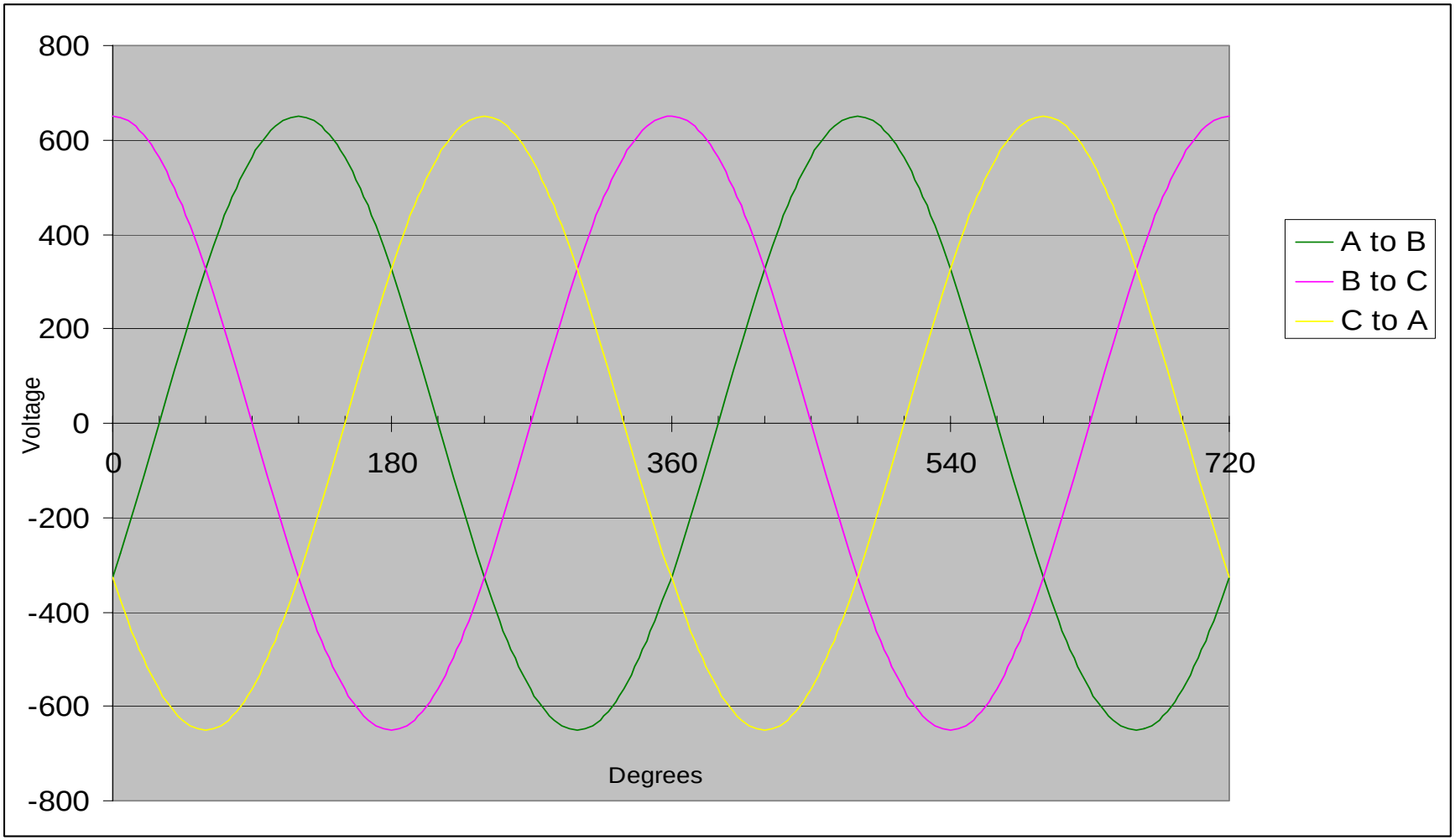
3 Phase Input



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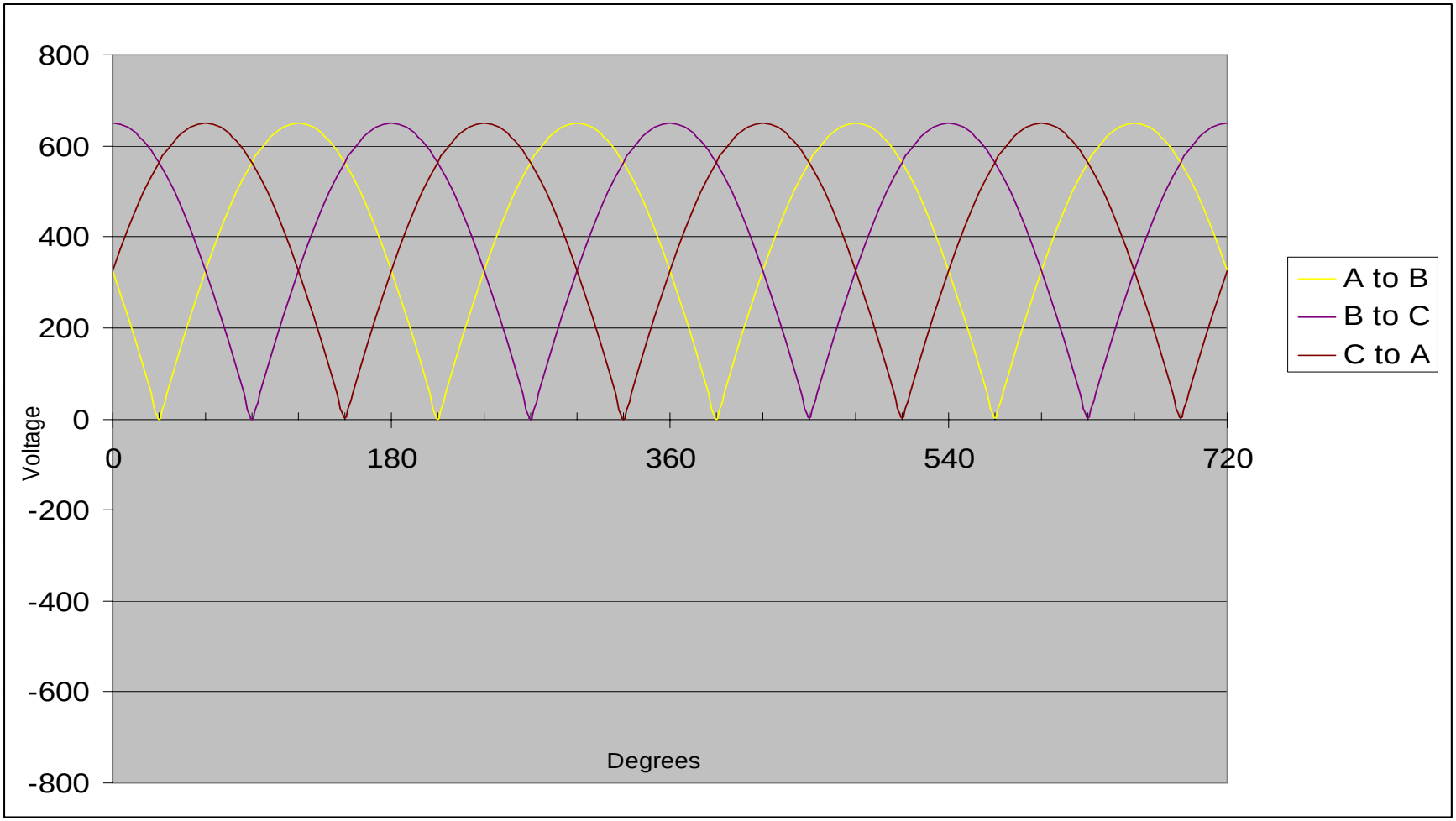
3 Phase Rectified



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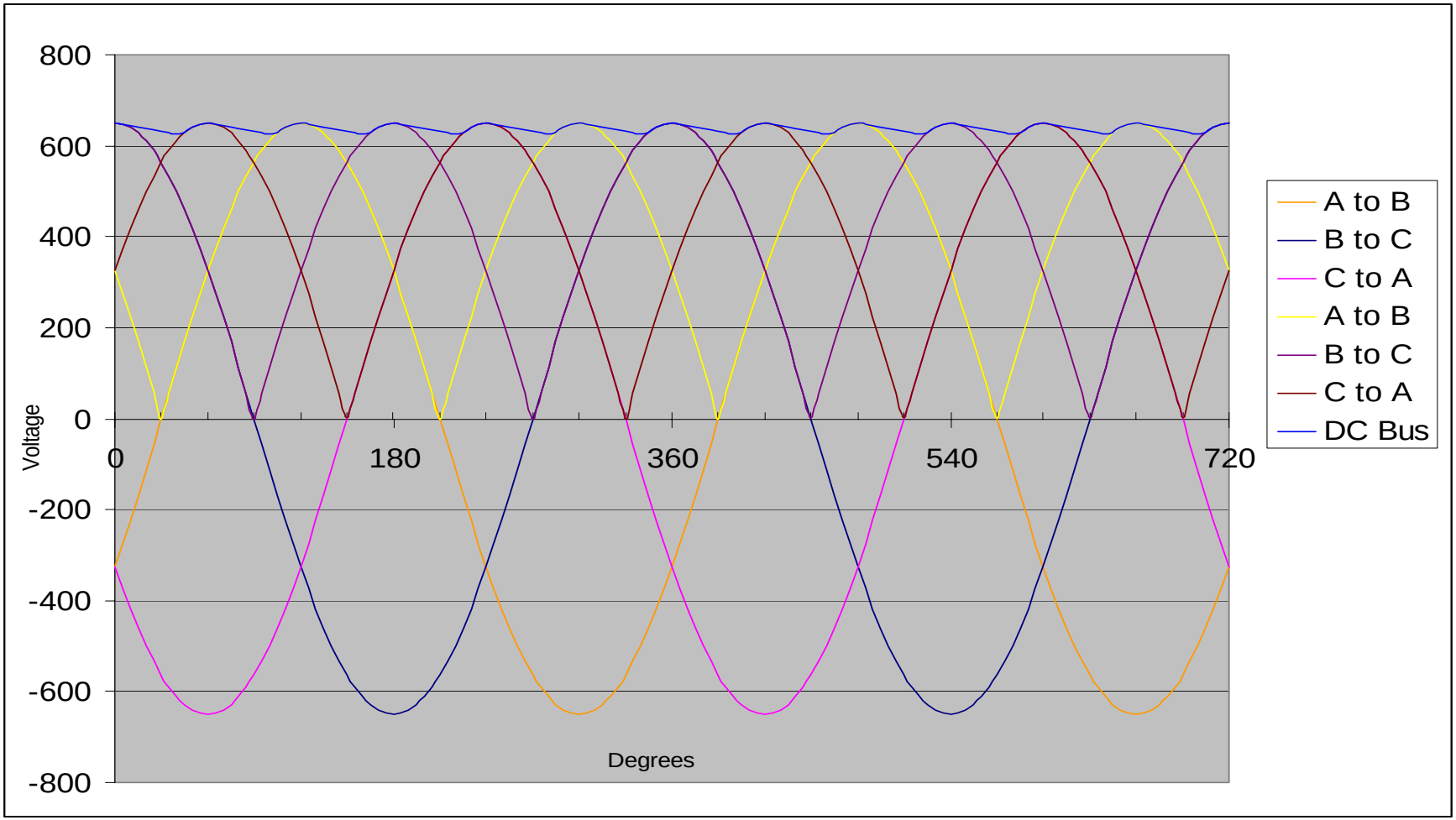
3 Phase AC, Rectified & DC



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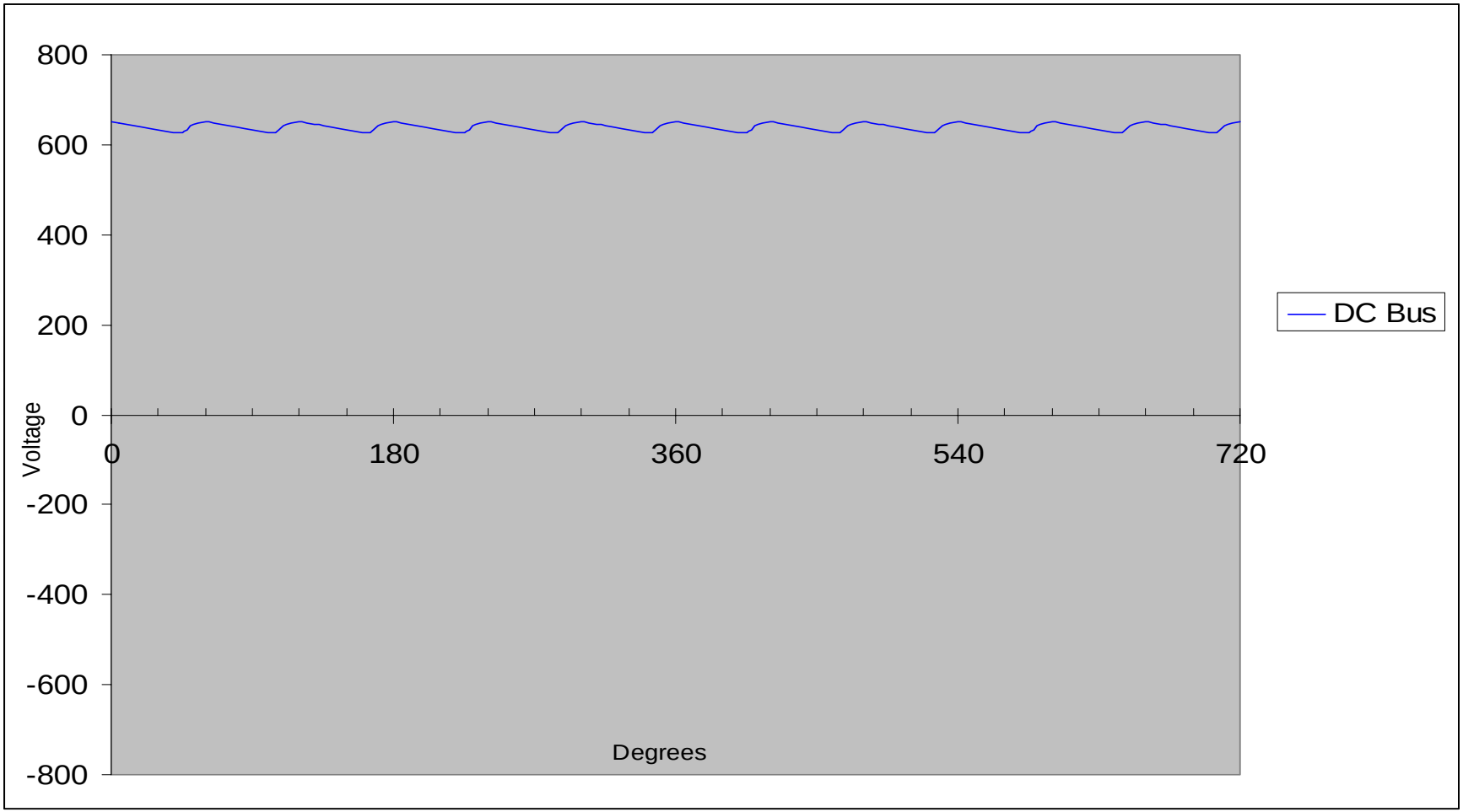
3 Phase Filtered



