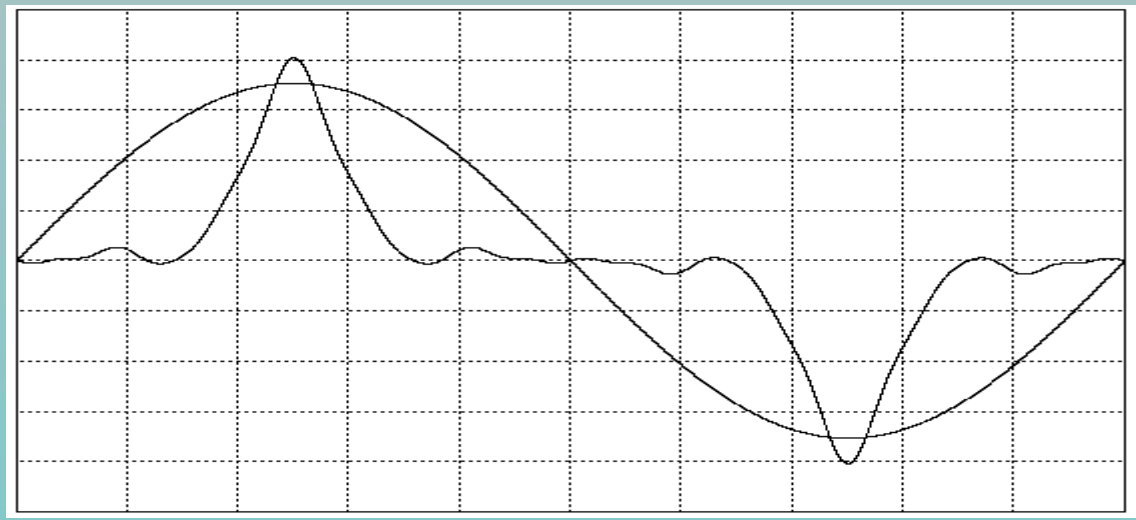
Trends in Active Power Filters



Dr. Mohamed Darwish
Brunel University

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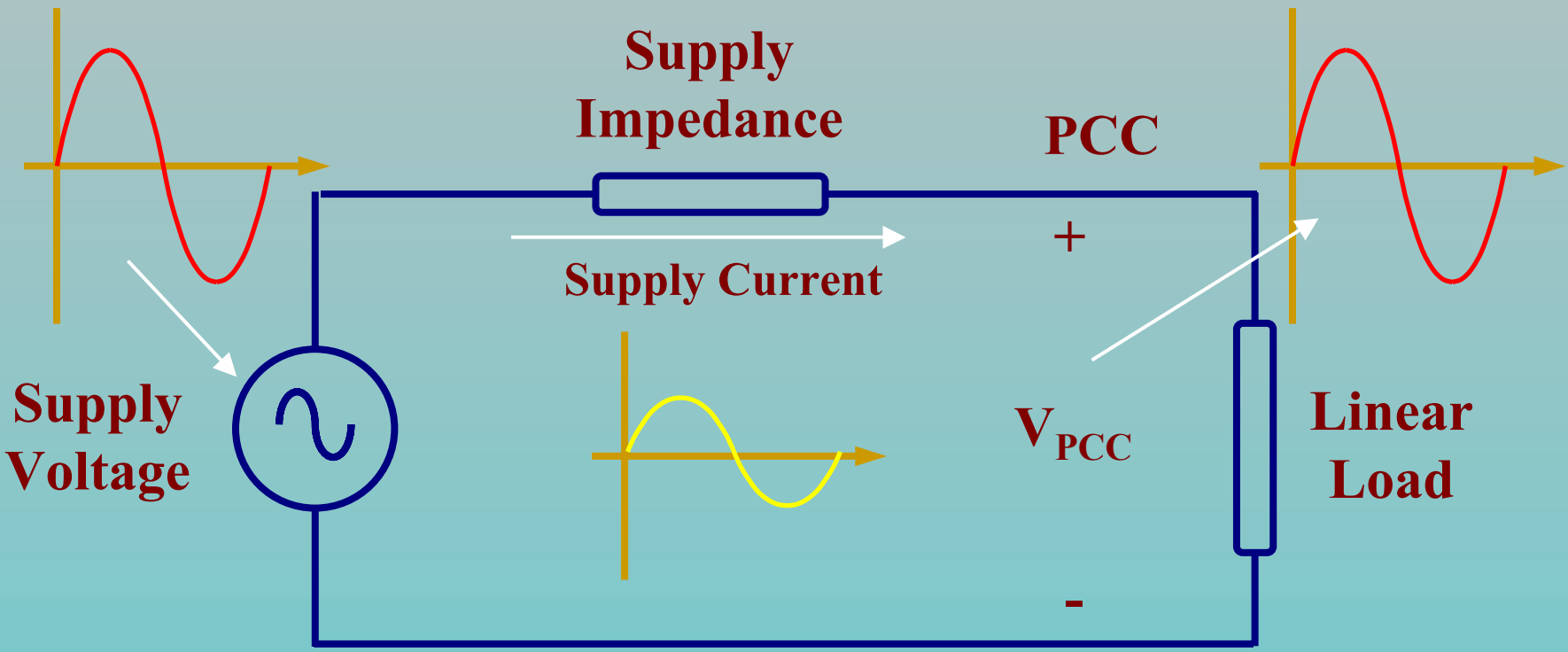
Normal Operating Conditions



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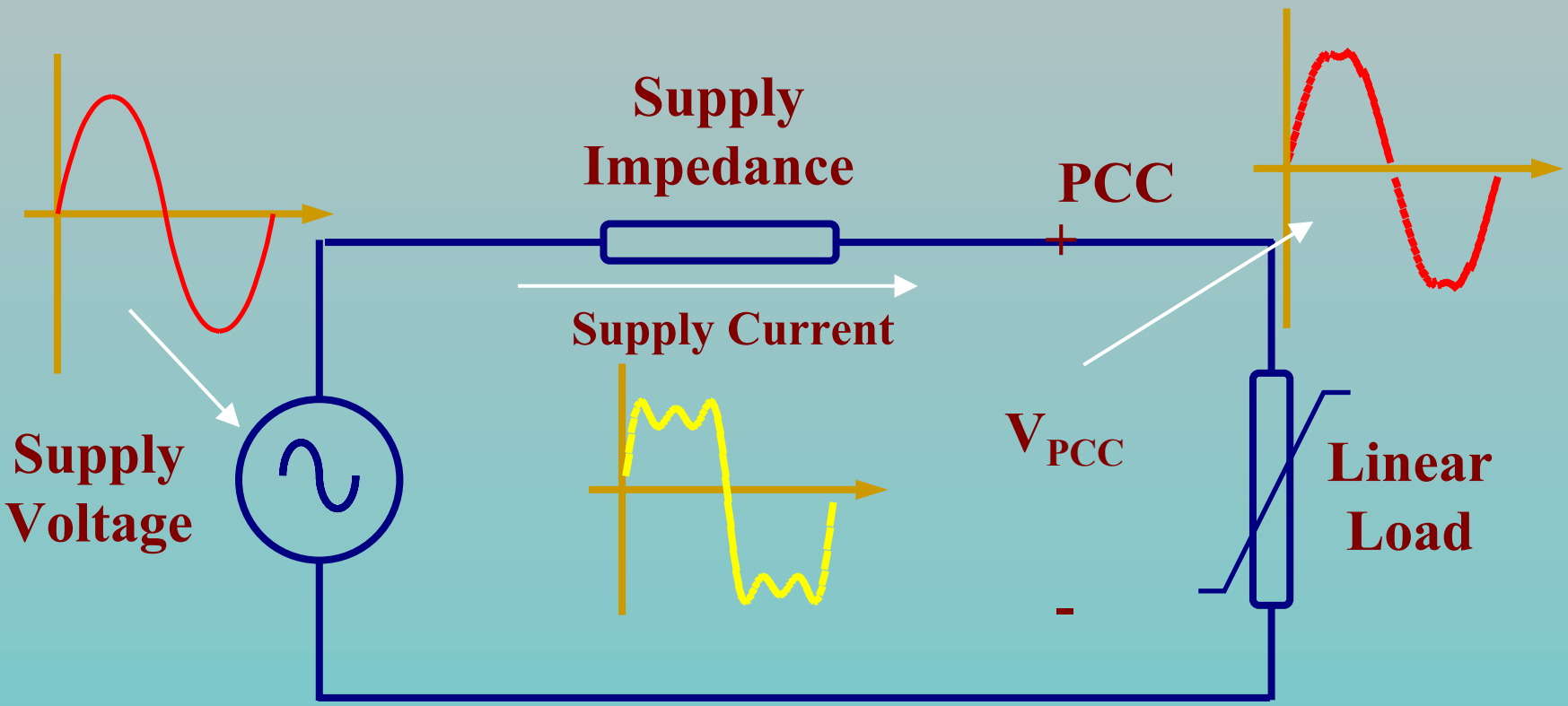
Non-linear Operating Conditions



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Source of Power System Harmonics

- Large Sources
  - Arc-furnaces
  - Megawatts sized adjustable-speed-drive (ASD) systems
  - Static converters
  - Transformer magnetisation non-linearities
- Small sources
  - TV sets
  - Computer equipments
  - Fluorescent and other discharge lighting

