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*"THE POWER TO TRANSFORM"*

# Utilizing Sensors to Evaluate Power Systems

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# Overview

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- Utilizing Sensors to Evaluate Power Systems in Glass Manufacturing

Objectives:

- Electrical Processes in the Glass Manufacturing Process
- Examples of Sensors Available in the Process
- Examples of Data from the Sensors
- Analysis of the Data (Today a lot of Data is Collected but is it used?)

This presentation is a high level look at the high electrical power aspects of a glass manufacturing plant, from the Melting/Boosting, thru the Distribution and Forming processes. The Goal is to look at examples of sensors, data and analysis that can be used in areas such as preventative maintenance, process feedback and internal documentation

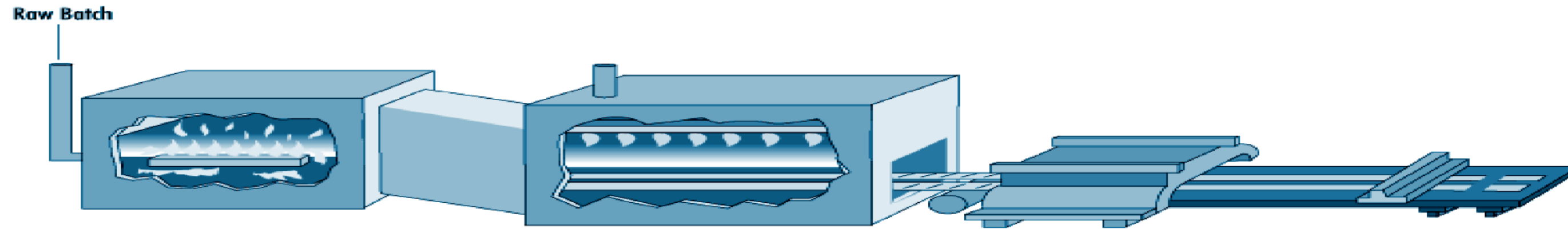
# Background Information

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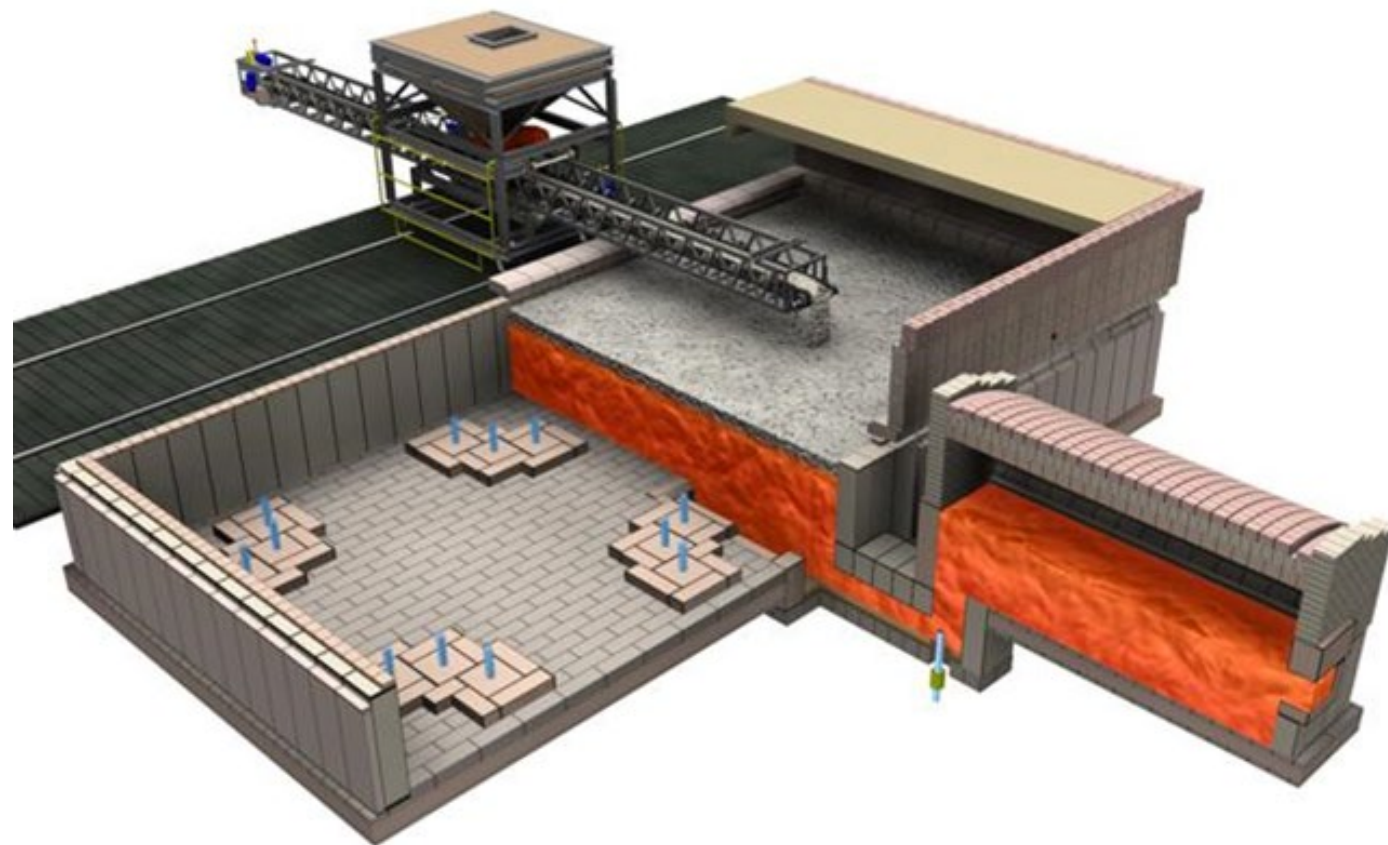
I have a Bachelor's Degree in Electrical Engineering (BSEE) from GMI Engineering & Management Institute (now renamed Kettering) and have worked for RoMan Manufacturing for 35+ years and specifically 30 years in the Glass and Resistance Heating markets. I am also currently the Immediate Past President of the GMIC. RoMan Manufacturing is a Transformer and Power Systems manufacturer for the glass industry