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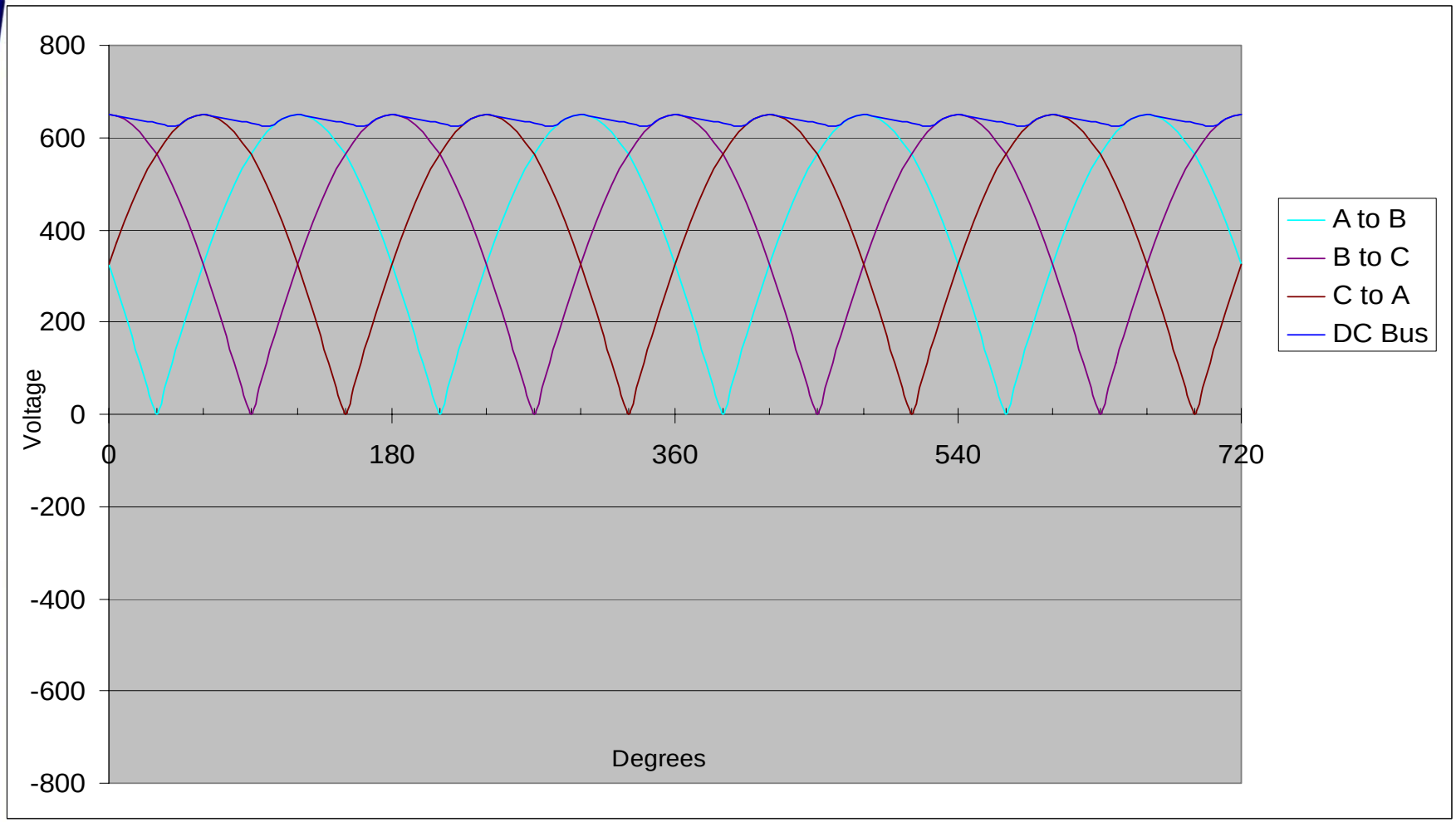
3 Phase, Light Load, Big Cap



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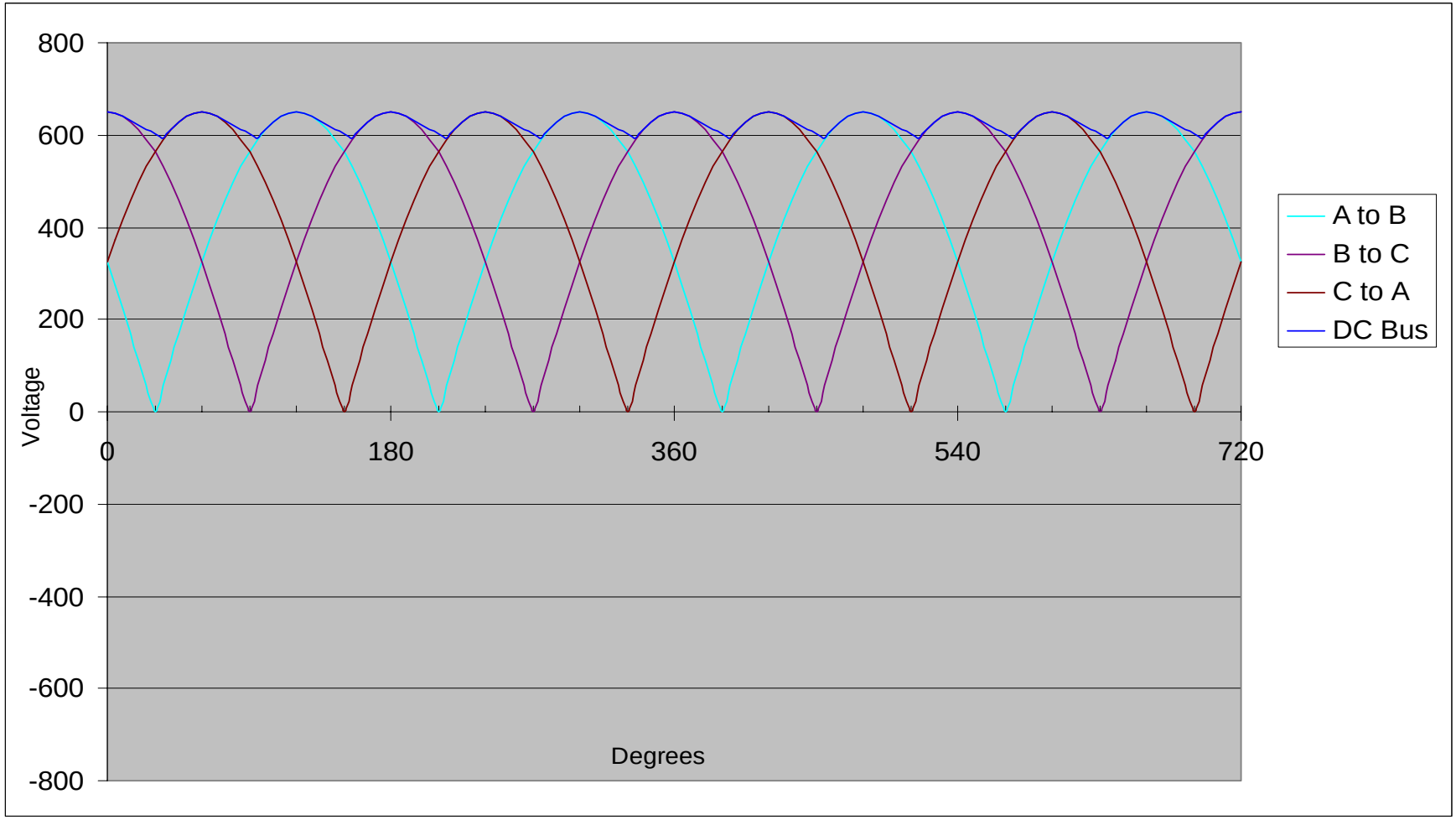
3 Phase, Heavier Load, small Cap



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Increasing Bus Capacitance

- **Decreases the Ripple voltage**
- **Typically sized for 1 to 4 Cycles of Power Loss Ride-Thru**

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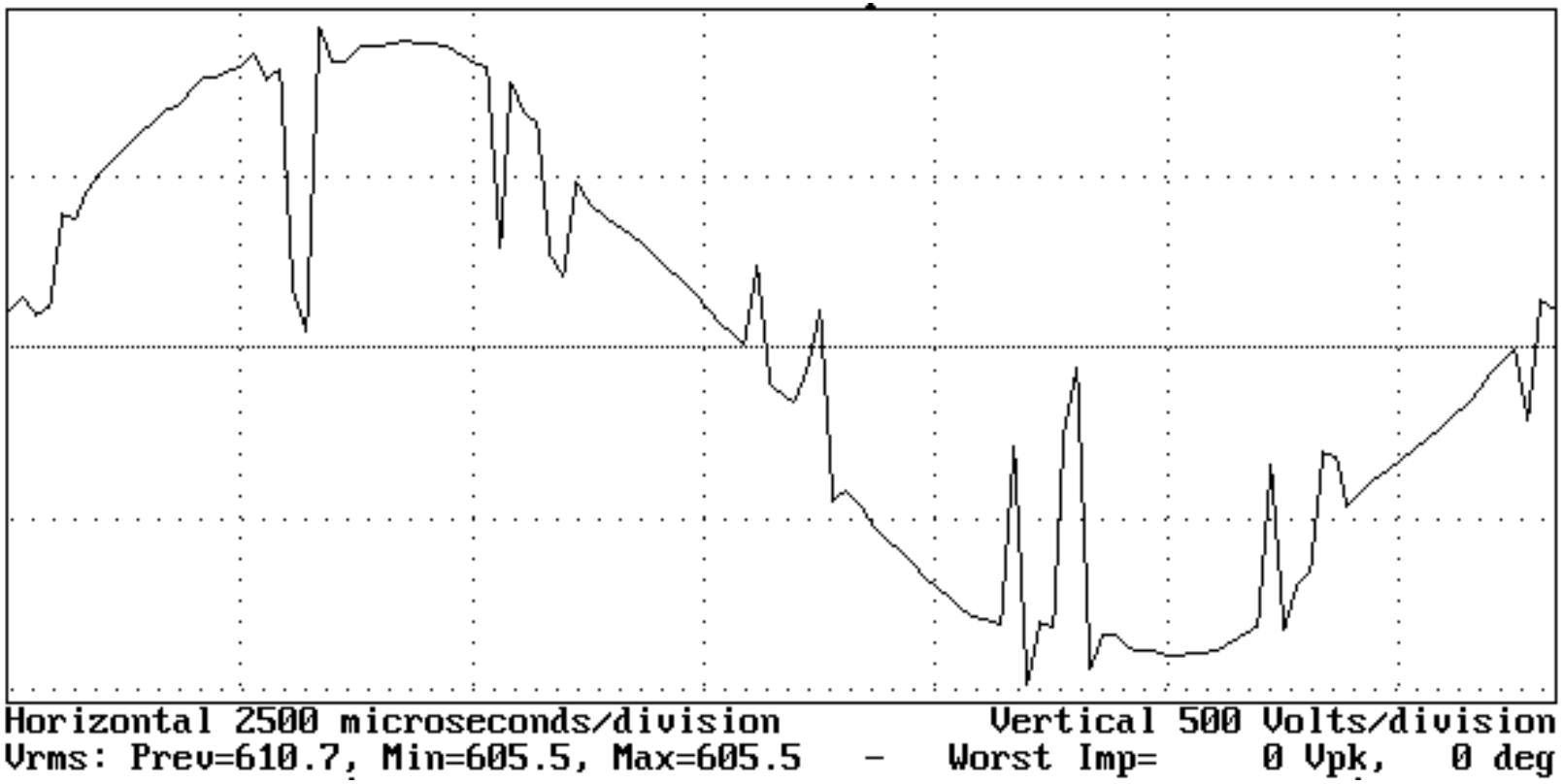
Over and Under Voltage Faults?