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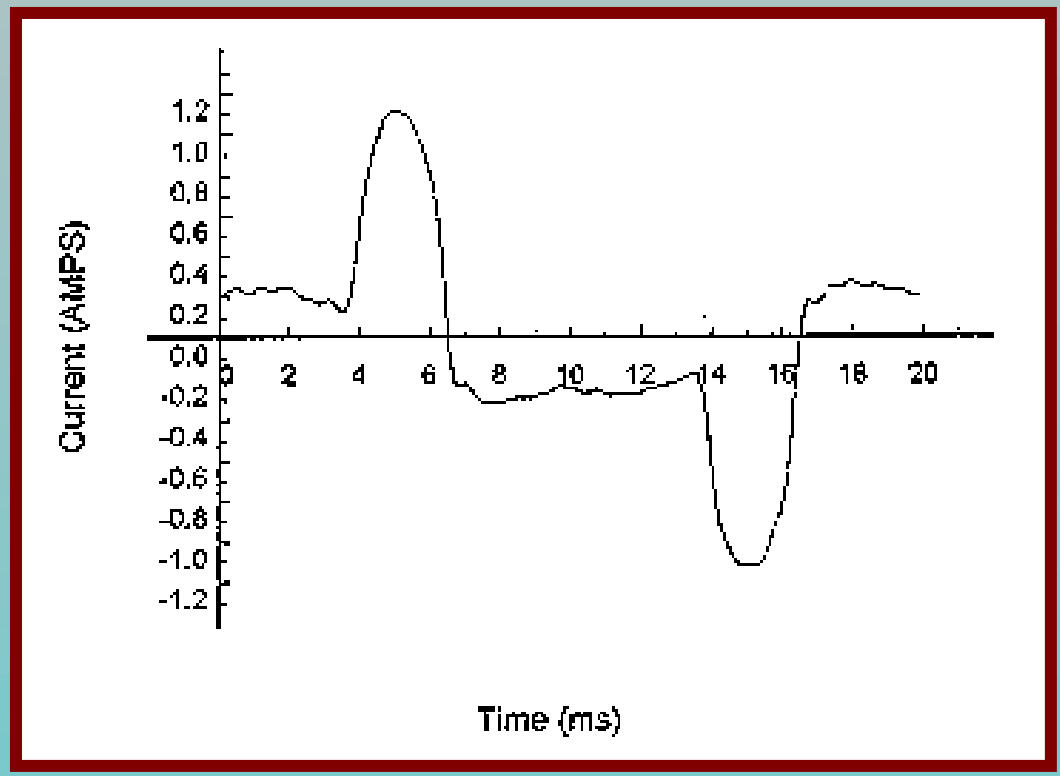
A Typical Computer Load Current



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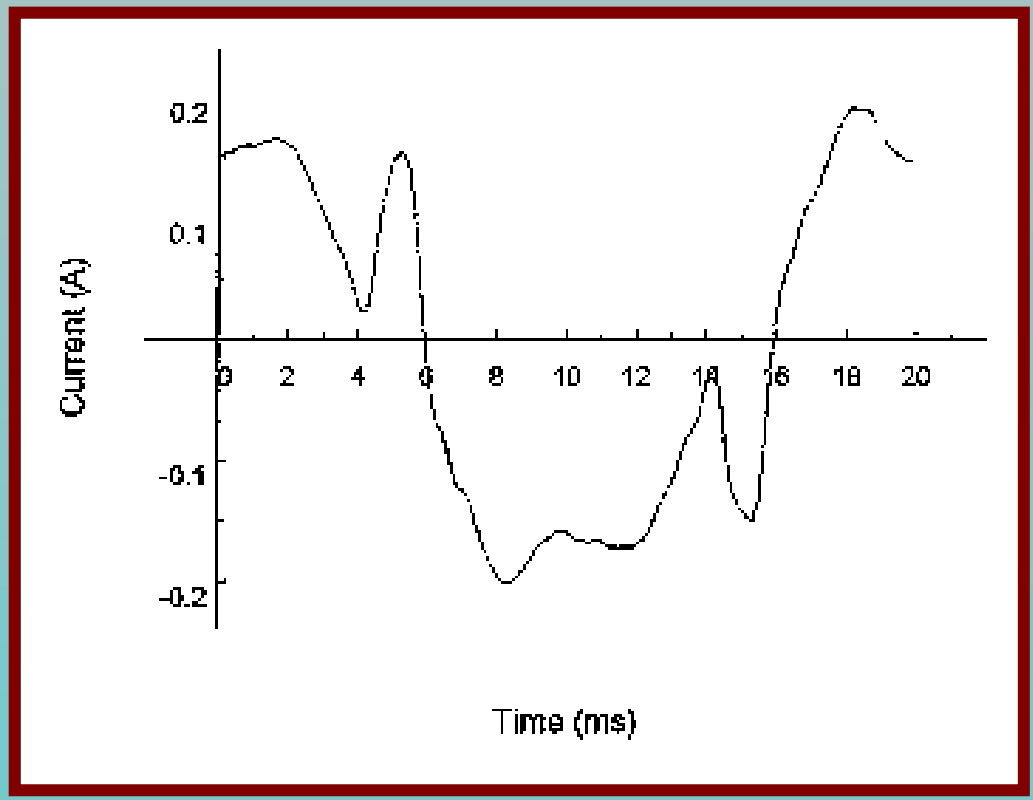
A Typical Computer Load Current in Sleep Mode



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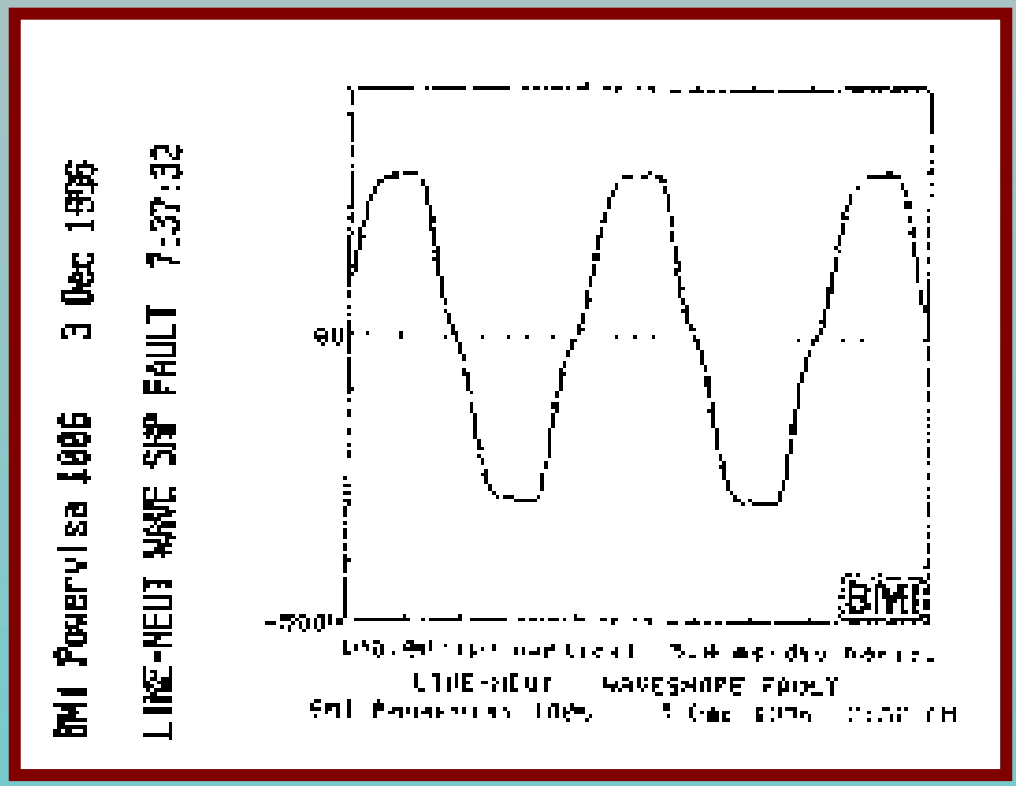
Voltage Harmonics in Residential Areas



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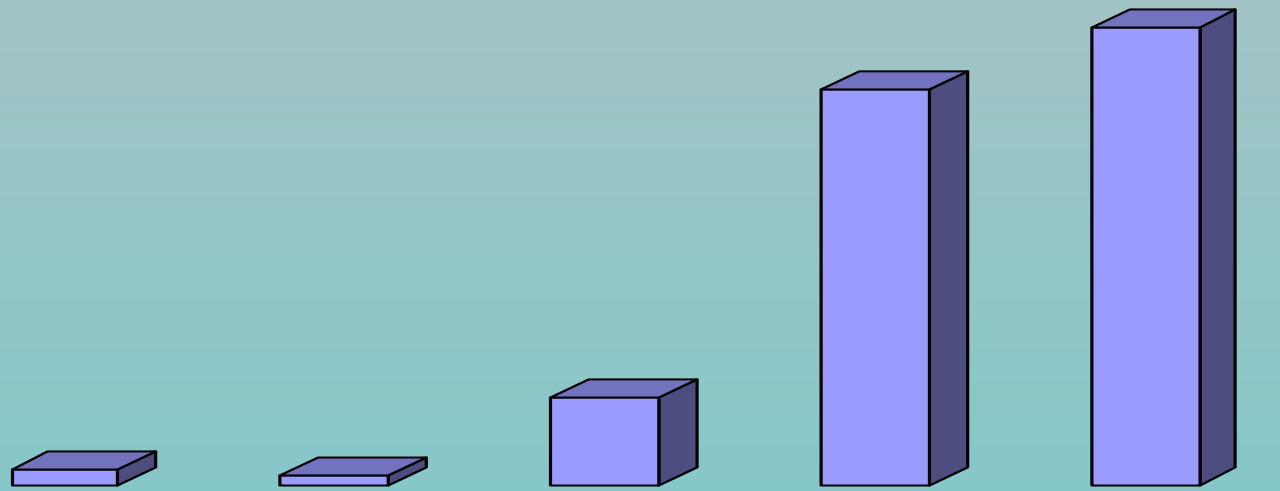
Example of total harmonic distortion caused by a typical residential home



Washer Dryer	Fridge/ Freezer	Microwave	T.V.	Personal Computer
26%	14%	27%	121%	140%