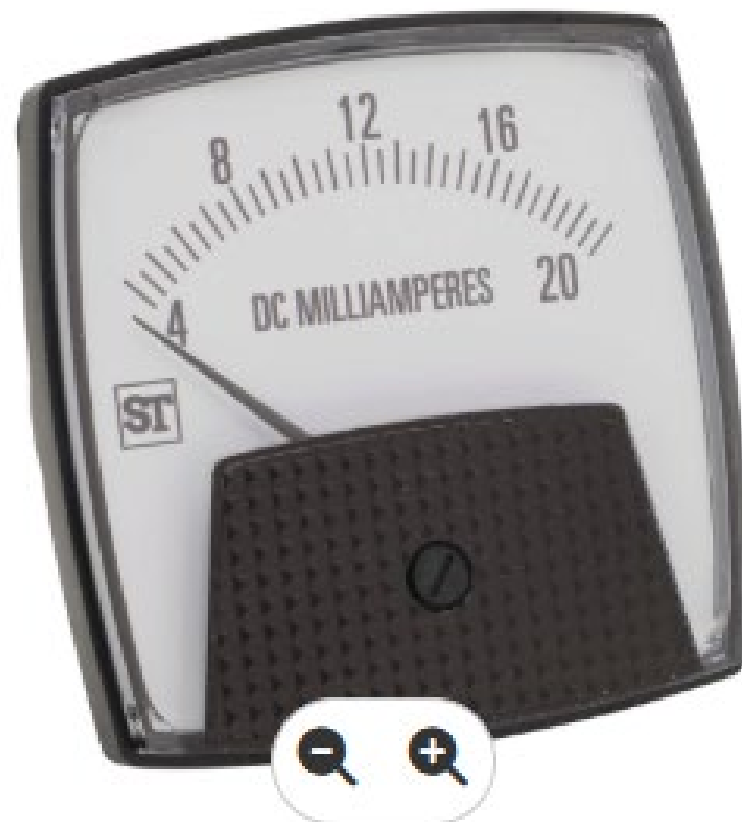
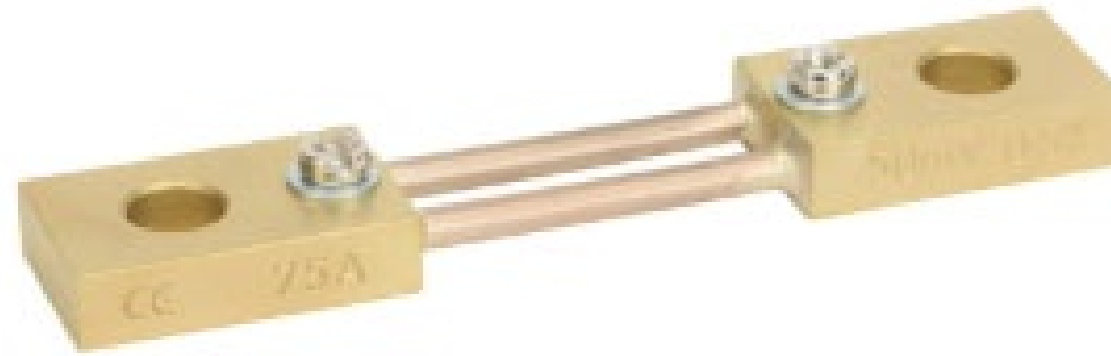
# Glass Plant Overview