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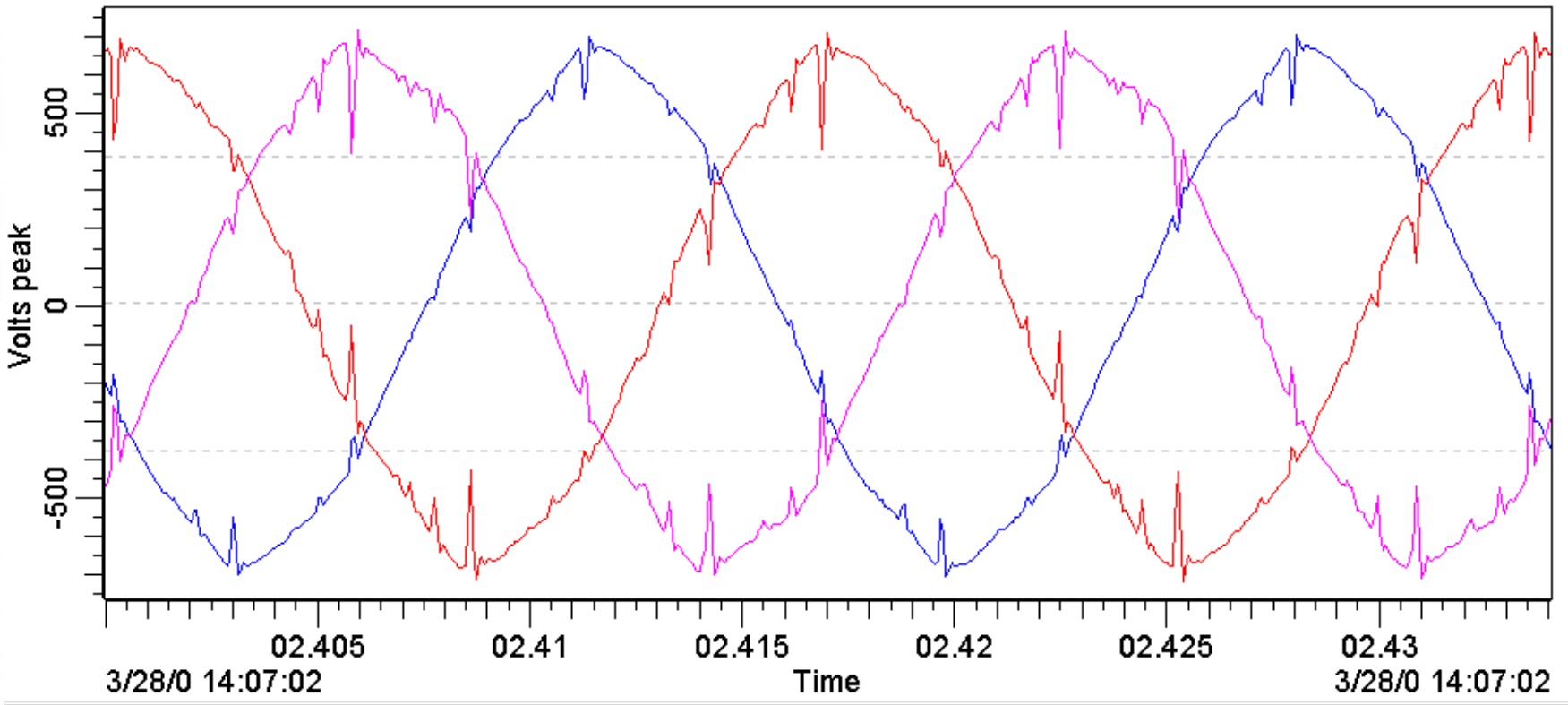
Faults ?



Measurement	Minimum	Maximum
Time	March 28, 2000 14:07:02.399	March 28, 2000 14:07:02.434
Voltage Waveform L1L2 Inst.	-702.2Vpk	707.1Vpk
Voltage Waveform L2L3 Inst.	-715.8Vpk	711.9Vpk
Voltage Waveform L3L1 Inst.	-703.6Vpk	719.8Vpk

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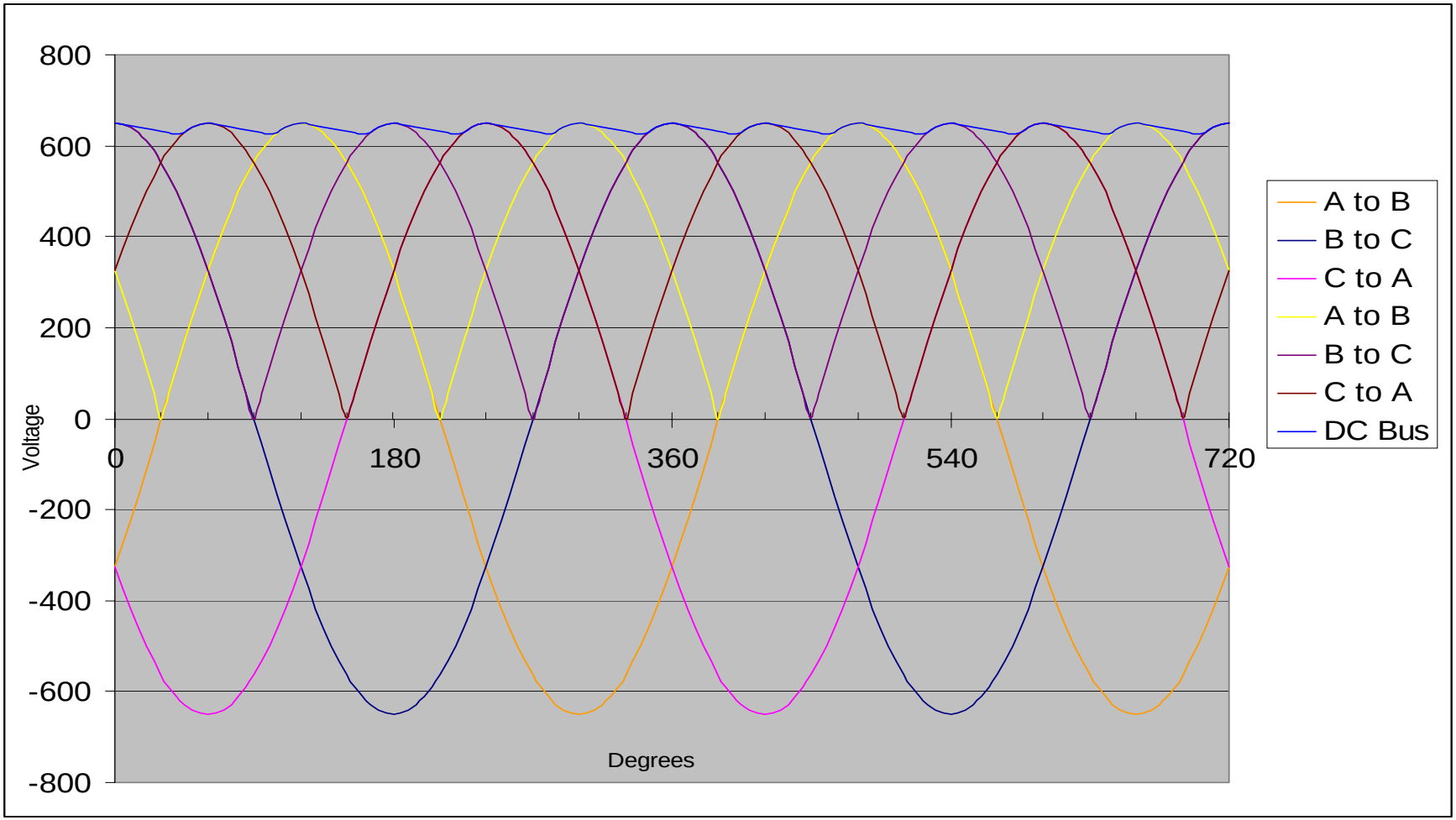
3 Phase AC, Rectified & DC



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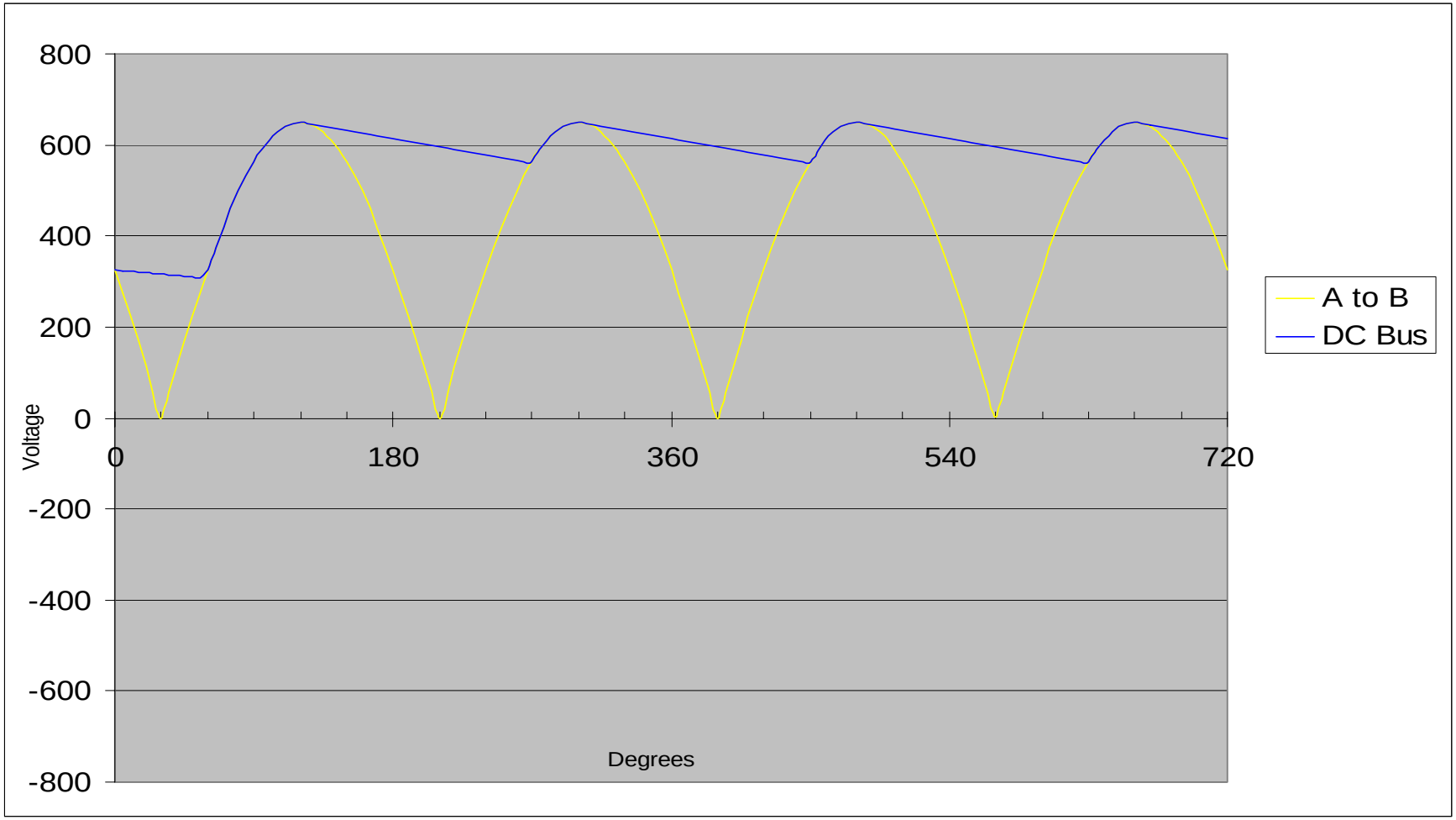
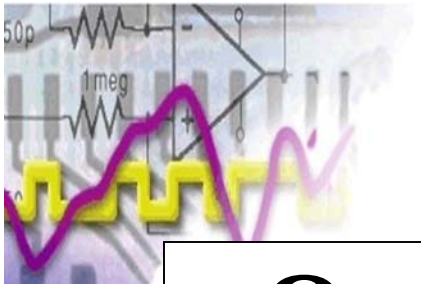
Single Phase, Blown Fuse





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Over Voltage Faults from Load

When

- **Motor Braking**

How

- **Parallel Bridge across IGBT's**

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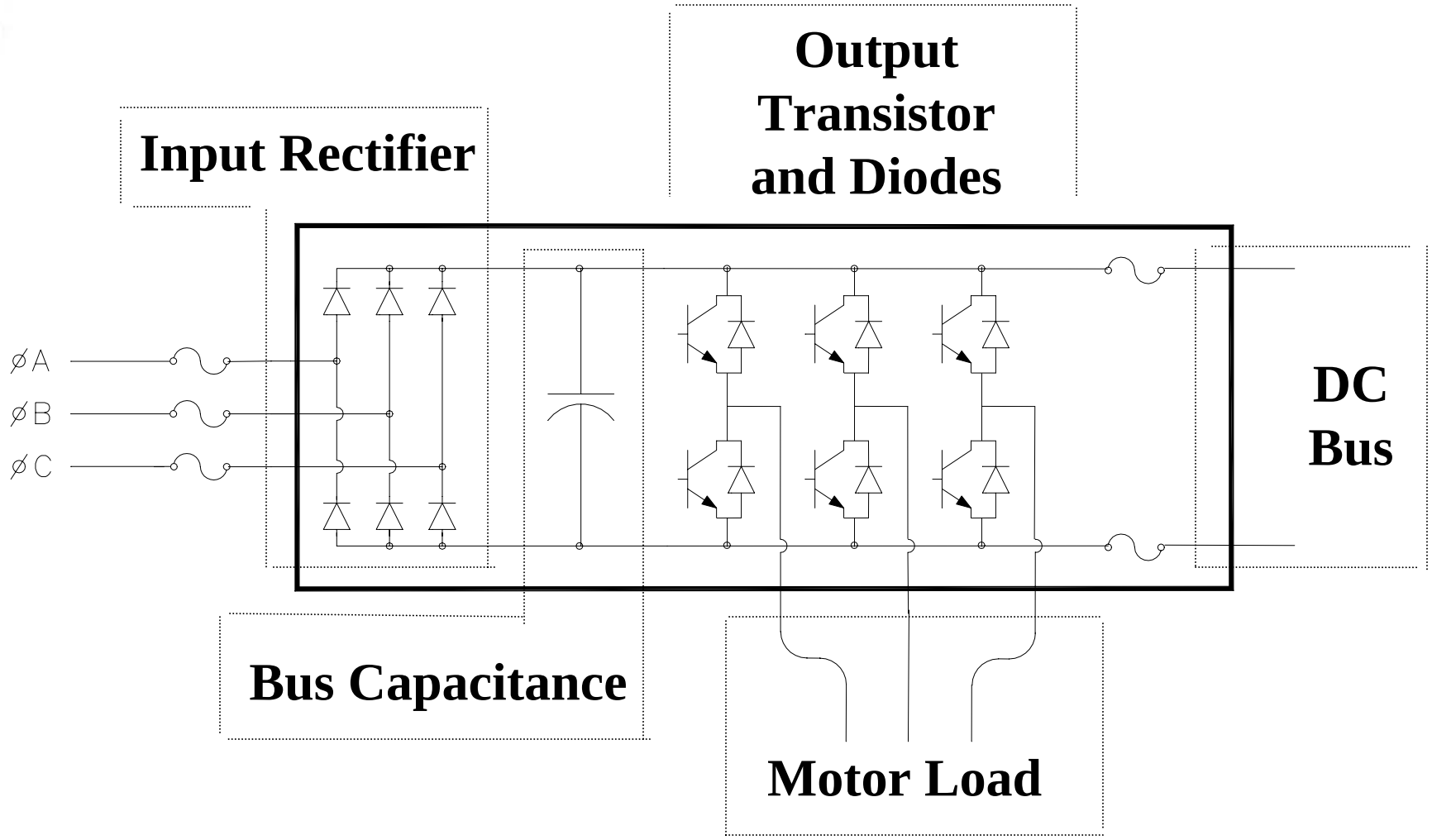
Typical PWM Drive Topology