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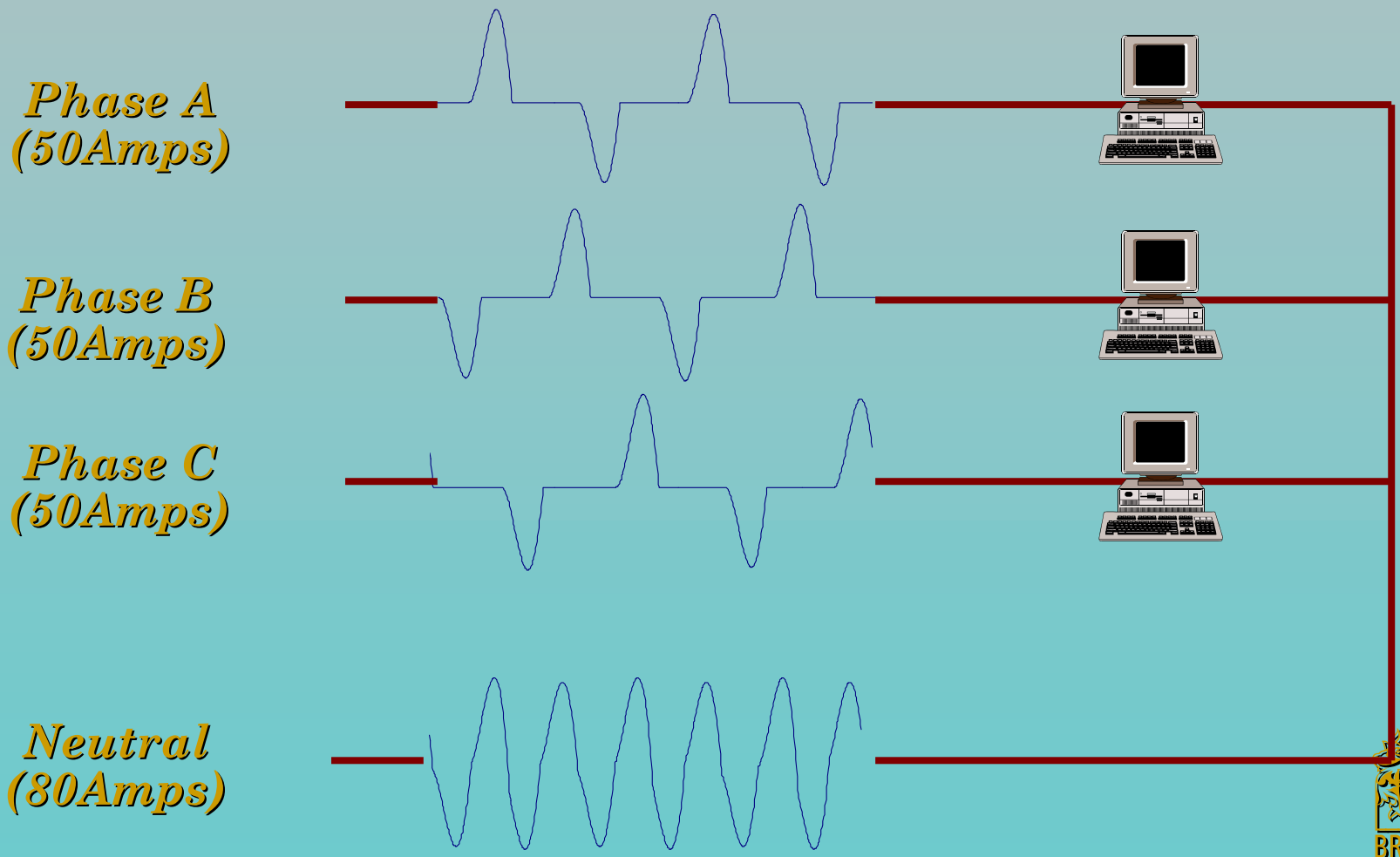
A Typical Harmonic Problem



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Effect of Harmonics

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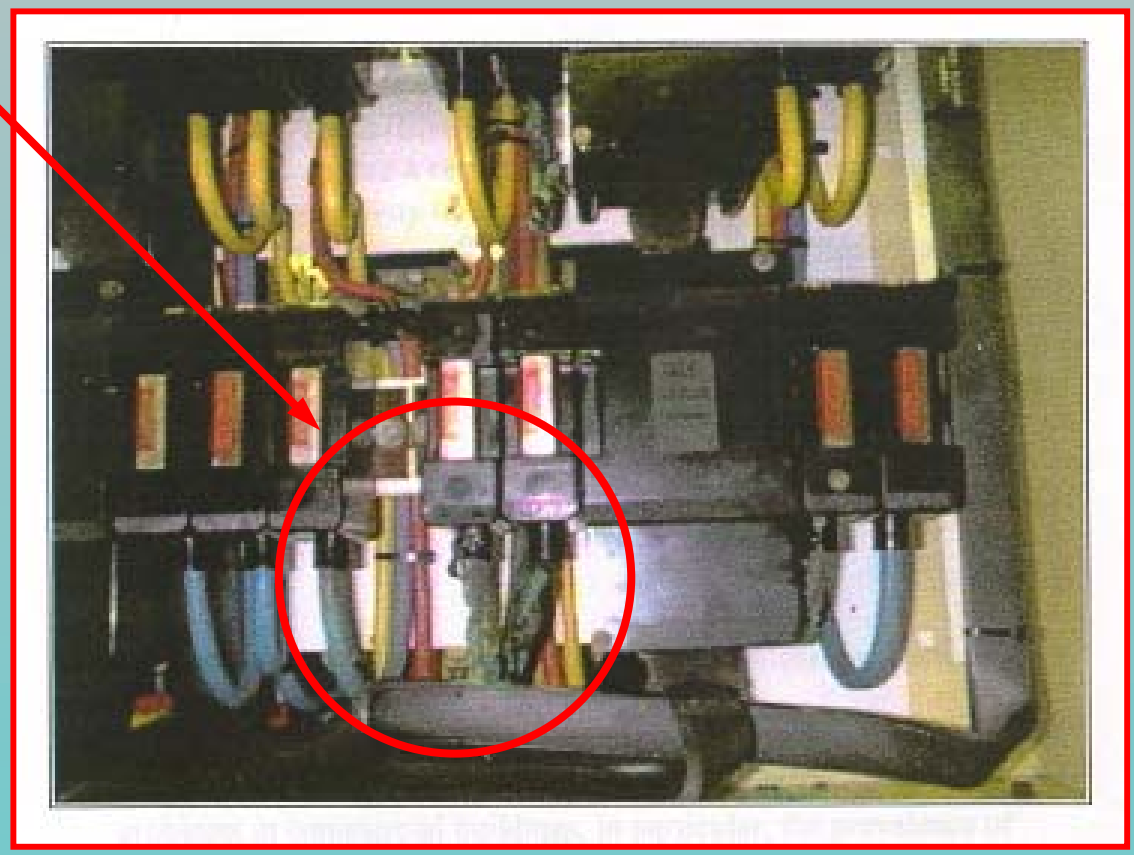
Effect of Harmonics



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How to Eliminate Harmonics

- **Preventing harmonic generation for newer systems**
  - —*High input power factor regulators*
  - —*Switching regulators*
  - —*High pulse number AC/DC converters*
- **For existing sources of harmonics**
  - – *Installing filters on DC side of rectifier*
  - – *Installing filters on AC side*

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Need for Filters

- Eliminate / Reduce harmonics in voltage & current waveforms.
- Improve power factor.
- Reduce harmonic power losses.
- Combinations of the above.

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Available Filter Configurations

Shunt configuration

- *Provides a low impedance path to ground*
- *Does not necessitate a series filter*

Series configuration

- *Provides a high series impedance path*
- *Must work in conjunction with a shunt filter*

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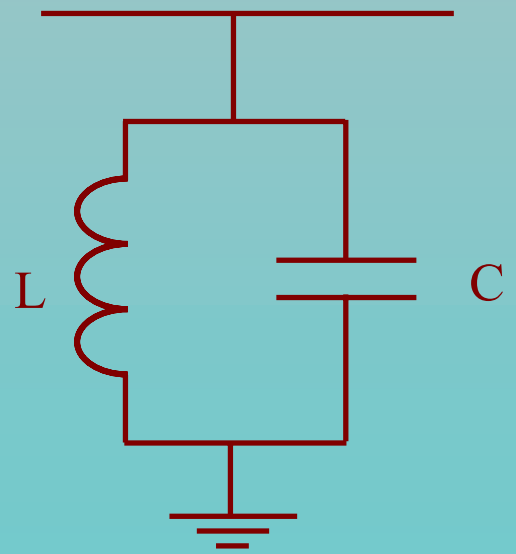
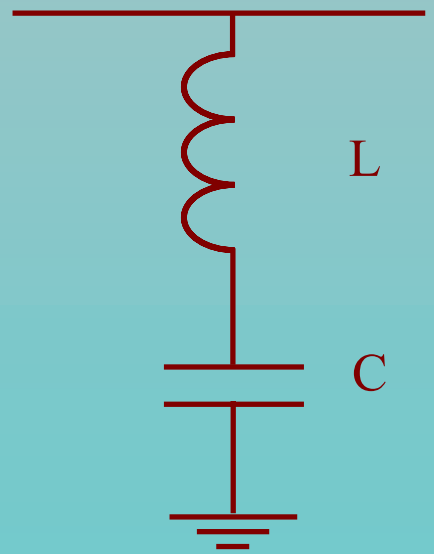
Passive Filters

- Use L - C tuned components
- Tuned for the undesired harmonics





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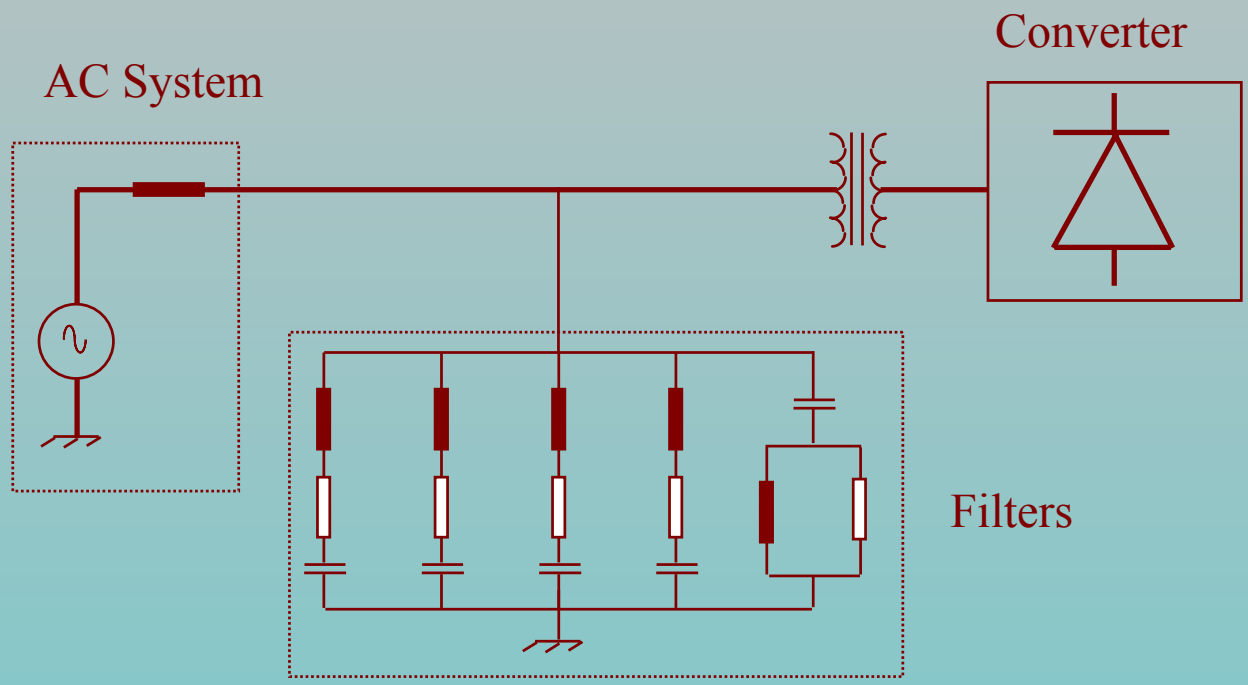
Passive Filters