**MELTING ZONE** → **BOOSTING ZONE** → **THROAT** → **REFINING** → **DISTRIBUTION** → **FORMING**



# Current Sensors



# Current Sensors

Current Creates Heat in the process

Joules Law:  $\text{Heat} = \text{Current} \times \text{Current} \times \text{Resistance}$

Current is a function of the material to be heated. Temperature of the glass/batch material changes the current required.

Most Glass Systems control by Heat (kW), current is squared in the equation for heat, so current becomes the most important parameter. It Dictates:

- Conductor Size (Cross Section)
- Transformer Rating
- Electrode Size (Cross Section) (Melting, Boosting and Forehearth)
- Precious Metal Content (Forming and Refining)
- Glow Bar Cross Section
- Breaker Sizing (Input and Possibly Output if Required)
- Electronic Control (SCR, IGBT etc.) if Required
- Cable Trays and Routing

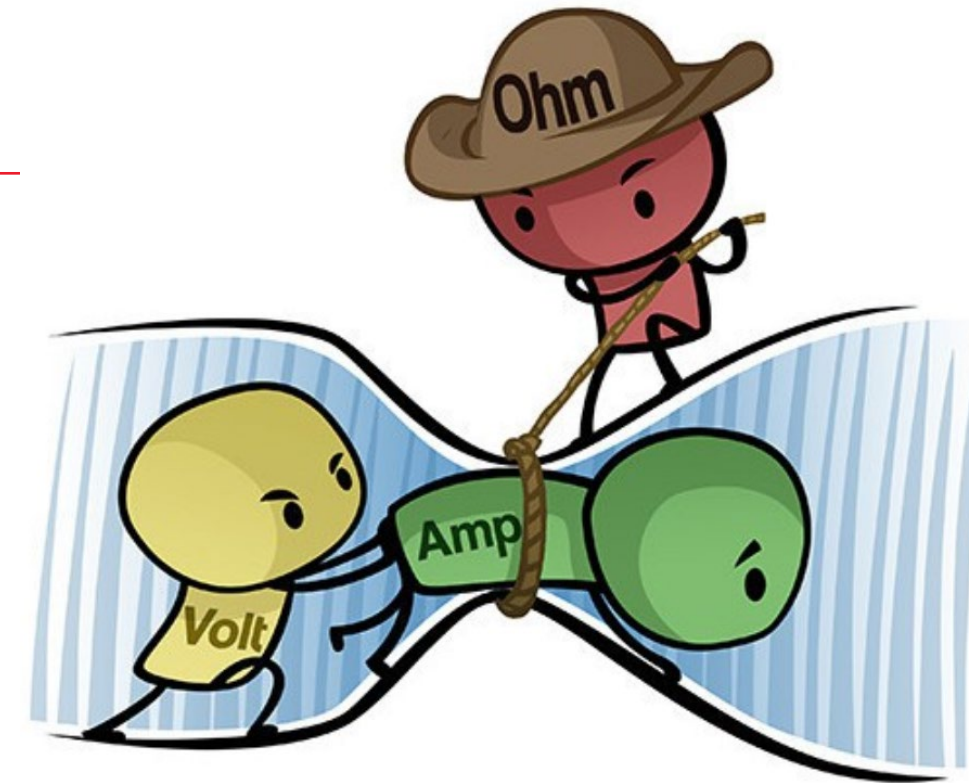
# Voltage Sensors



# Voltage Sensors

Voltage pushes the current thru the process.