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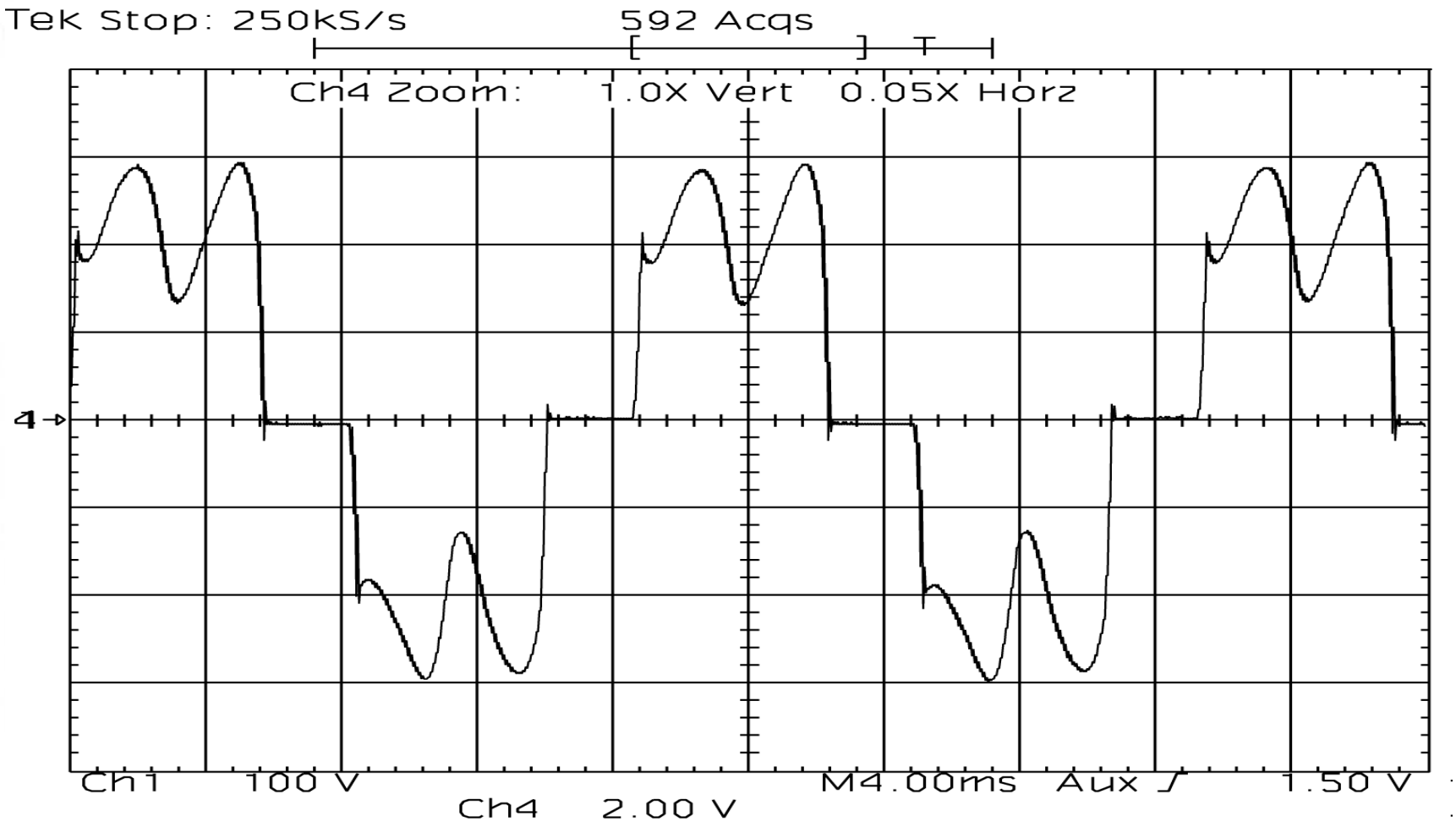
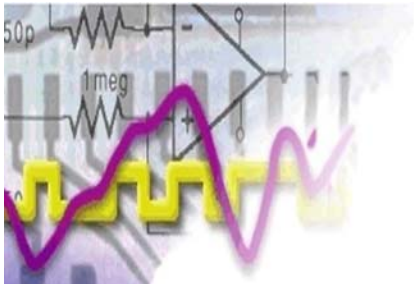
AC Drive Input Current





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Current Considerations

- **Magnitude**
- **Power Factor**
- **Distortion / Harmonics**

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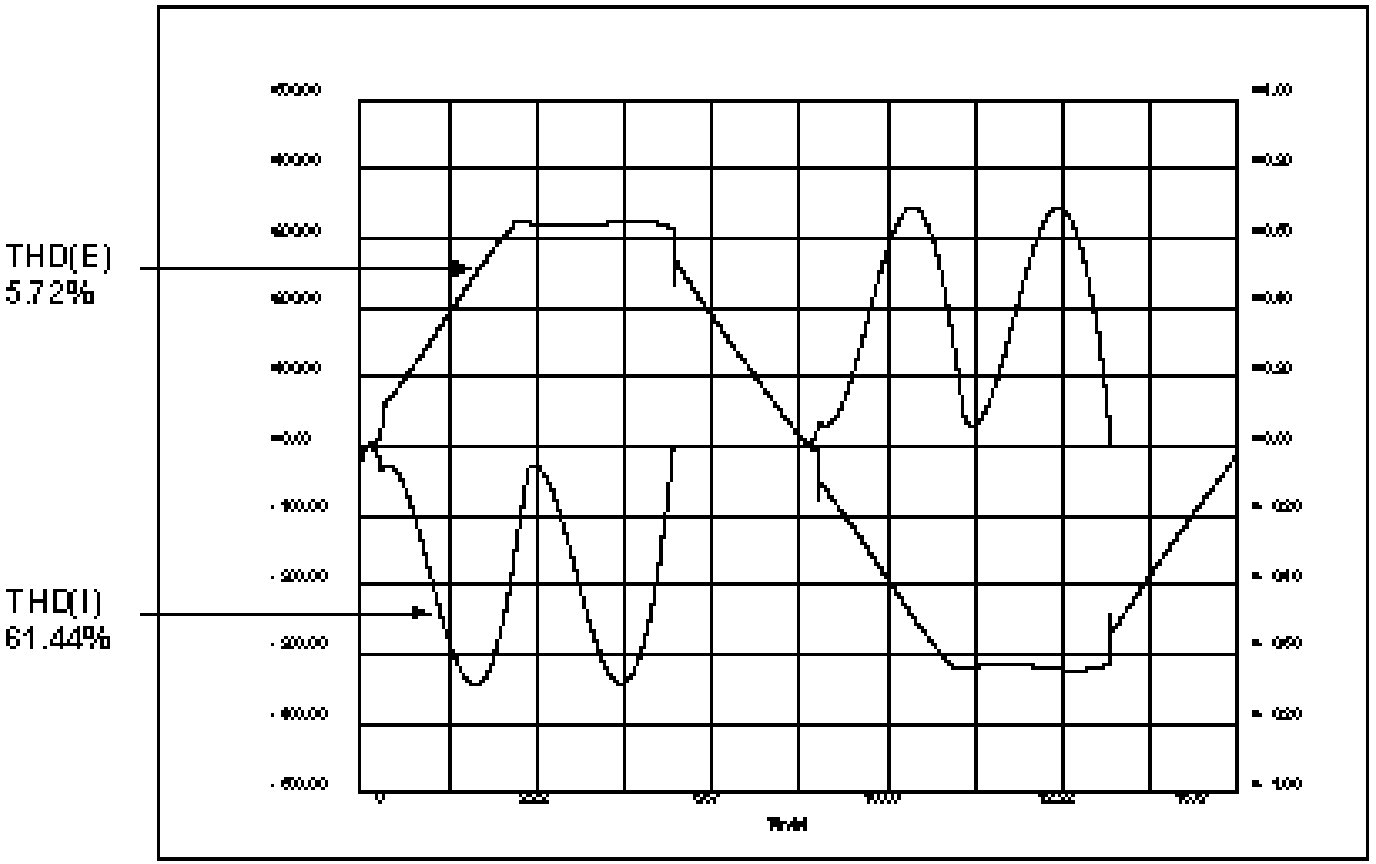
3 Phase Current Waveforms

VFD WITHOUT INPUT INDUCTORS



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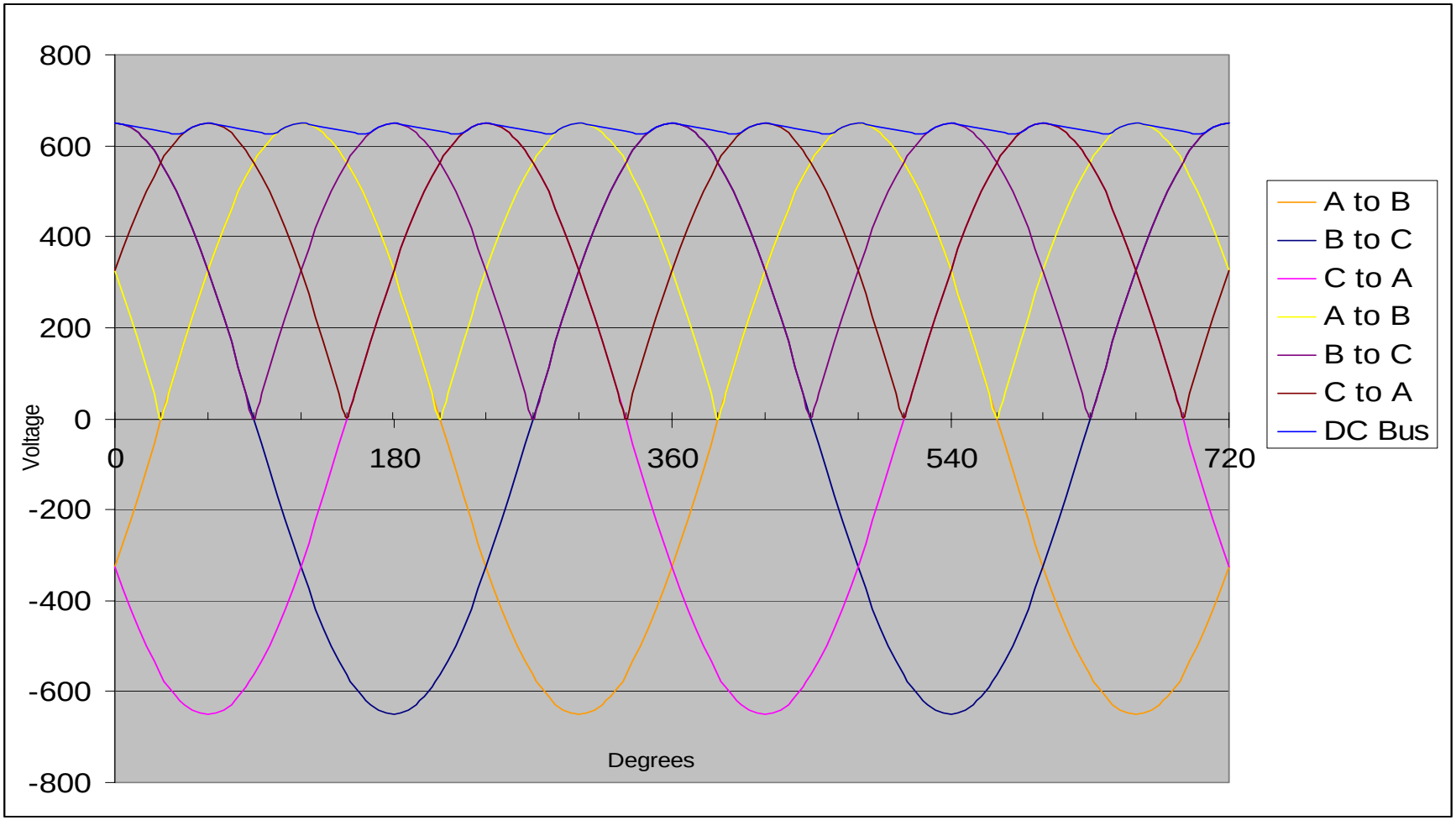
3 Phase AC, Rectified & DC



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Decrease Current Distortion

- **DC Link Chokes**
- **Input Line Chokes**

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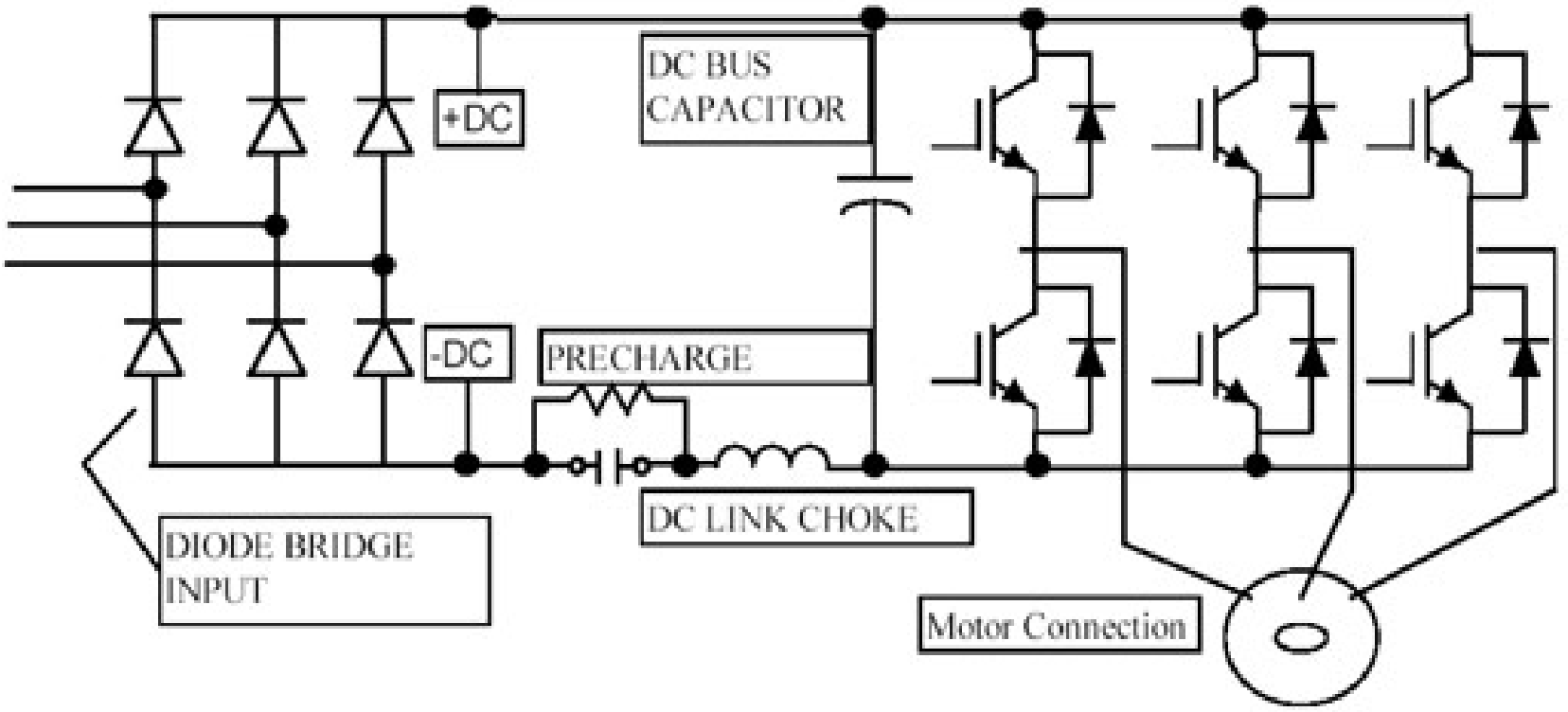
Drive Schematic