- Uncharacteristic Harmonics
- Higher Cost
- Bulky
- Depend on System impedance
- Reliable

Advantages of Passive Filters

- **Reliable operation**
- **Easy design procedure**
- **Act as reactive power compensators**
- **Cheap configurations per harmonic**

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Disadvantages of Passive Filters

- **Large number of components**
- **Bulky**
- **Depend on system impedance**
- **Tuned for a certain loading condition**
- **Parallel and series resonance may occur for certain harmonics**
- **Affected by capacitor ageing**

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Active Filters

- *Use active switching components*
- *Only one filter needed to eliminate all the unwanted harmonics*
- *Used for power factor correction*

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Classification of Active Filters

- *Active Filters attached to Large Single-Source Offenders*

- *Active Filters for 'Retrofit' Applications*

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Analogy Between Harmonic Pollution and Air Pollution Sources

SOURCES	HARMONIC POLLUTION	AIR POLLUTION
UNIDENTIFIED	• TV sets and PCs • Small electronic loads	• Gasoline-fuelled vehicles • Diesel powered vehicles
IDENTIFIED	• Bulk rectifiers • Cycloconverters • arc-furnaces	• Chemical Plants • Coal/oil steam power stations

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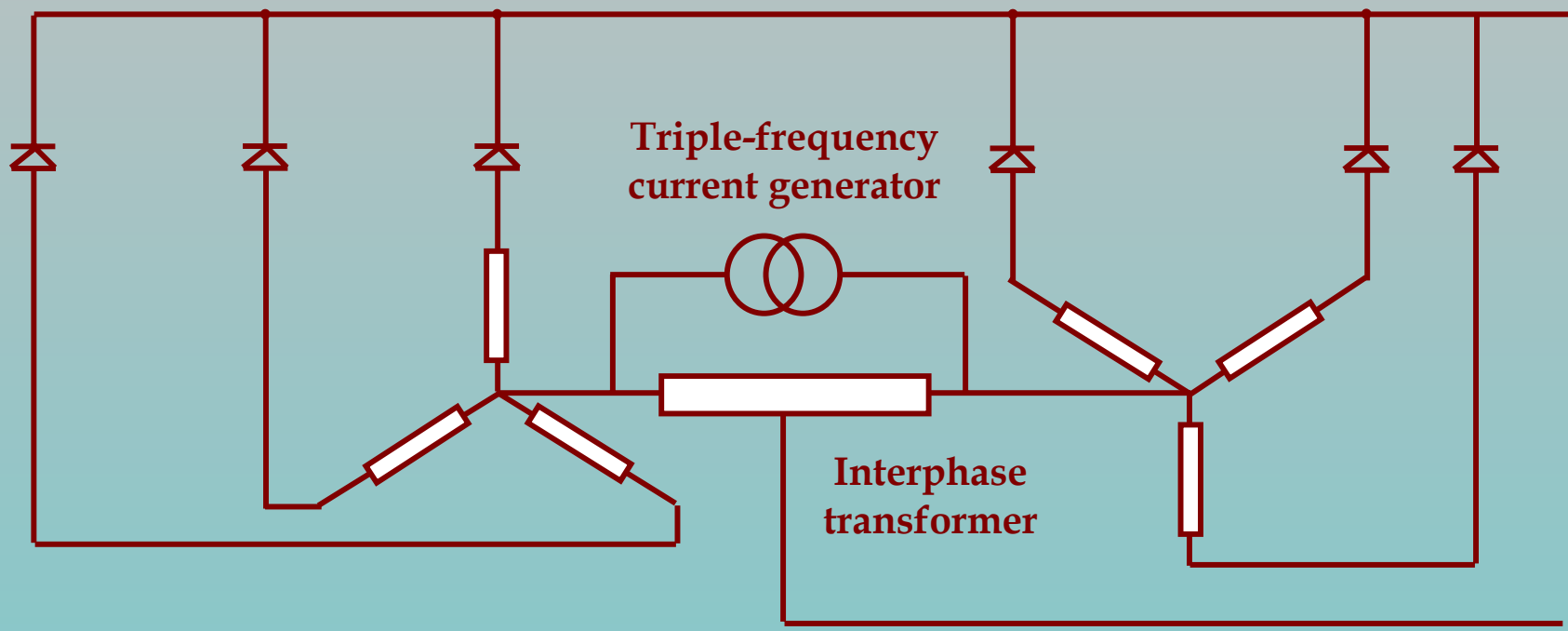

3rd Current Harmonic Injection Method

by Bird, Marsh, and Mclellan (1969)

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Active Filters for Retrofit Applications

- Active Filters based on voltage-fed inverters
- Active Filters based on current-fed inverter
- Variable Characteristics Filters

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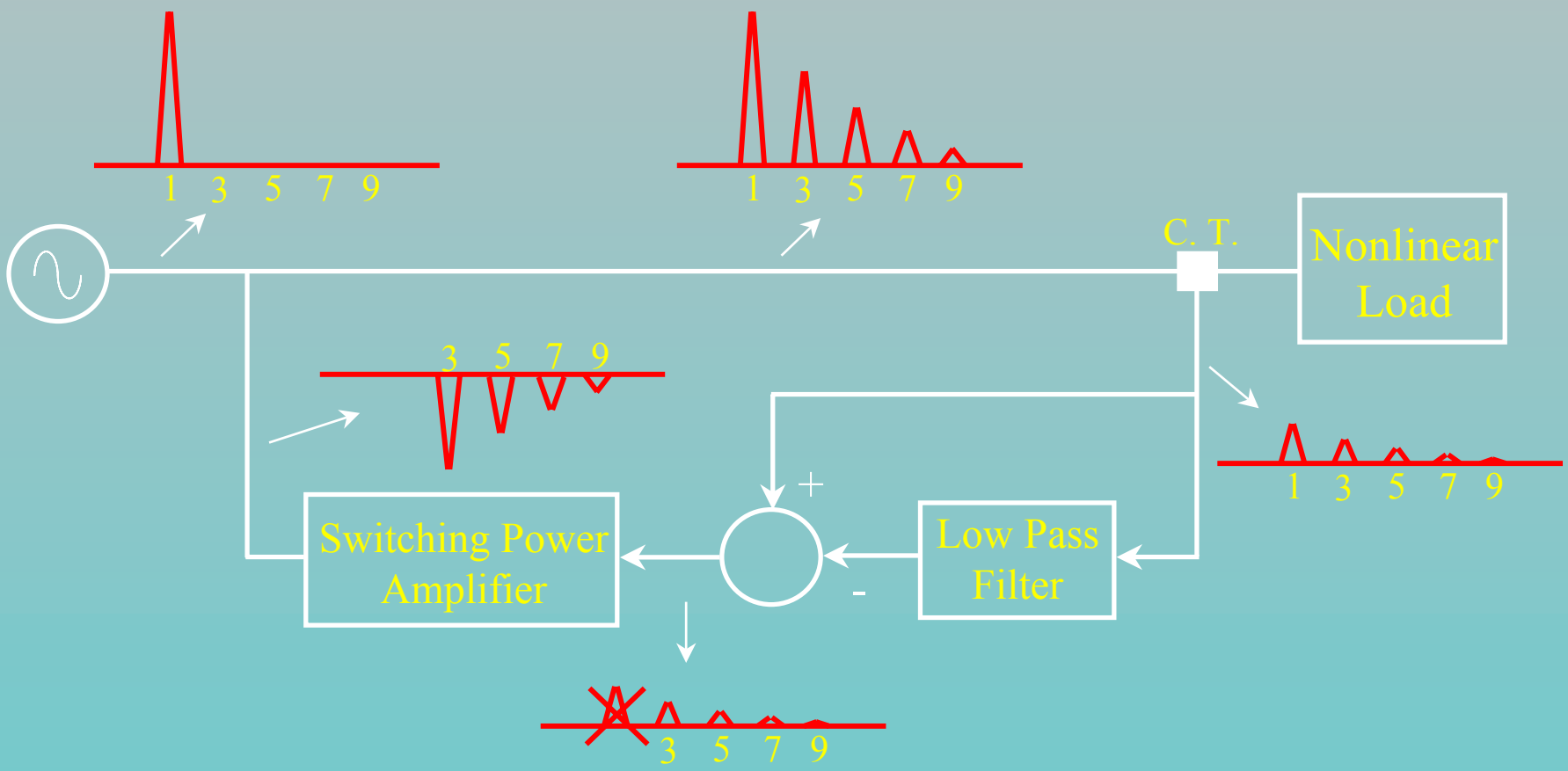
Basic Idea of Active Filters



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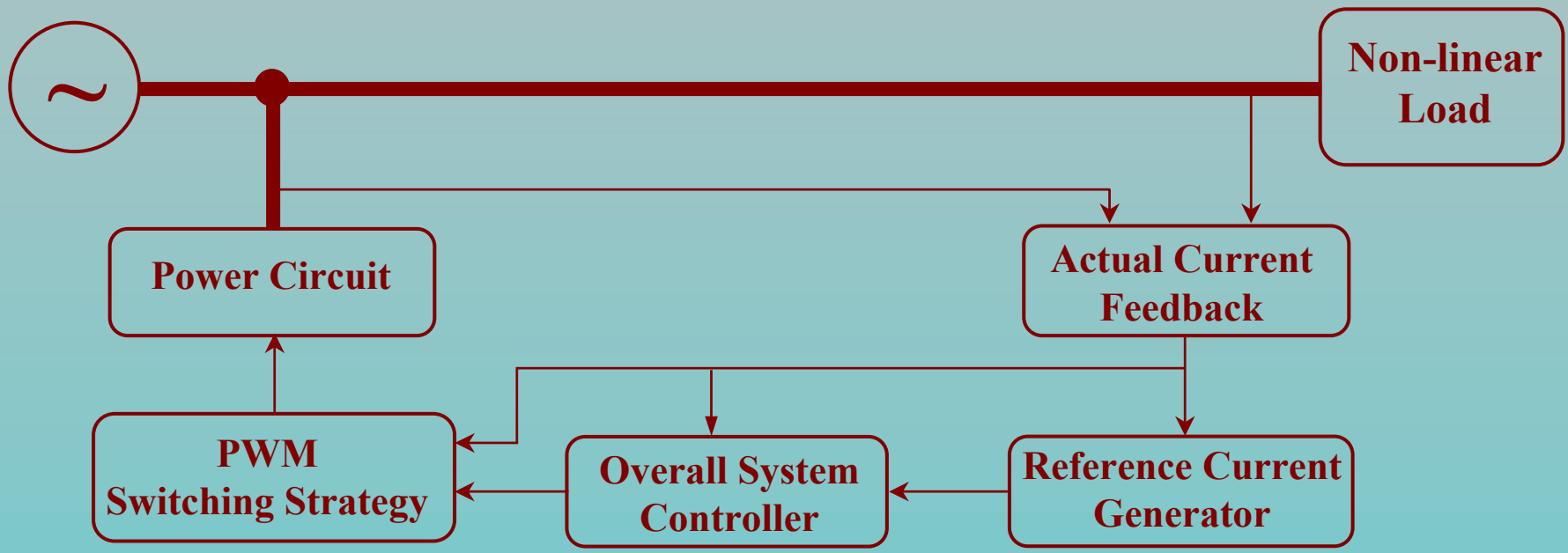
Typical Active Filter Circuit