Ohm's Law: Voltage = Current x Resistance



Normal Operation: Voltage increases, Current Increases, Heat in Process Increases

If Voltage increases and Current does not

- Loose Connection
- Broken Electrode
- Worn Out Conductor
- Misfiring SCR
- Batch Loading Quicker than Expected
- Glass Colder than Expected
- Transformer is Saturating
  - High Harmonic Content

If Voltage decreases and Current does not

- Short Circuit
- Change in Batch
- Batch Loading Slower than Expected
- Glass Hotter than Expected

# Wattage Sensors



# Wattage Sensors

Wattage is the multiplication of Current x Voltage

Normal Operation: Voltage and/or Current increases, Heat in Process Increases

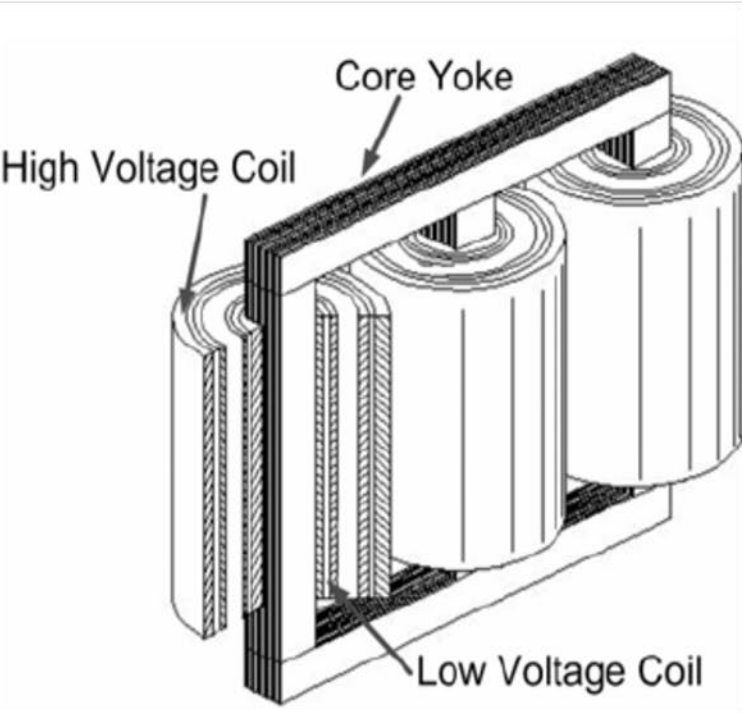
If Voltage increases and  
Wattage to process does not:

- Loose Connection
- Broken Electrode
- Worn Out Conductor
- Misfiring SCR
- Batch Loading Quicker than Expected
- Glass Colder than Expected
- Harmonic Interference from other zones
- Coupling to other Structures
- Transformer is Saturating
  - High Harmonic Content

If Current decreases and Wattage does not:

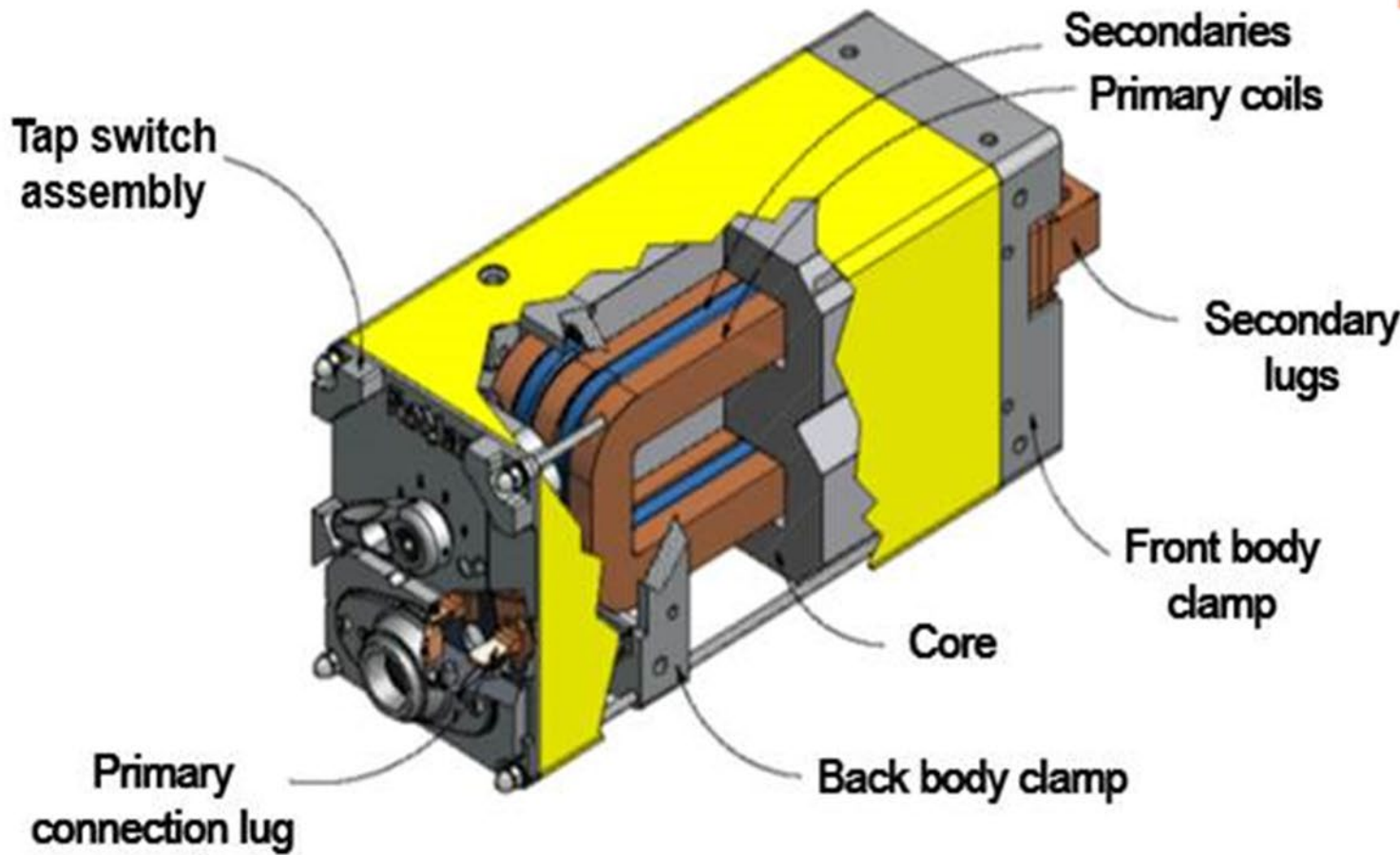
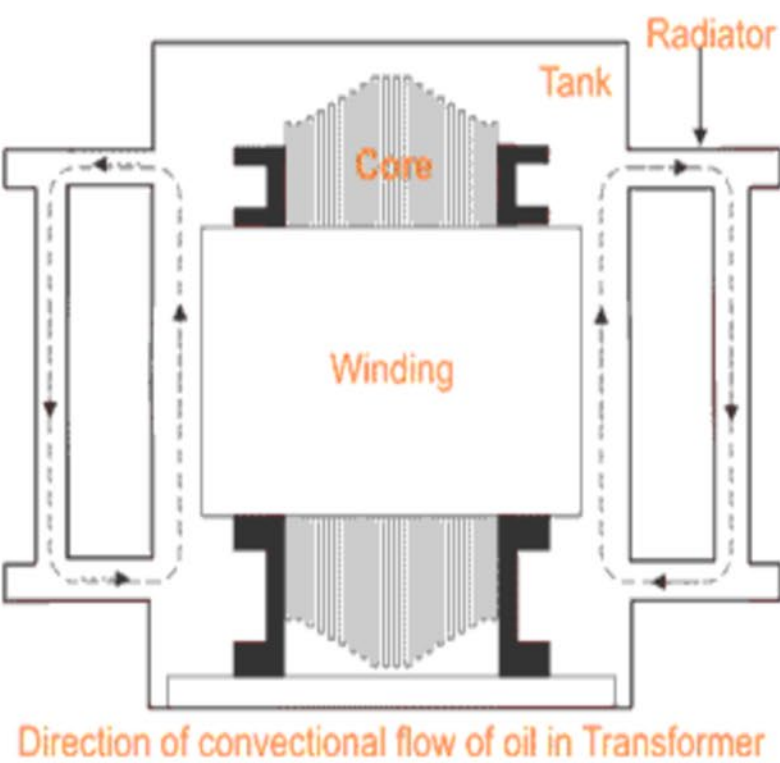
- Short Circuit
- Change in Batch
- Batch Loading Slower than Expected
- Glass Hotter than Expected
- Coupling to other Structures