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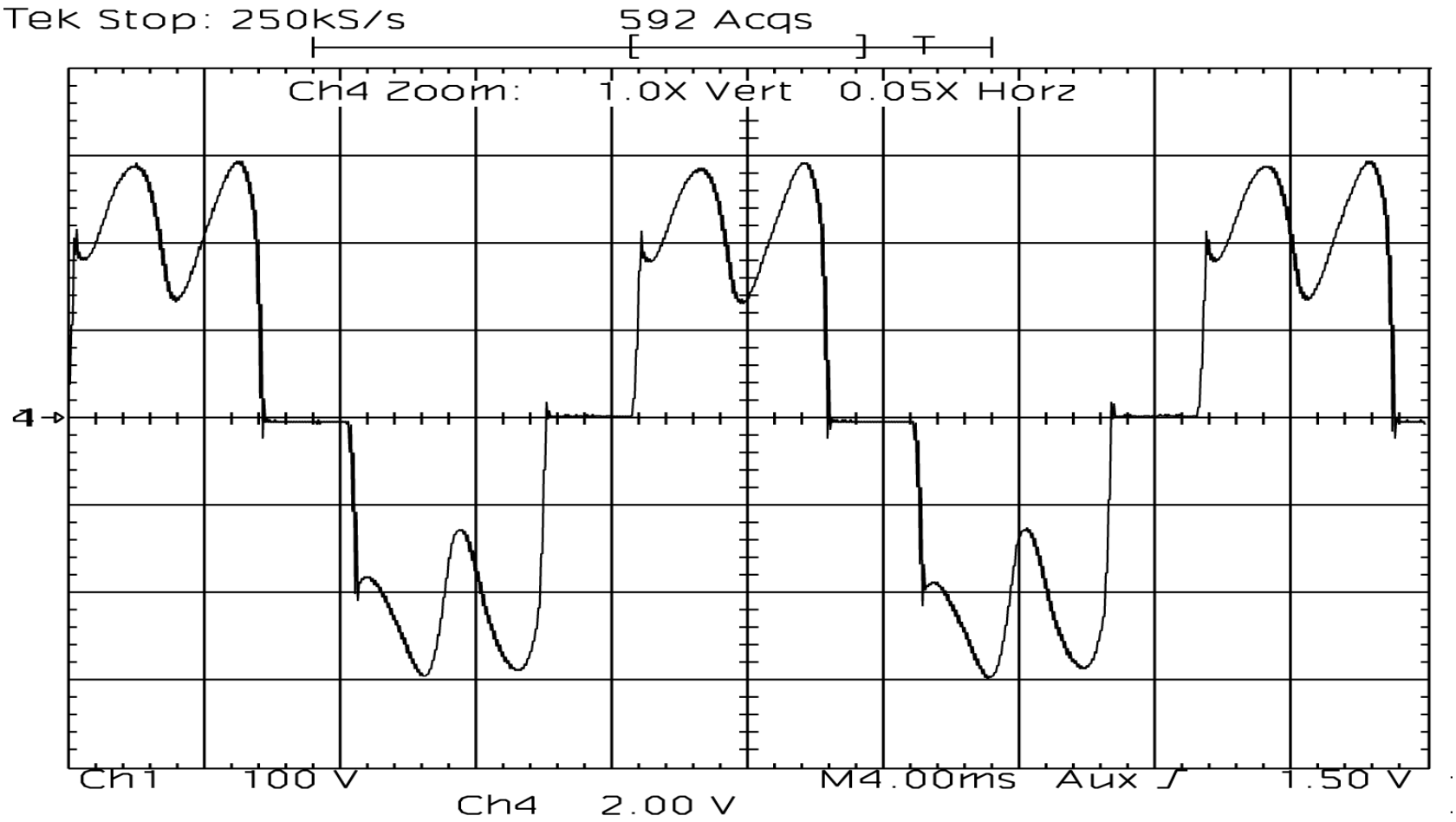
AC Drive Input Current



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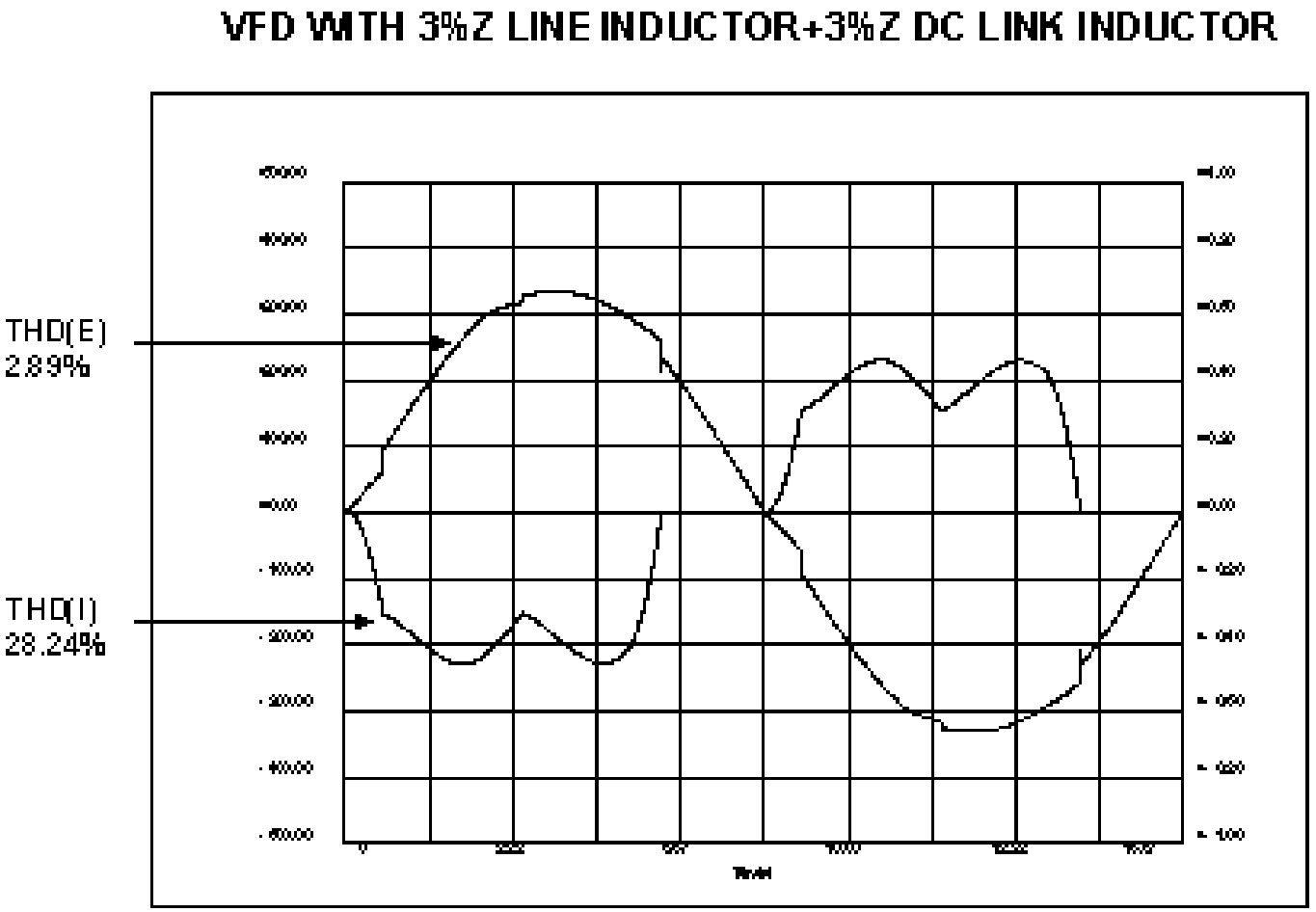
Diode Reactor Input Waveforms



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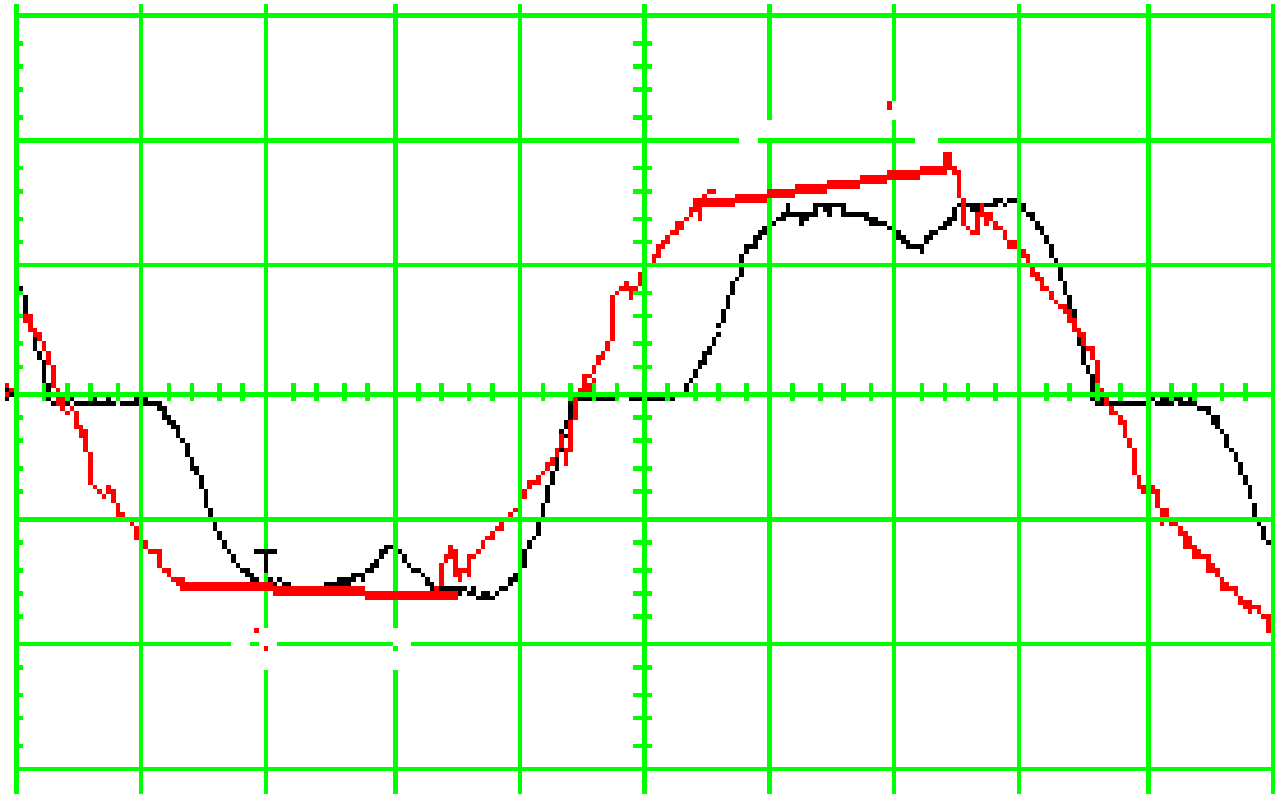
High Z – Flat Topping



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Increasing Bus Capacitance

$$I = C * (dV/dt)$$

- Increased Current Amplitude
- Increased Flat topping from IR drop
- Decrease in Conduction Time