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Active filters on Commercial Basis

Objective	Rating	Switching Devices	Applications
Harmonic compensation with or without reactive power compensation	below 100KVA	IGBT MOSFETS IGCT	Diode or thyristor rectifiers and cycloconverters for industry
Flicker compensation	100VA ~ 10 MVA	GTO IGBT	Arc furnaces
Voltage regulation	above 10MVA	GTO	Sinkansen (the Japanese “bullet” trains)

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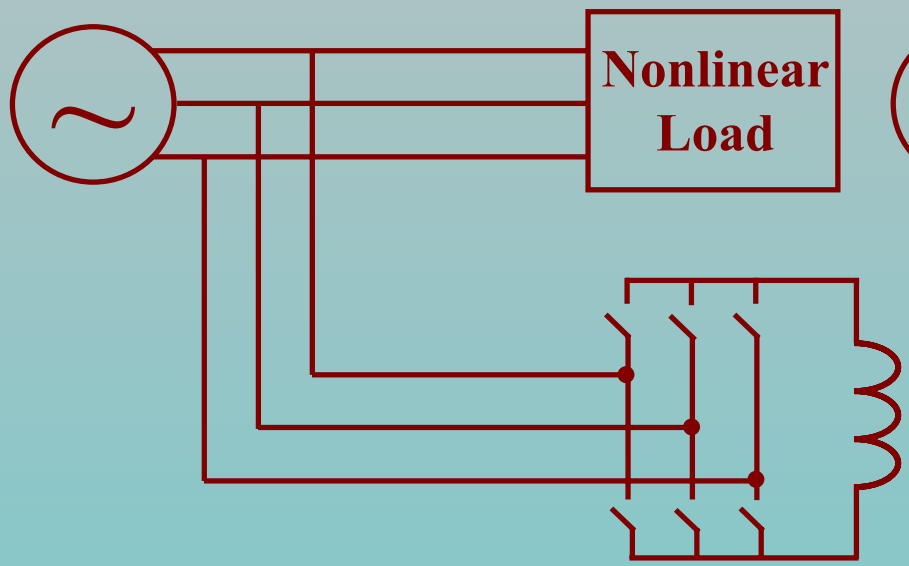
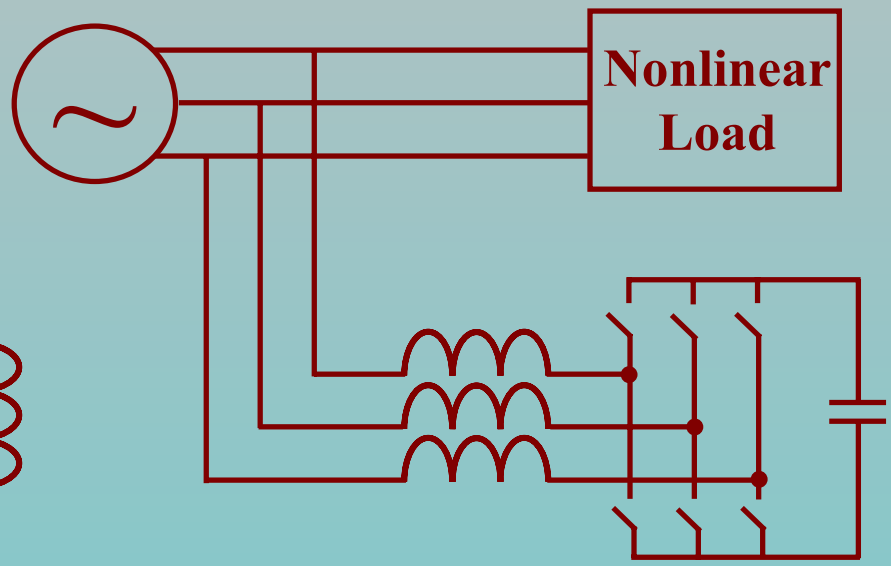
Inverter Configurations



Current-Fed Inverter Filter



Voltage-Fed Inverter Filter

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Disadvantages of Inverter Filters

- High tracking switching frequency particularly at zero crossing.
- Large reservoir capacitor (in voltage source inverters).
- Difficulties in keeping voltages constant on dc-link capacitor.

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New Configurations

- *Reactive Power Compensation.*
- *Switched-Capacitor SC side Filters.*
- *Variable Characteristics DC Filters*
- *Lattice Structure Filters*
- *Voltage Regulator Configuration*
- *Active/Passive Filter combinations.*
- *& Others . . .*

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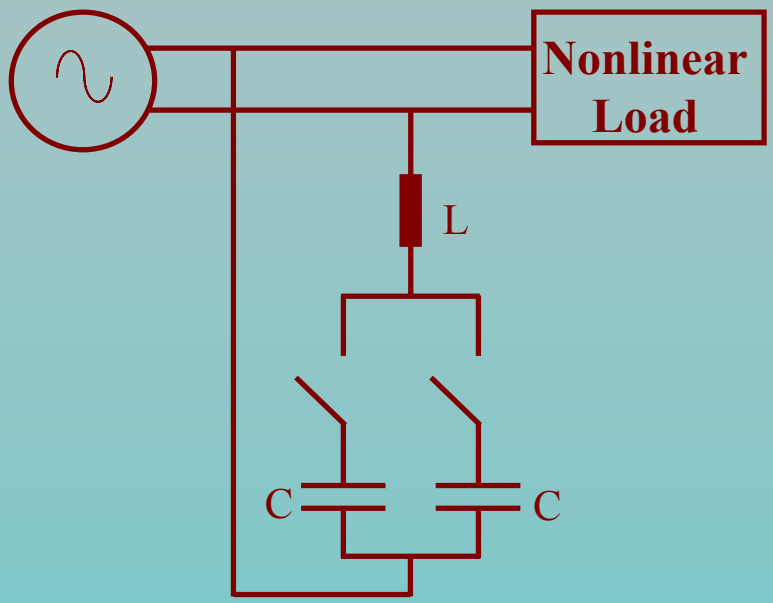
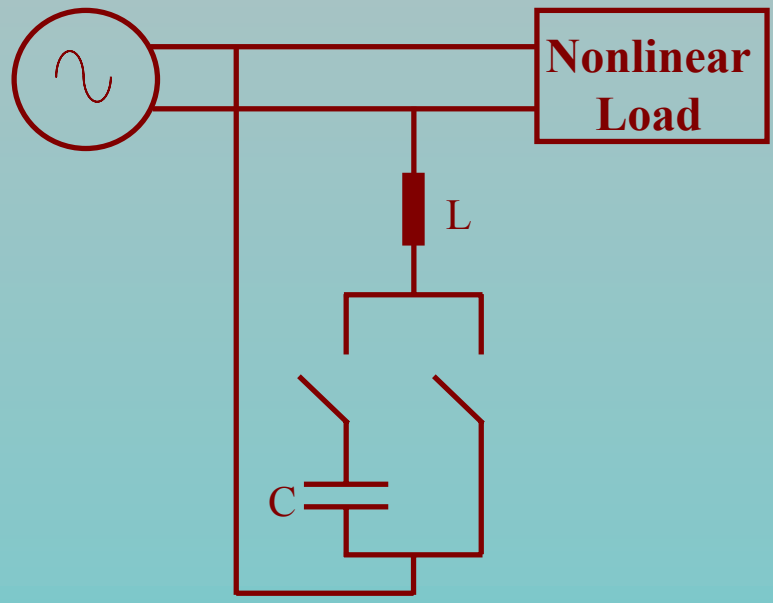
Switched-Capacitor Techniques