# Transformer Construction

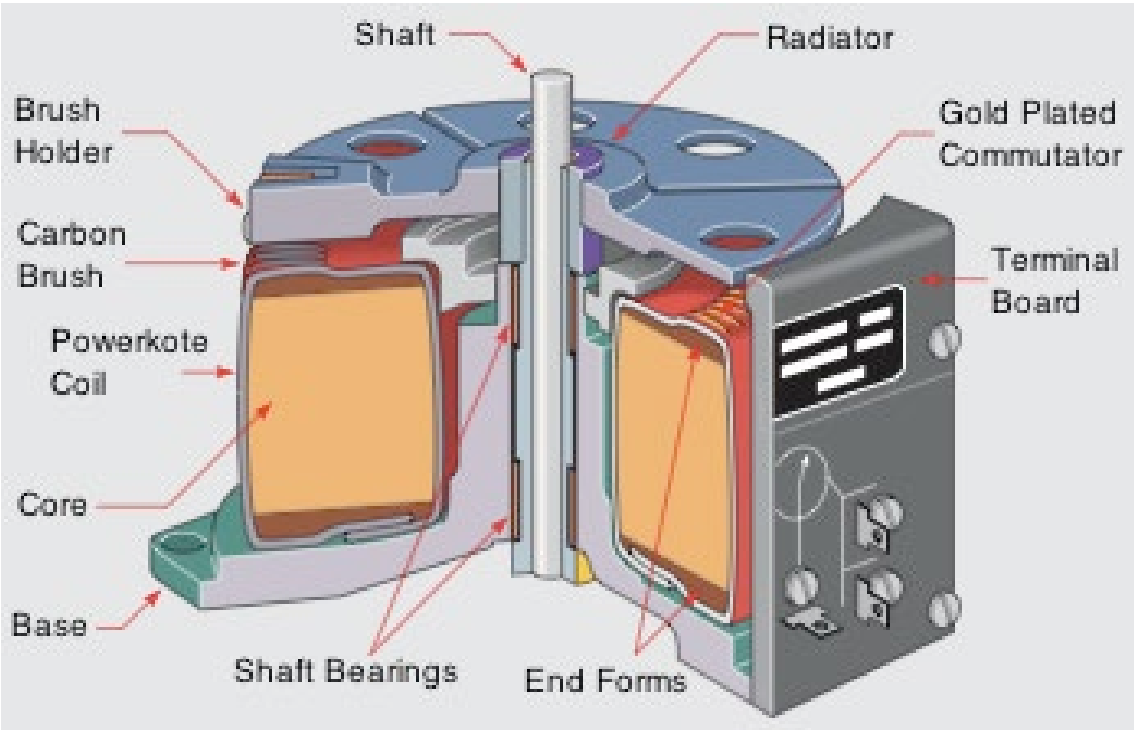


Air  
Cooled

Oil  
Cooled

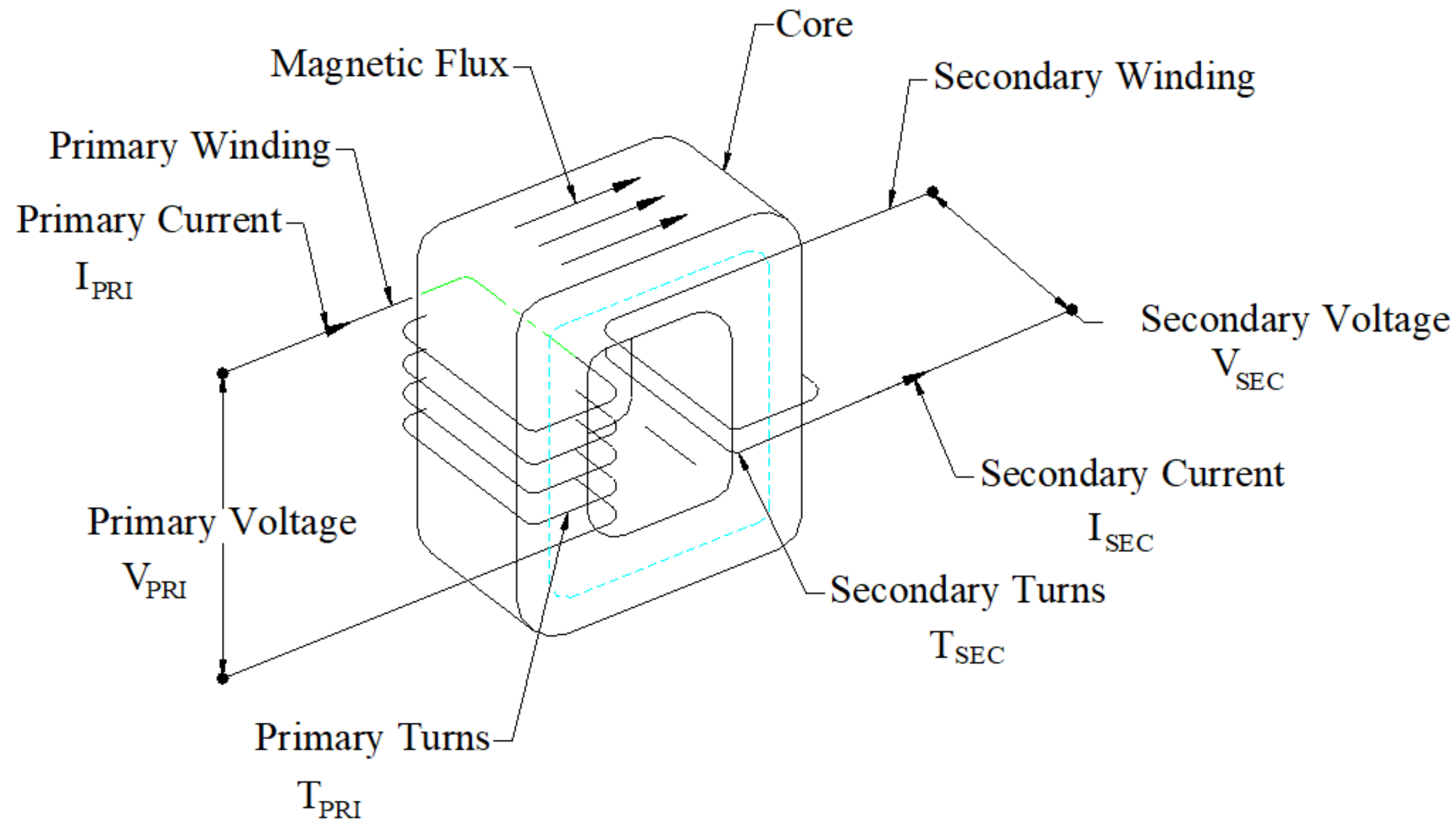


Water  
Cooled



Brushed Transformer  
Oil Filled with an Air to  
Water Heat Exchanger