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Harmonic Solutions

What

- **Multi Pulse Inputs**

  ie 12 pulse, 18 pulse

Requires

- **Additional Diode Bridge**
- **Phase shifted Transformer**

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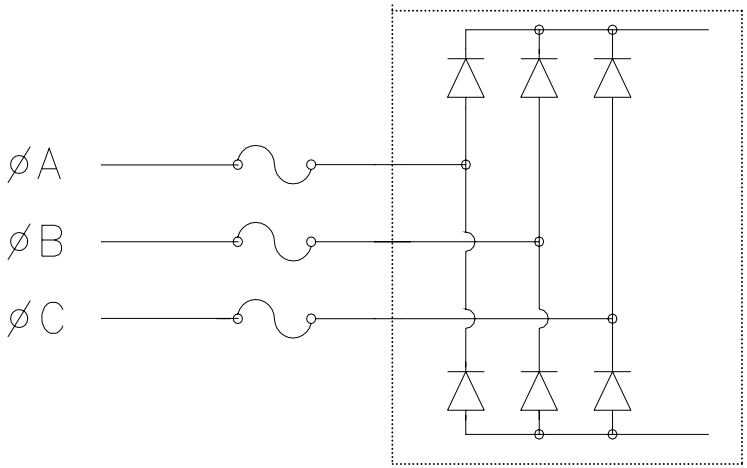
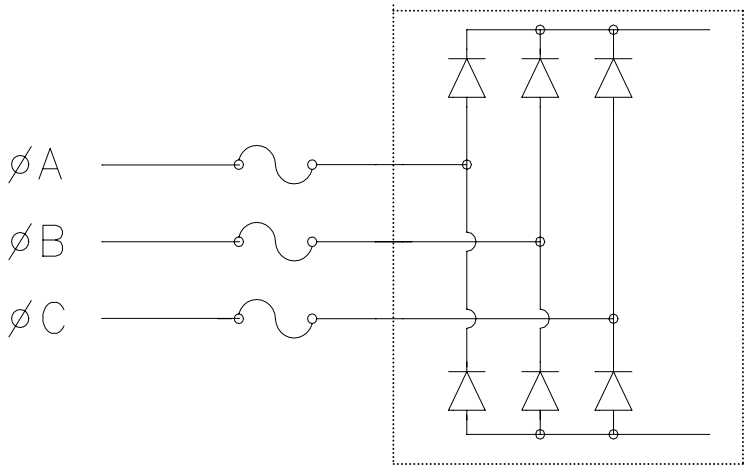
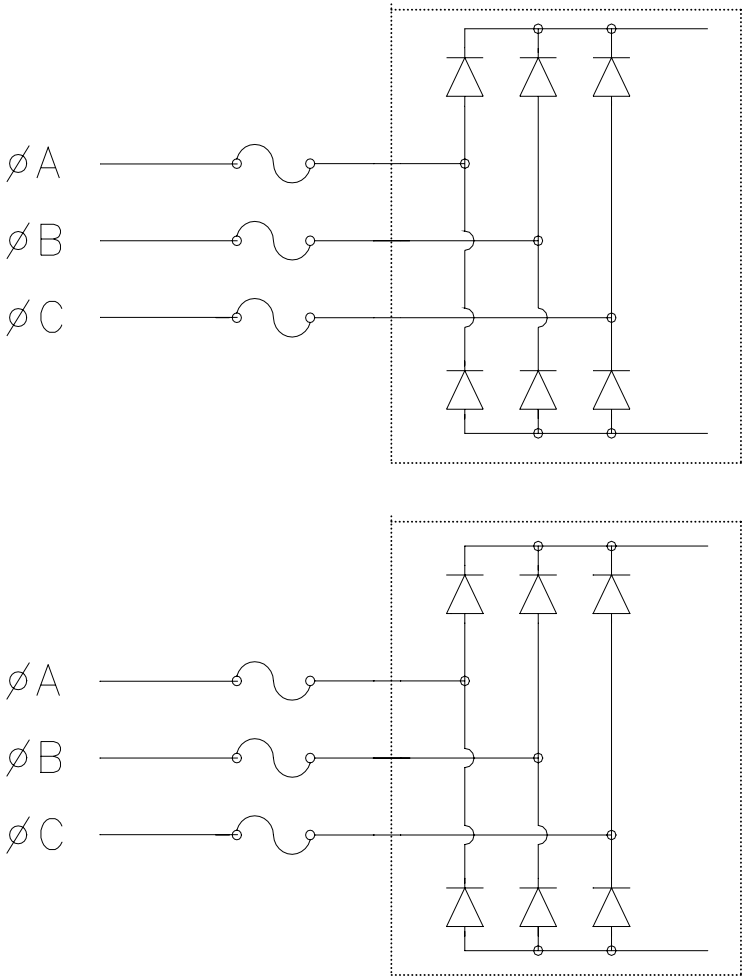
Multi Pulse Parallel





- **1:1 Transformer w/phase shift**
- **Easier to Implement**
- **Balancing, Cancellation Problems**
- **Lower Losses**

Multi Pulse Series



- **Equal Currents**
- **Forced Cancellation**
- **Higher Losses**
- **2:1 Transformer**

  w/phase shift

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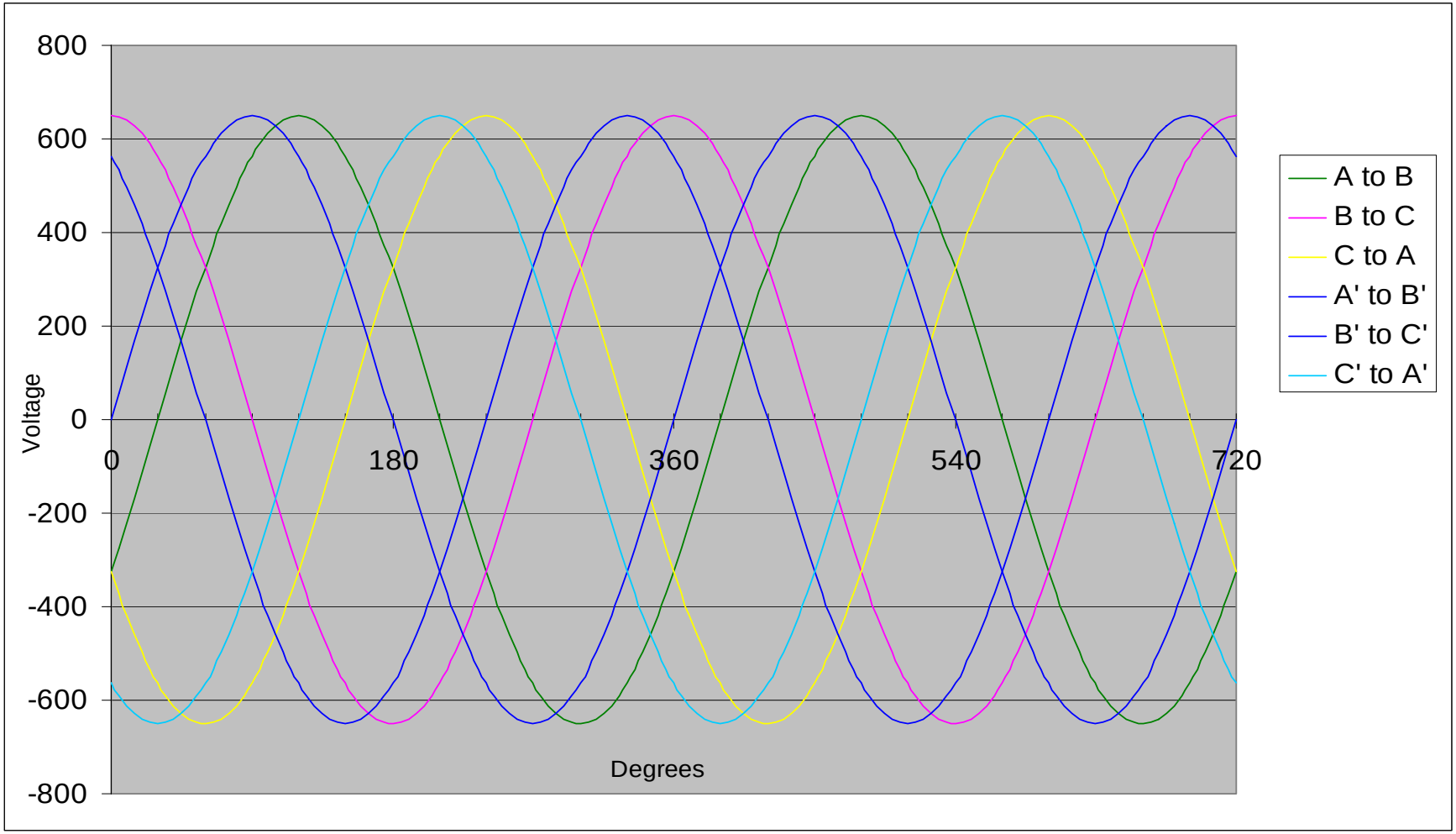
12 Pulse AC



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Multi Pulse Timing

• 1 phase	2 Pulse	120 Hz	8.3 msec
• 3 phase	6 Pulse	360 Hz	2.7 msec
• 3 phase + 30 º	12 Pulse	720 Hz	1.4 msec
• 3 phase +/- 20º	18 Pulse	1080 Hz	0.9 msec

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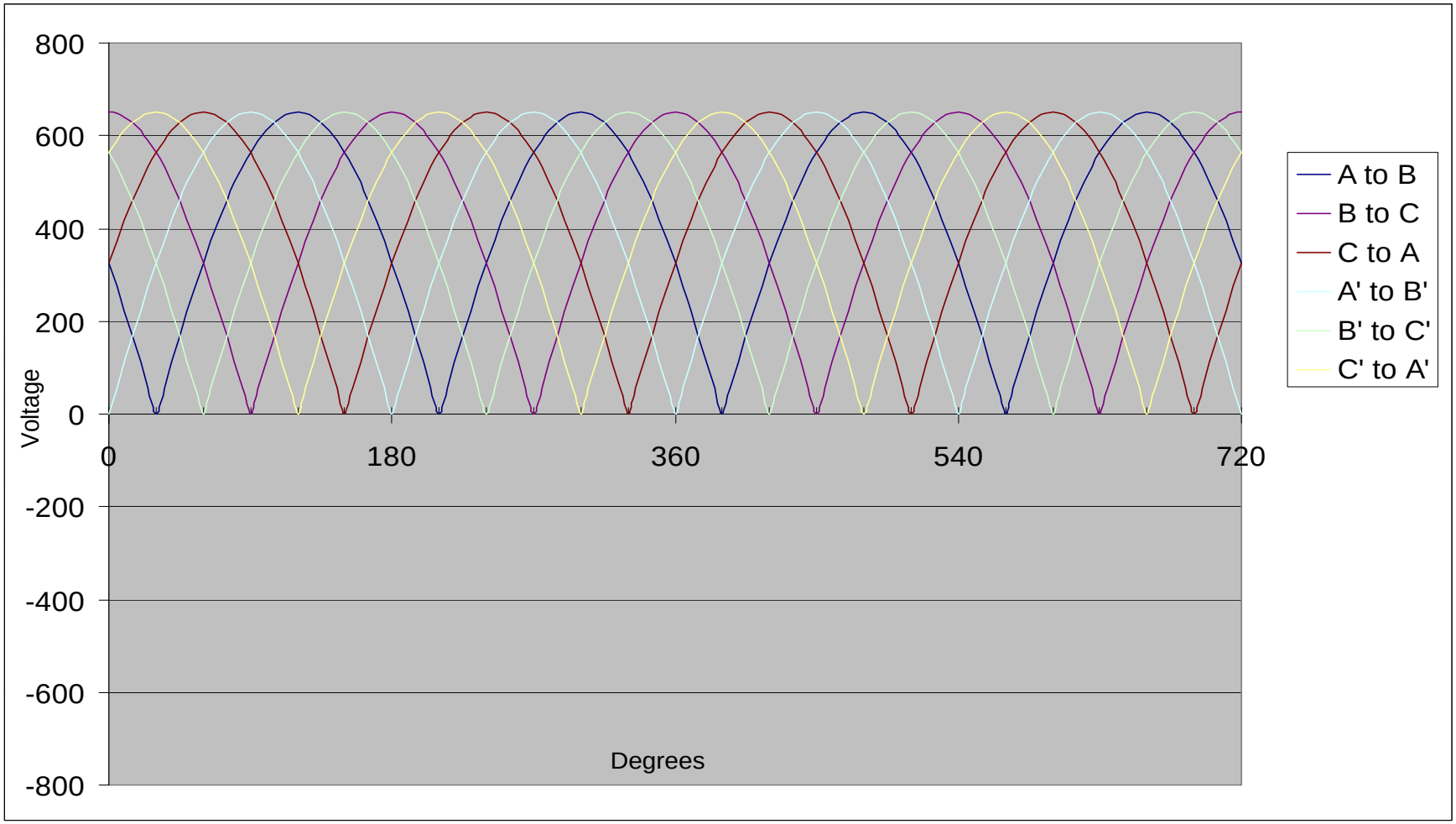
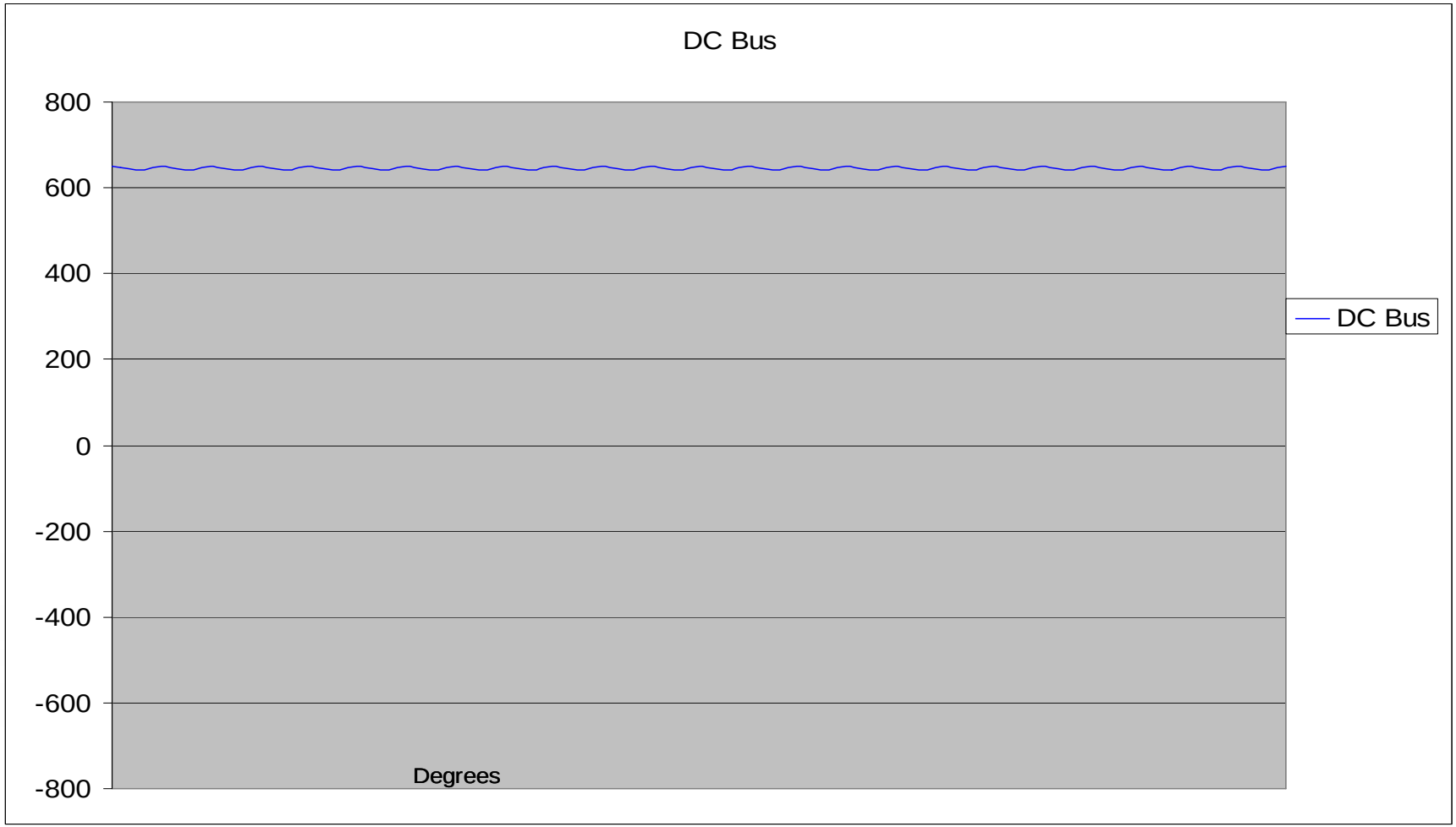
12 Pulse Rectified