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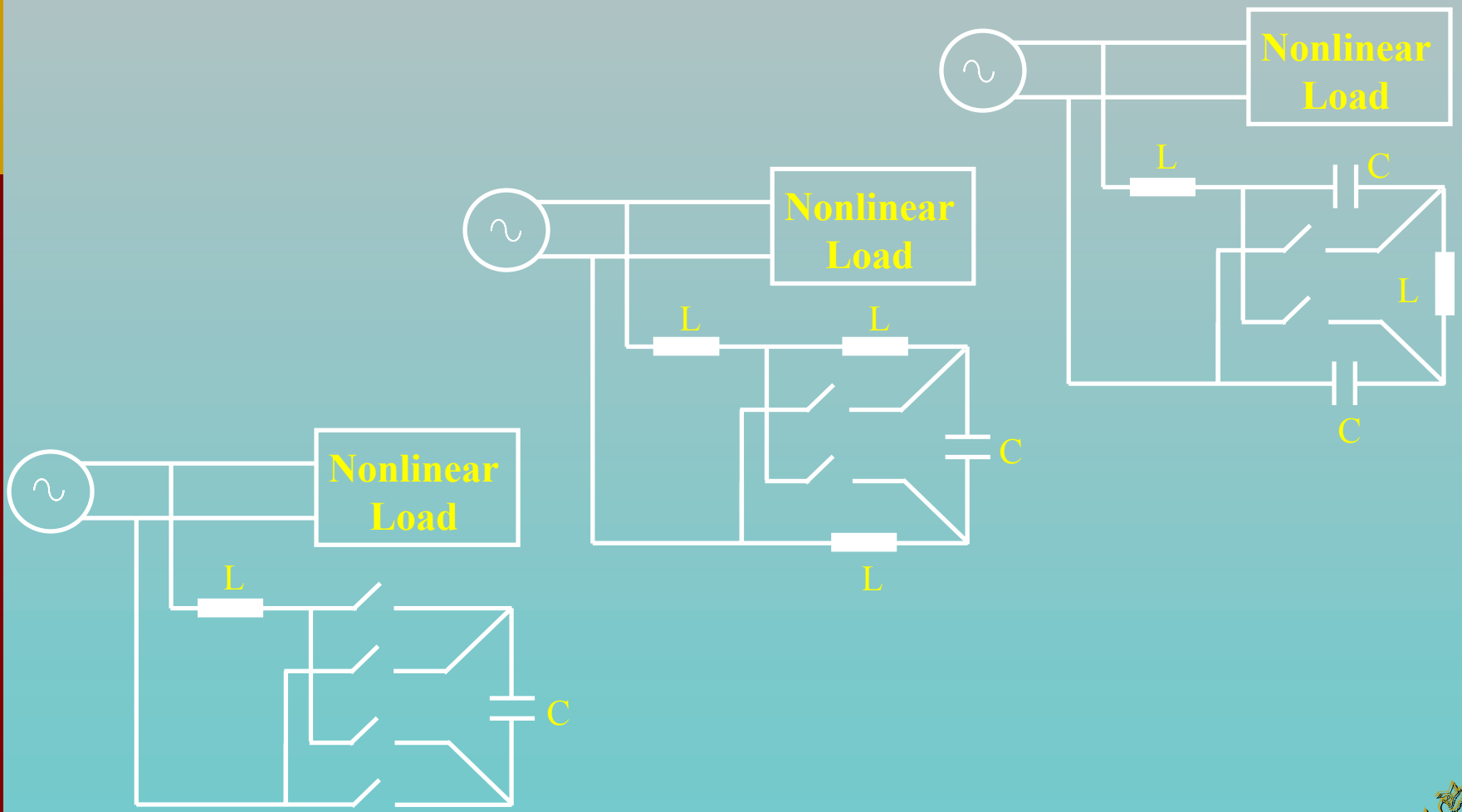
Lattice Structures



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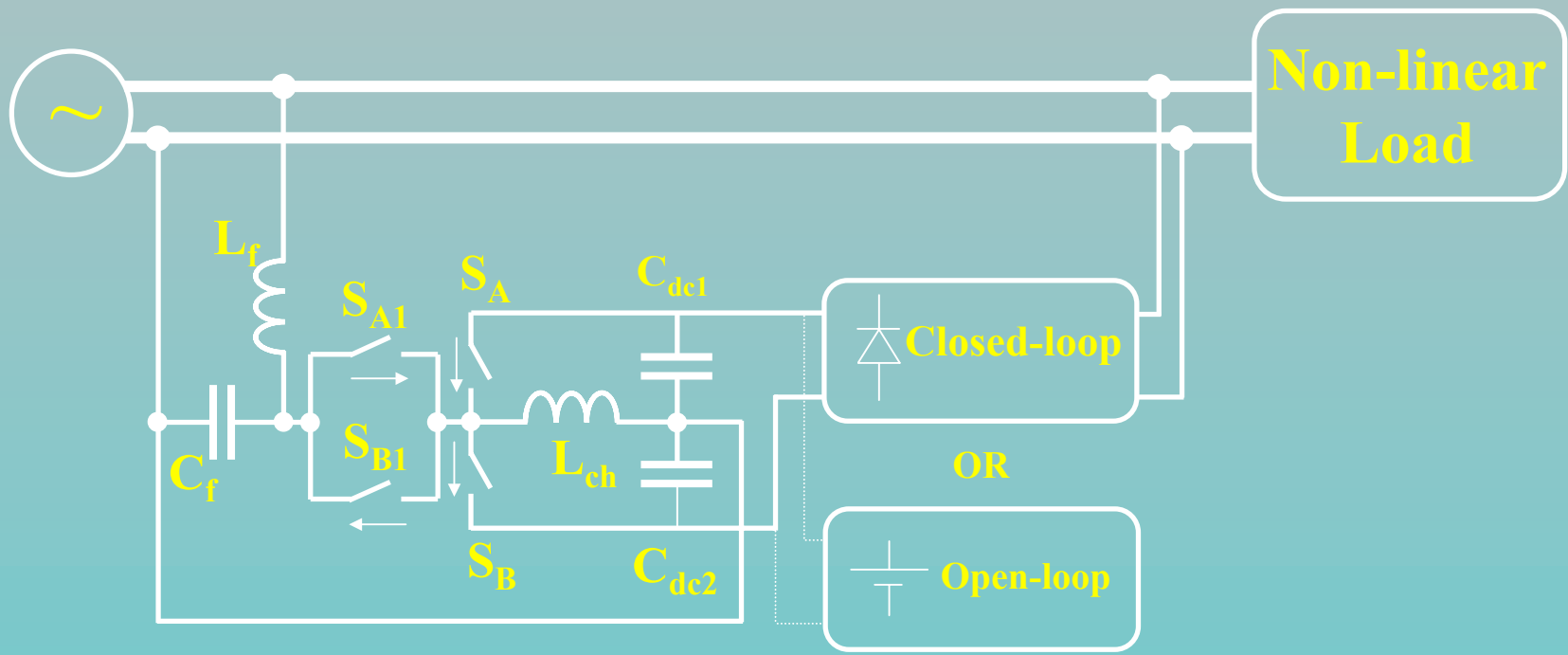
Voltage Regulator Filters



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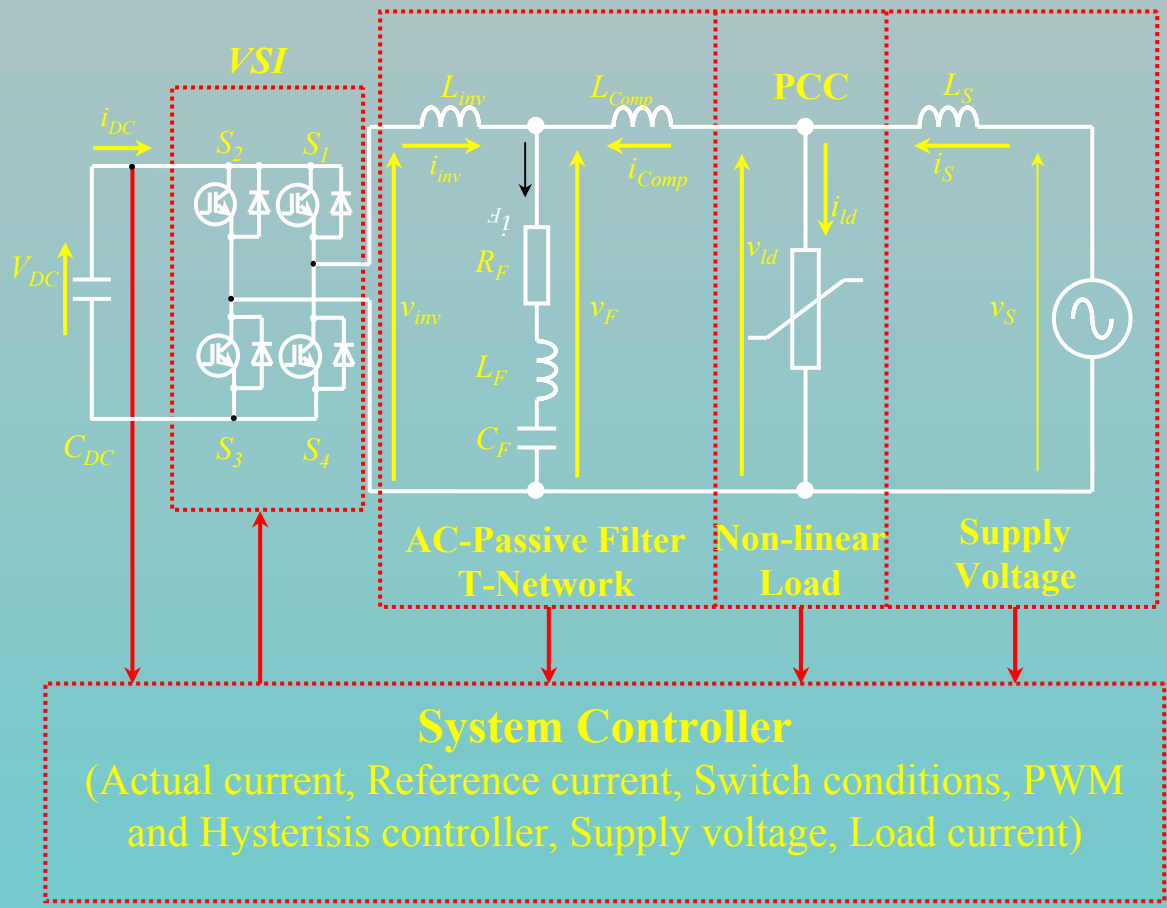
Passive / Active Filter Combination



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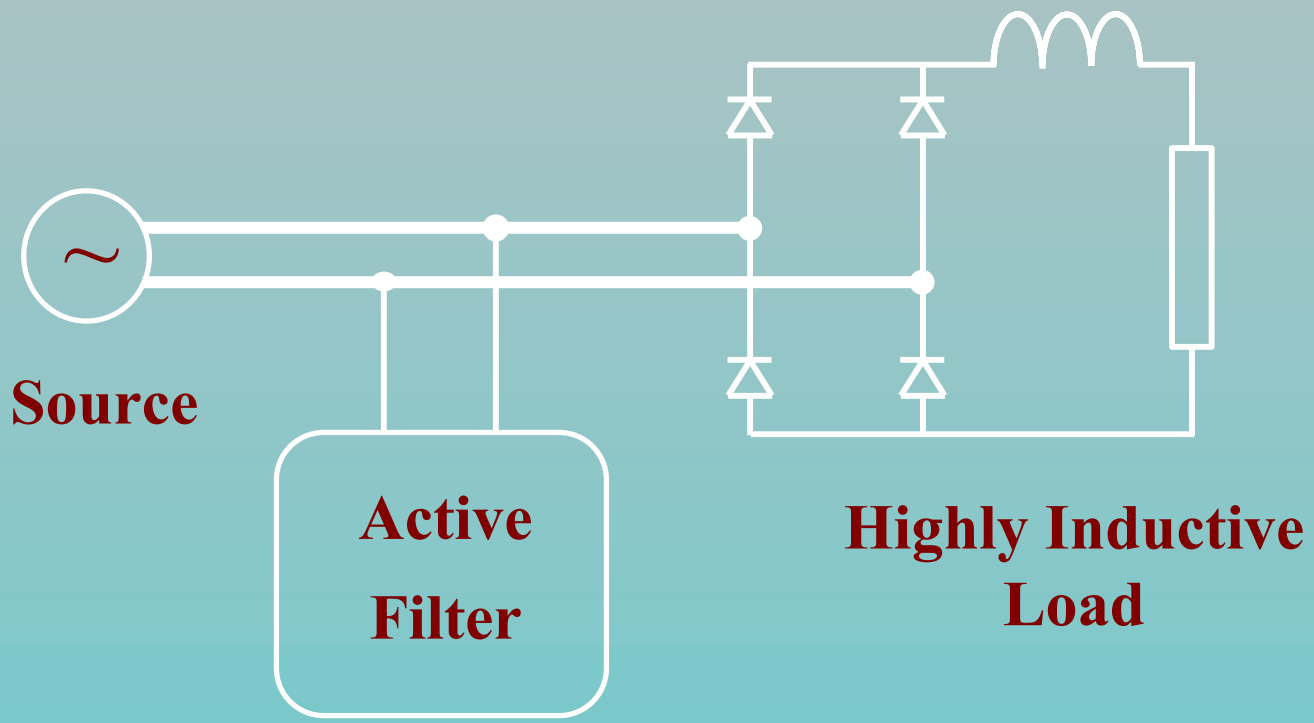
Active Filter with R-L Load