# Transformer Theory



$$\text{TURNS RATIO} = \frac{V_{PRI}}{V_{SEC}} = \frac{T_{PRI}}{T_{SEC}}$$

POWER INPUT = POWER OUTPUT

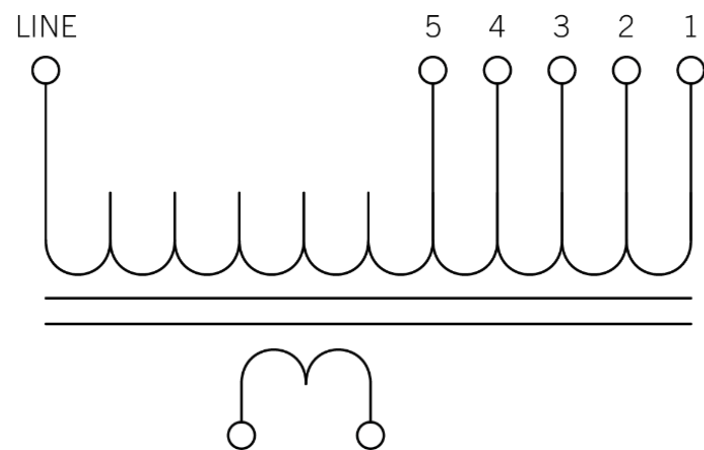
$$V_{PRI} \times I_{PRI} = V_{SEC} \times I_{SEC}$$