12 Pulse DC



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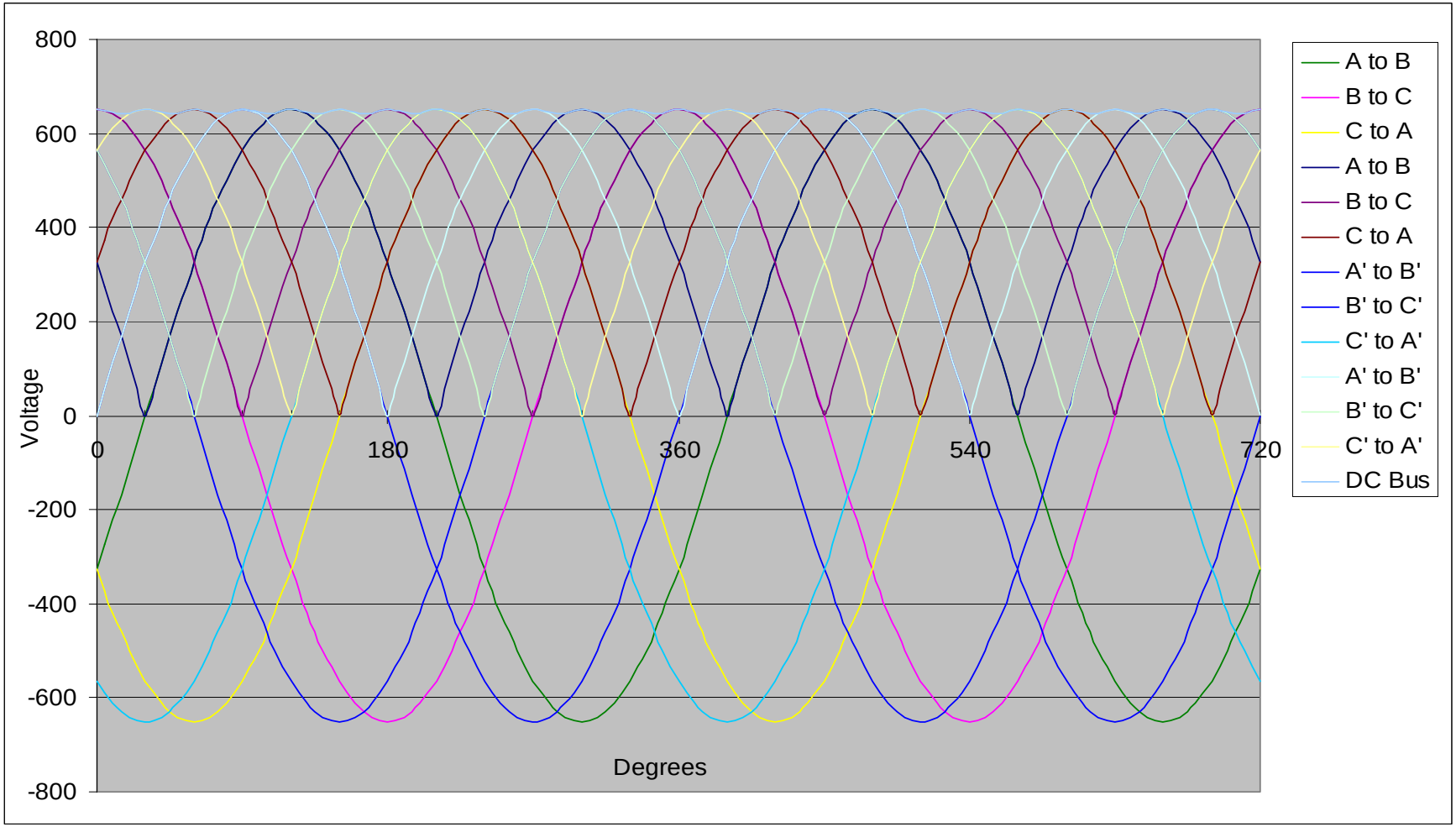
12 Pulse AC, Rectified, DC



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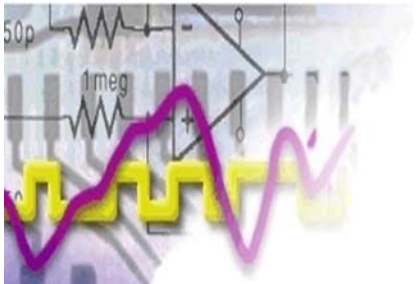
Increasing Pulses

- **Decrease in Current Amplitude**
- **Increased Cap refresh rate**
- **Harmonic Cancellation**



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Harmonic Solutions

What

- **Active IGBT Input Bridge**

Advantage

- **+/- 20% DC bus Regulation Typical**

•Disadvantage

- **Electronic Cost and Heat Losses**
- **Requires Inductance 8 – 12%**

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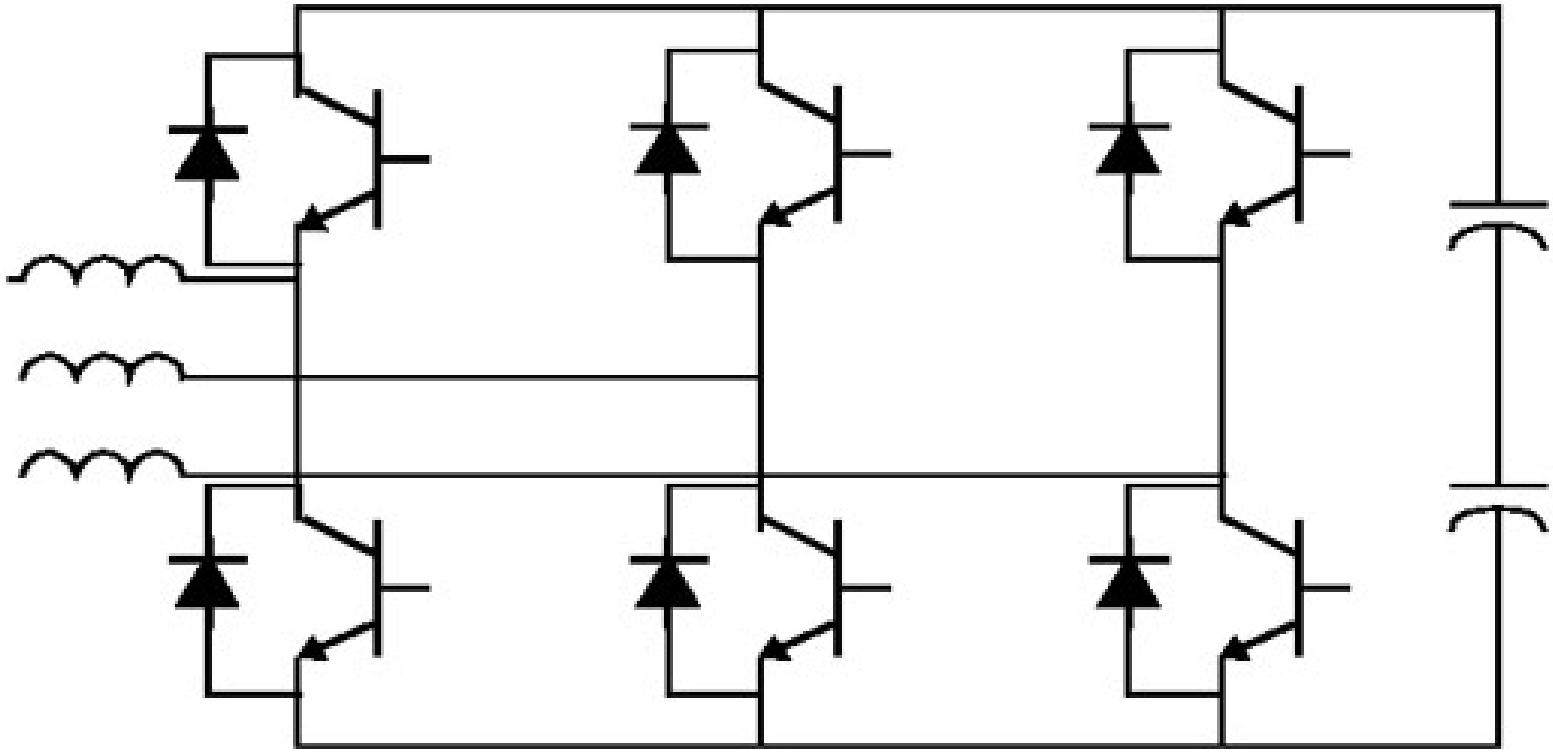
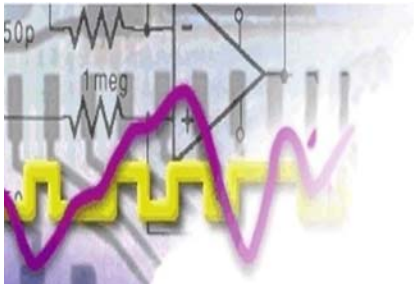
Drive Schematic - Active



PWM gating to achieve Sinusoidal Current



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PWM Waveform

- **Requires Additional Impedance**
- **Requires Carrier Frequency Filter**

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Sag Solutions

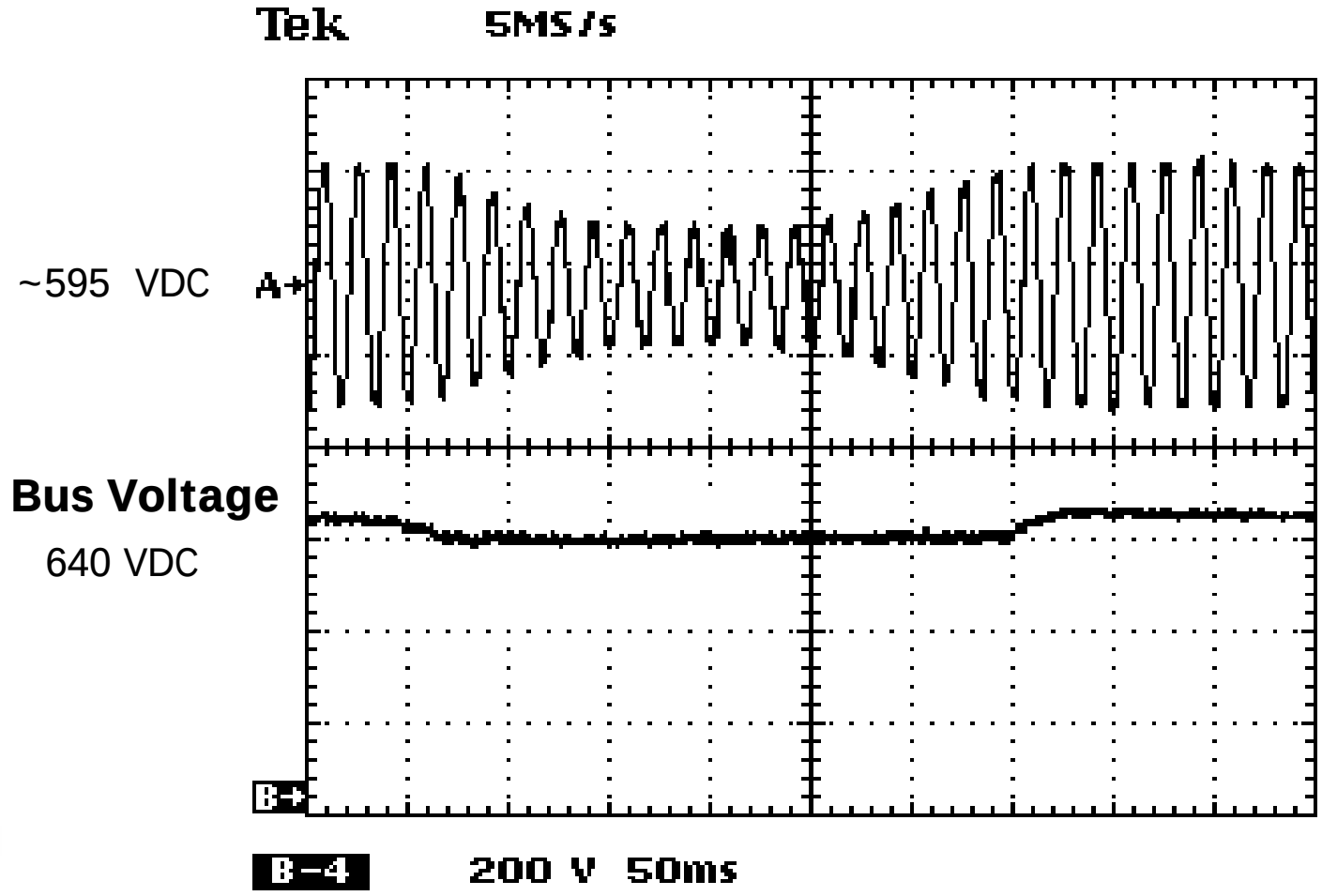
When

- Low voltage for more than a cycle

Solutions

- Increased Capacitance
- Boost Regulators
- Active IGBT Front End

Sag Event Example



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Power Ride Through Options

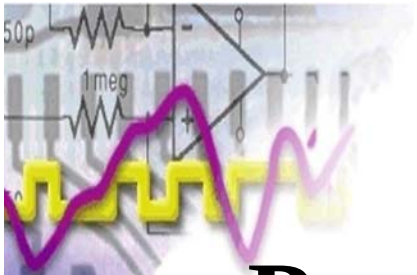
Unregulated Speed/Toque

Shut Down with Auto Restart

- Loss of Process Control
- May fail on successive Retries

Kinetic Buffering

- Requires specific Drive Firmware
- Speed is decreased on Power Dip sense
- Motor becomes a Generator to the Drive
- Inertia of Motor System is used to Hold up Drive Bus
- Does not work well with frictional loads