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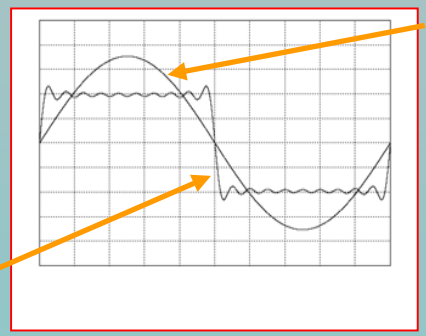
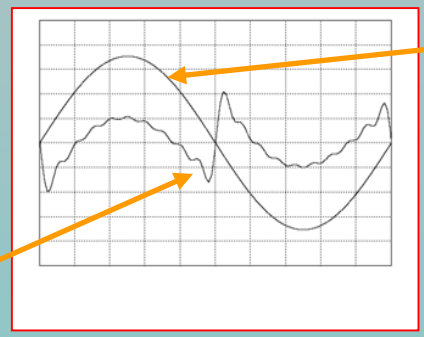
Active Filter with R-L Load



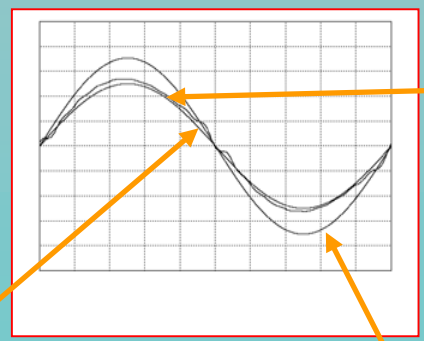
Supply Voltage

Load Current



Supply Voltage

Filter Current



Supply Current

Reference Supply Current

Supply Voltage

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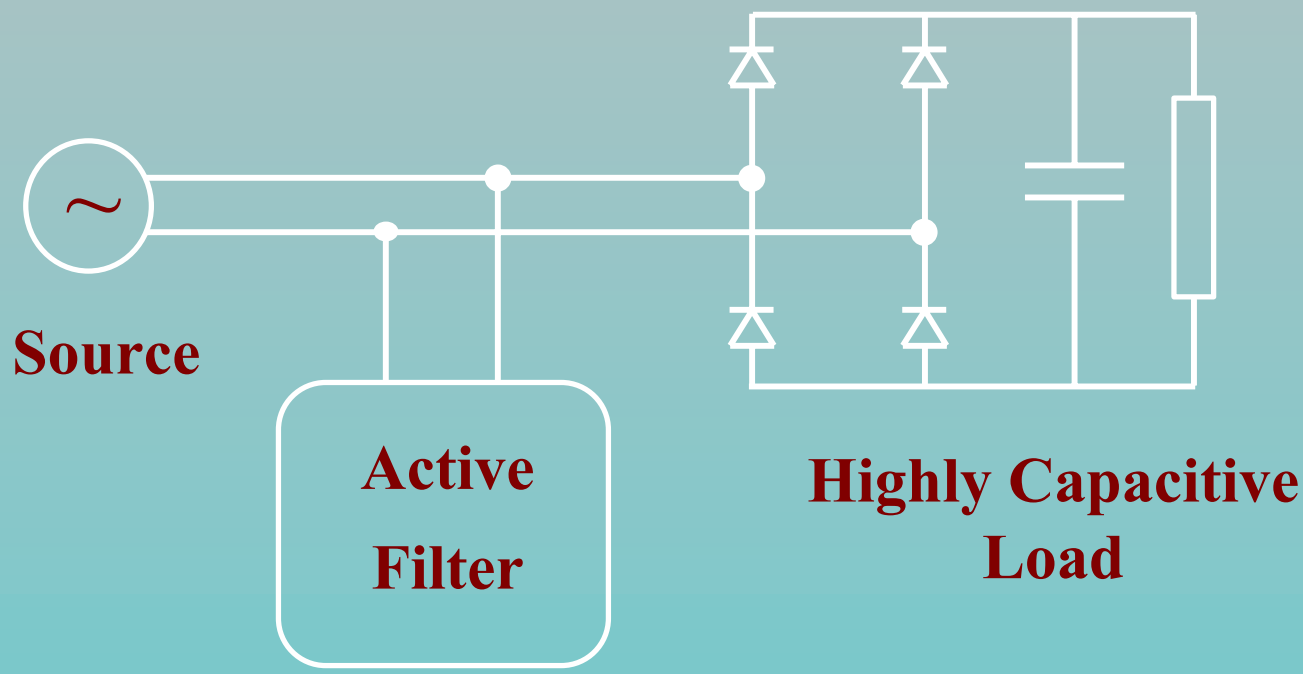
Active Filter with R-C Load



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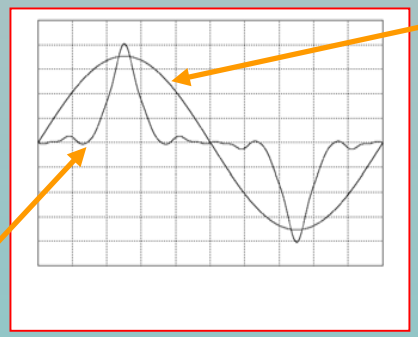
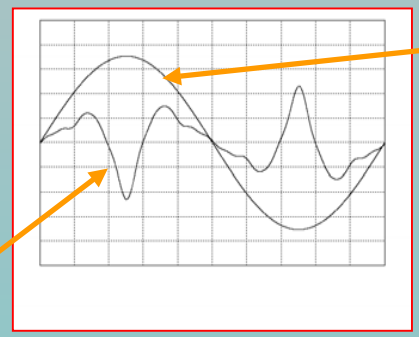
Active Filter with R-C Load



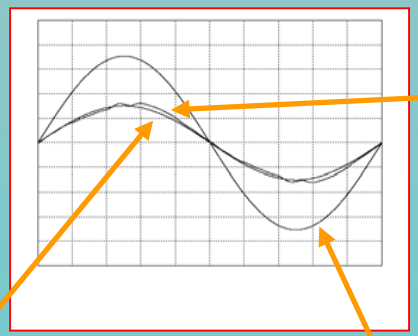
Supply Voltage

Load Current



Supply Voltage

Filter Current



Supply Current

Reference Supply Current

Supply Voltage

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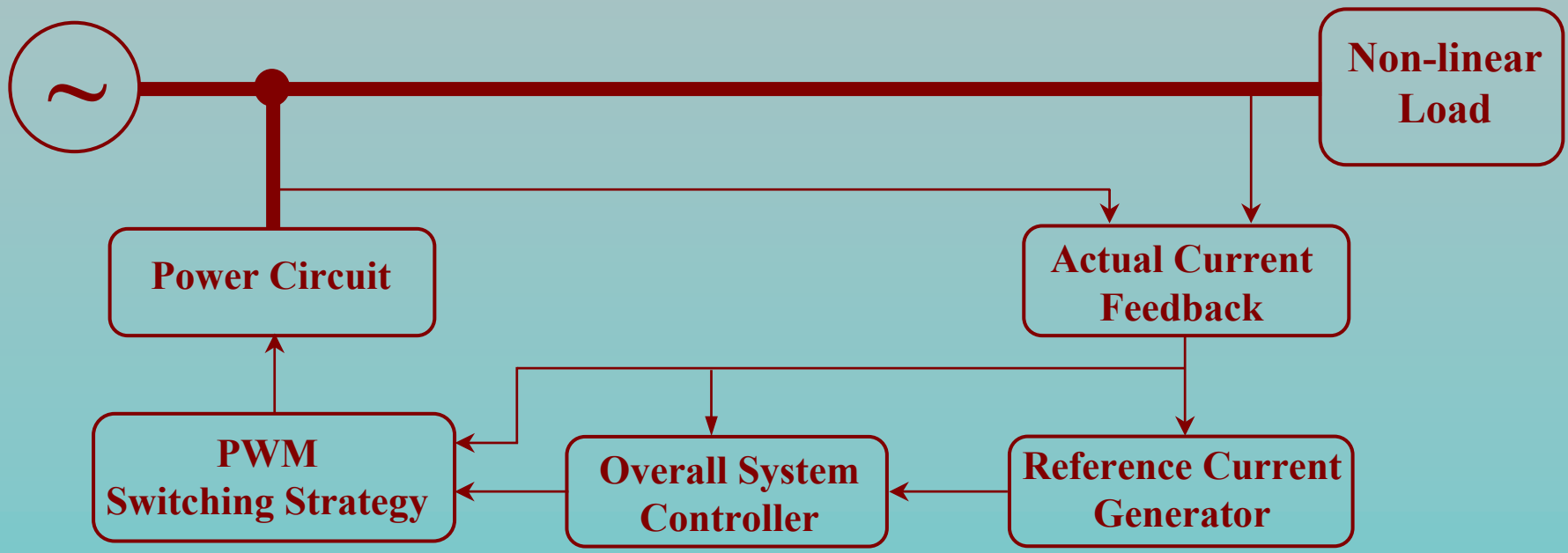
Typical Active Filter Circuit