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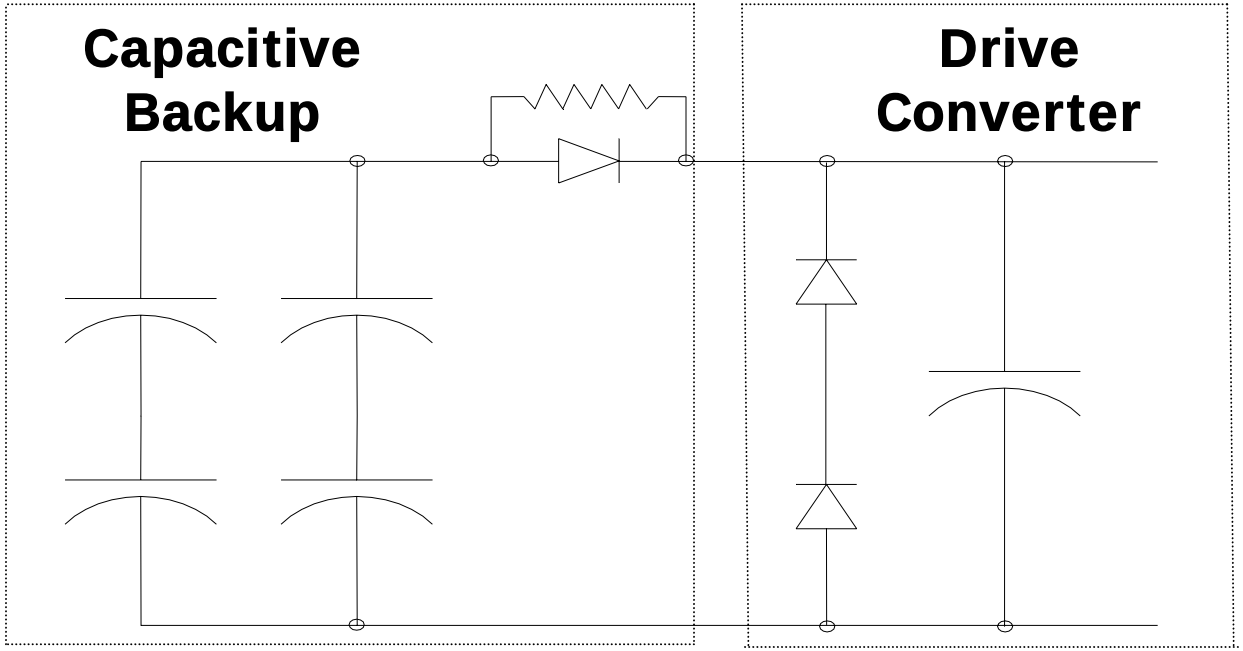
Power Ride Through Options

Regulated Speed/Toque

- Capacitance Backup
- Chopper Boost Regulator
- Chopper Boost Regulator with Capacitors
- Active Front End

Capacitive/Battery Ride Through



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Capacitive Energy Storage

$$J = \frac{1}{2} C V^2$$

$$J = \frac{1}{2} C (V_1 - V_2)^2$$

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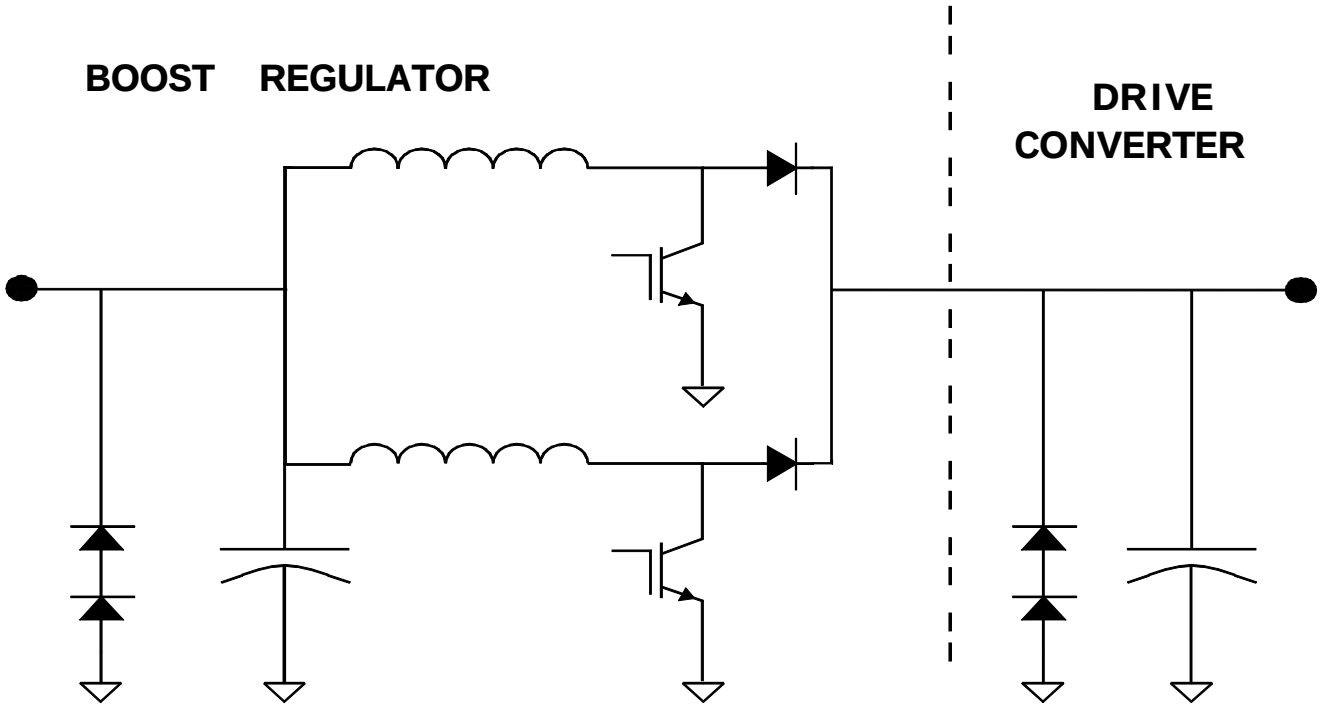
Boost Chopper



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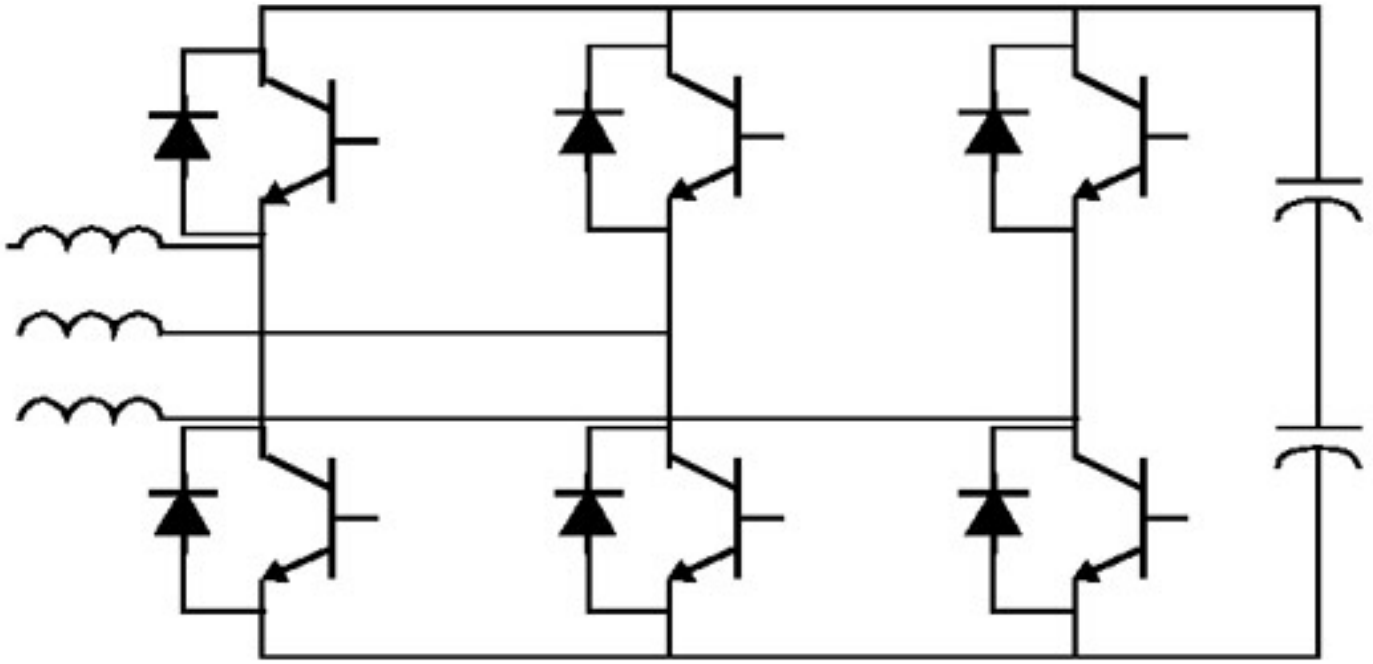
Drive Schematic - Active



PWM gating to achieve Sinusoidal Current

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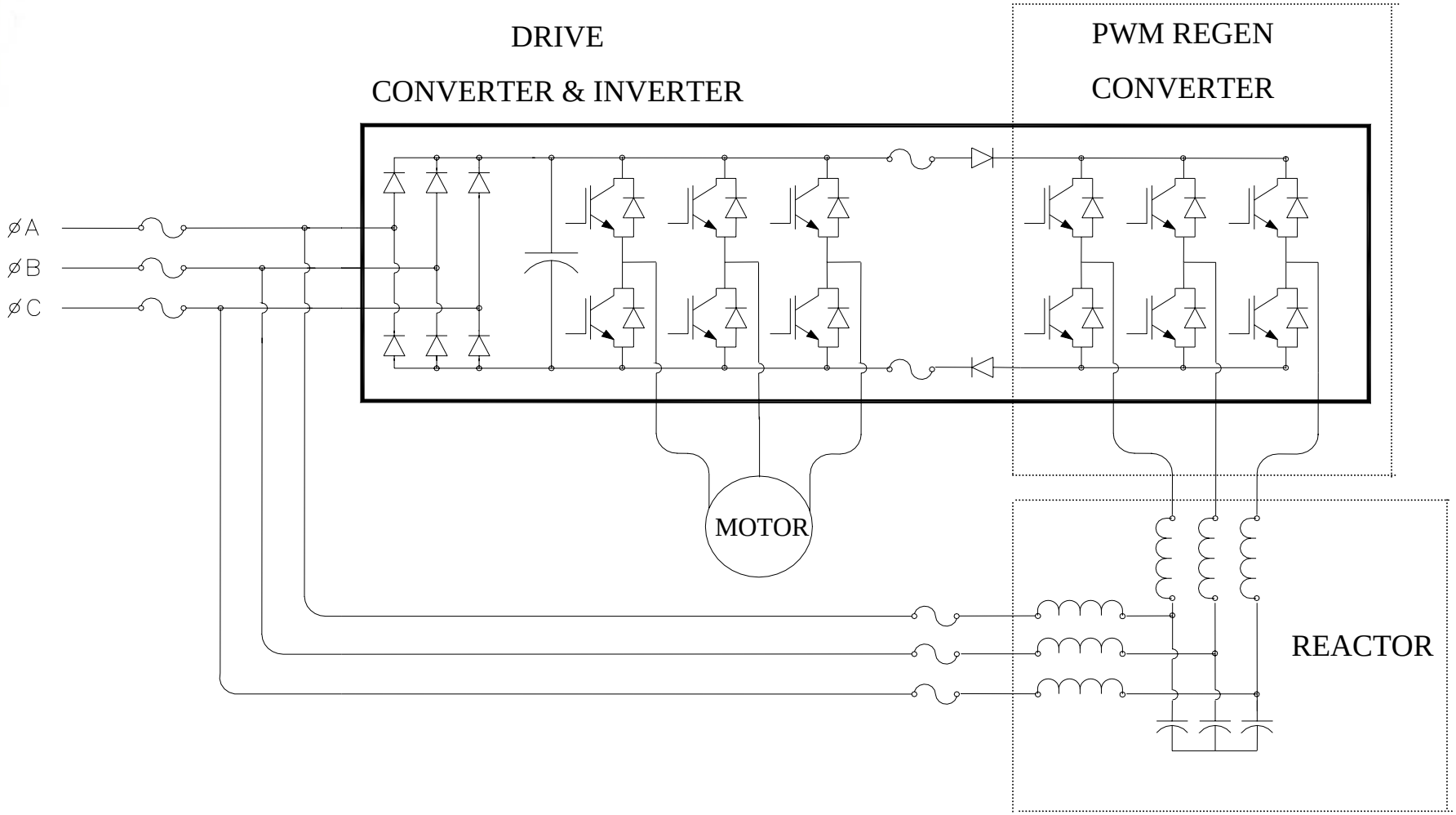
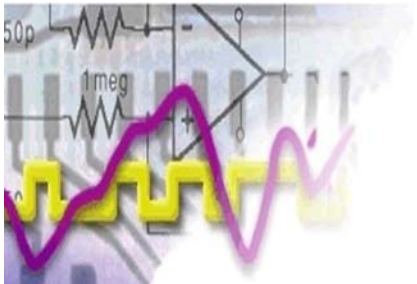
PWM Regen





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Resources

- **www.drivesmag.com**
- **www.epri-peac.com**
- **www.bonitron.com**

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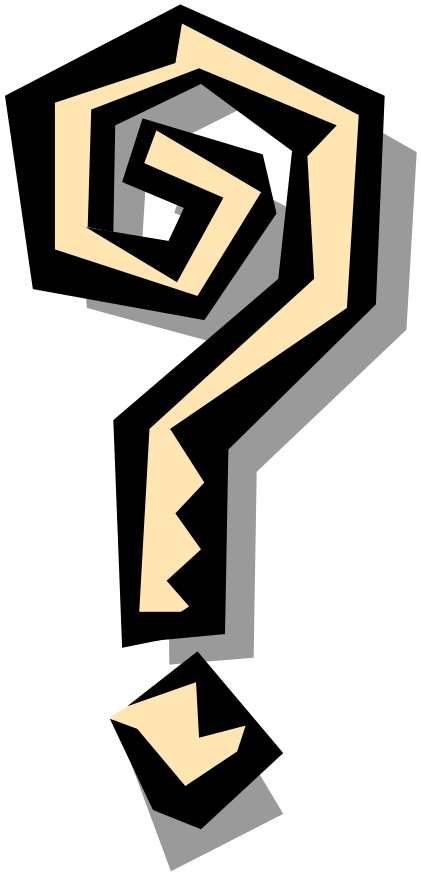

QUESTIONS