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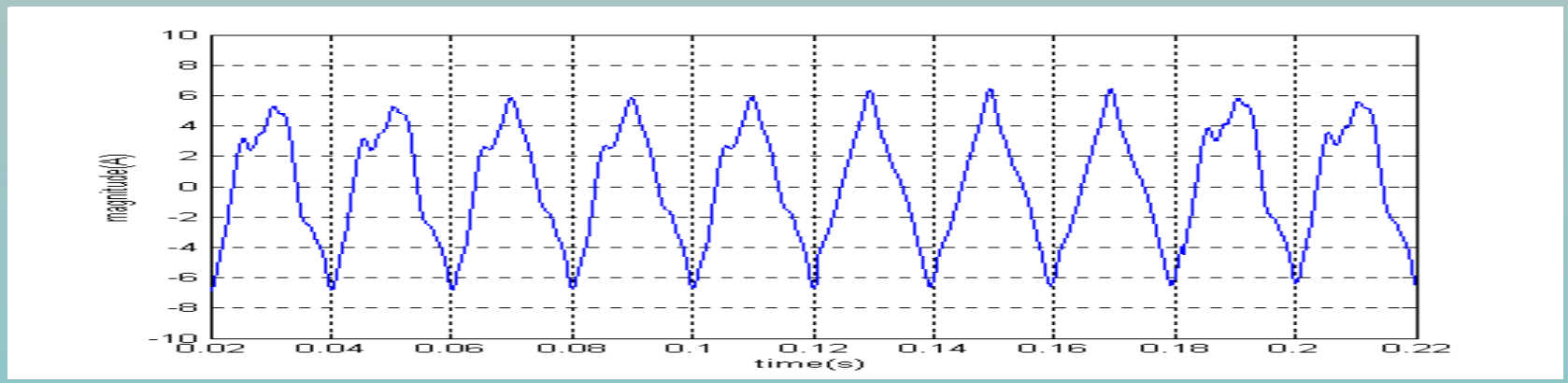
Control of Active Filters using Wavelet Transform



Active filtering of the variable harmonic contents of an arc furnace current

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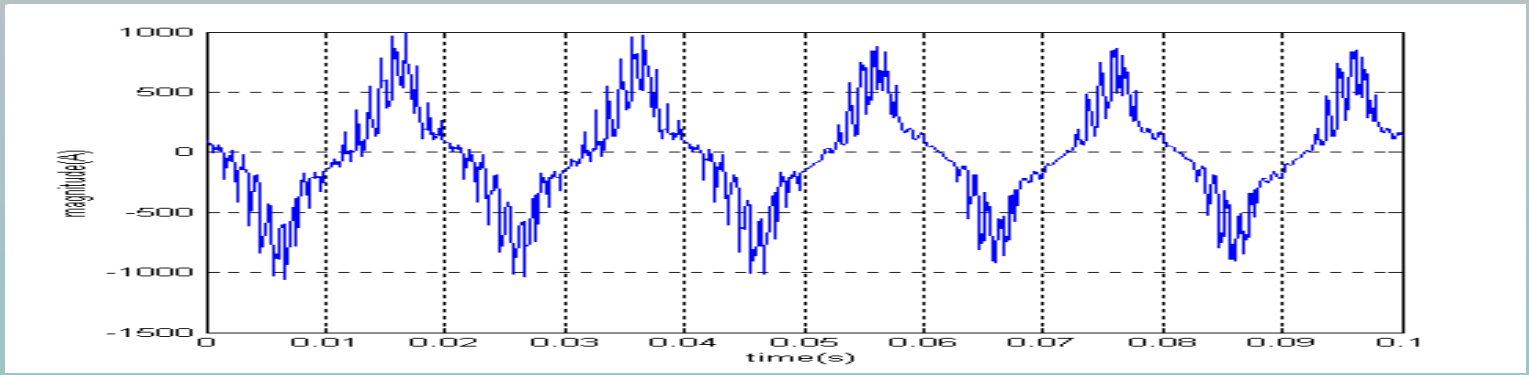

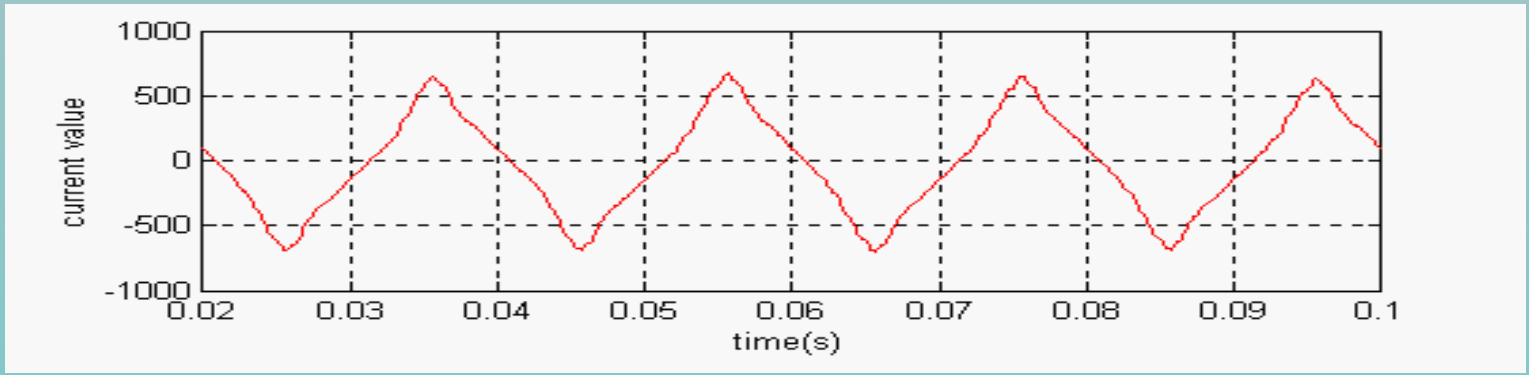

Active filtering of several disturbances such as: spikes, notches, transient responses, harmonics of several orders etc.

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New Ideas for Control

- *DSPs*
- *Genetic Algorithms*
- *Adaptive Controllers*
- *Fuzzy Logic Controllers*
- *Neural Networks*
- *& Many others*

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Advantages of Active Filters

- *Lower switching frequency*
- *Smaller sizes of components*
- *Cheaper solutions*
- *Basis for future improvements*

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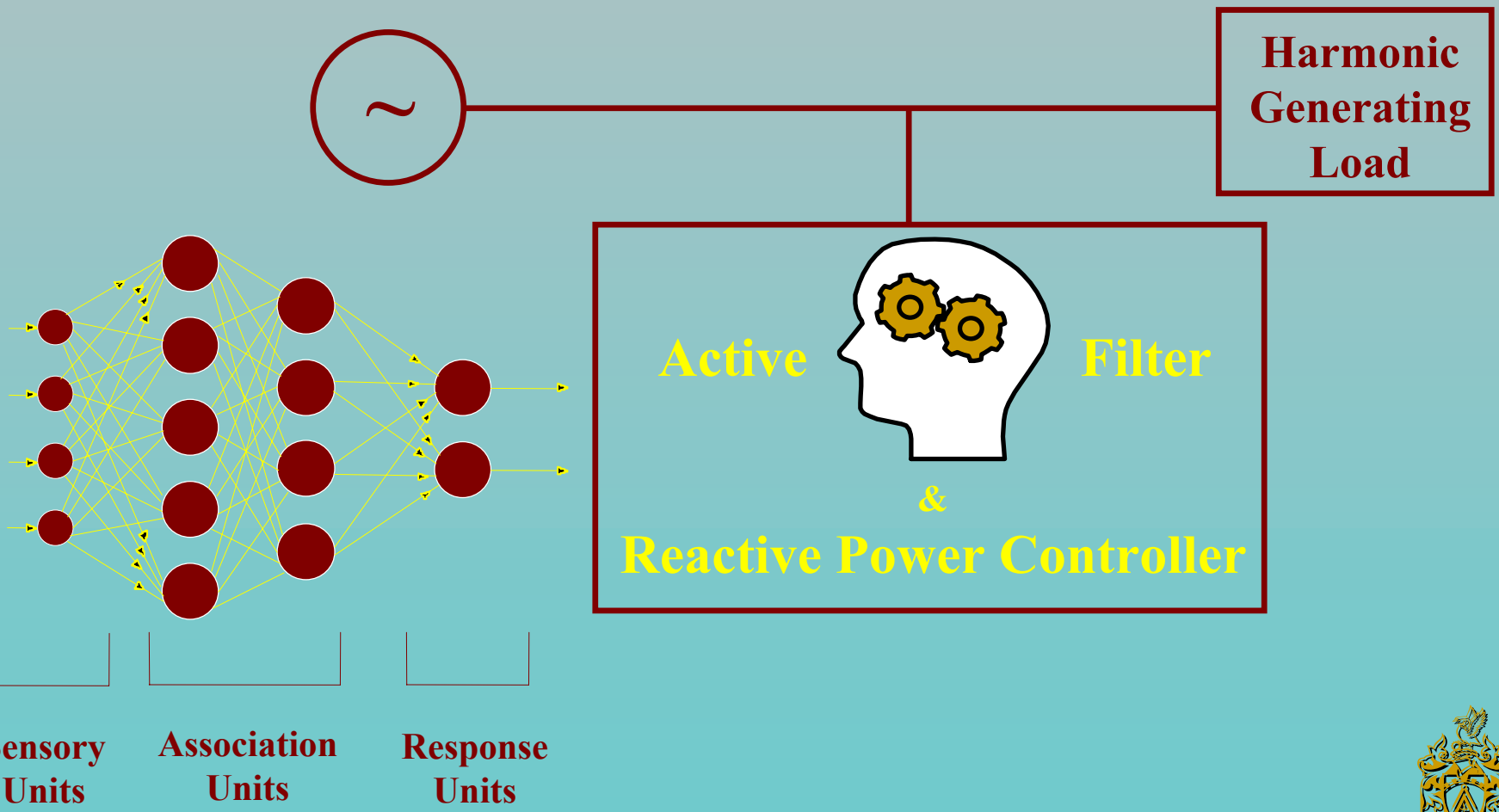
Future Control Strategies for Active Filters Using ANN



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Conclusions

- *Passive Filters*
- *Active Filters & Reactive Power Controllers*
  - *Large Offenders*
  - *Retrofit Applications*
  - *AI ? (NeuraLogix's NLX420 Neural Processor Slice)*
- *Devices ?*
- *Control ?*
- *Availability & Cost ?*
- *Regulations & Standards ?*

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