Things to Monitor:

- Does Turns Ratio Change
- Power In vs. Power Out
- Transformer Temperature
- Waveform at Primary and Secondary
- DC Content (Primary and Secondary)

# Thermal Rating (kVA) of Transformers

All transformers are not designed equally for the same Thermal (kVA) rating. This can and has led to confusion in what the Thermal Rating of a transformer represents. Generally multi tap transformers will fall into one of three types of ratings, Constant Secondary Current, Constant kVA or a Hybrid System. Below are example ratings for a single phase, 480 volt 60 Hz primary and 100 kVA transformer.



Constant Secondary Current

| Tap | Primary Turns | Secondary Turns | Secondary Volts | Primary Current | Secondary Current | kVA   |
|-----|---------------|-----------------|-----------------|-----------------|-------------------|-------|
| 1   | 96            | 1               | 5.00            | 104.2           | 10,000            | 50.0  |
| 2   | 81            | 1               | 5.93            | 123.5           | 10,000            | 59.3  |
| 3   | 68            | 1               | 7.06            | 147.1           | 10,000            | 70.6  |
| 4   | 57            | 1               | 8.42            | 175.4           | 10,000            | 84.2  |
| 5   | 48            | 1               | 10.00           | 208.3           | 10,000            | 100.0 |

Constant kVA

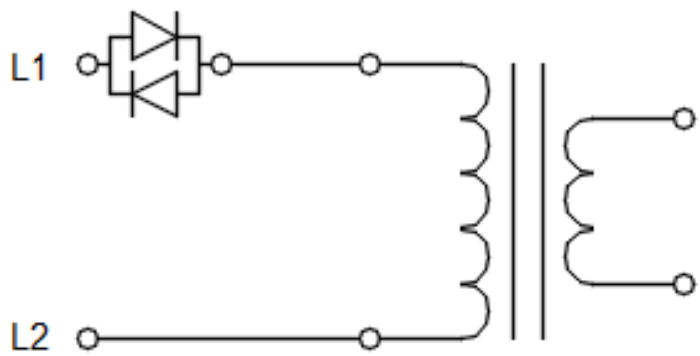
| Tap | Primary Turns | Secondary Turns | Secondary Volts | Primary Current | Secondary Current | kVA   |
|-----|---------------|-----------------|-----------------|-----------------|-------------------|-------|
| 1   | 96            | 1               | 5.00            | 208.3           | 20,000.0          | 100.0 |
| 2   | 81            | 1               | 5.93            | 208.3           | 16,875.0          | 100.0 |
| 3   | 68            | 1               | 7.06            | 208.3           | 14,166.7          | 100.0 |
| 4   | 57            | 1               | 8.42            | 208.3           | 11,875.0          | 100.0 |
| 5   | 48            | 1               | 10.00           | 208.3           | 10,000.0          | 100.0 |

Hybrid System

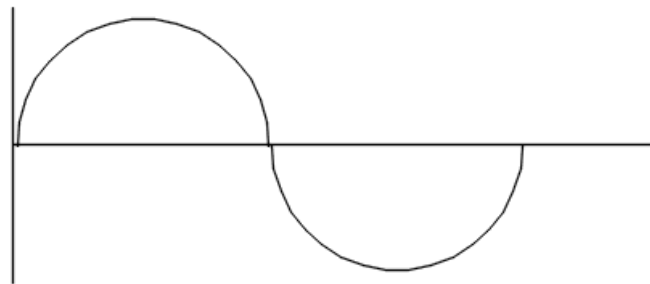
| Tap | Primary Turns | Secondary Turns | Secondary Volts | Primary Current | Secondary Current | kVA   |
|-----|---------------|-----------------|-----------------|-----------------|-------------------|-------|
| 1   | 96            | 1               | 5.00            | 147.6           | 14,166.7          | 70.8  |
| 2   | 81            | 1               | 5.93            | 174.9           | 14,166.7          | 84.0  |
| 3   | 68            | 1               | 7.06            | 208.3           | 14,166.7          | 100.0 |
| 4   | 57            | 1               | 8.42            | 208.3           | 11,875.0          | 100.0 |
| 5   | 48            | 1               | 10.00           | 208.3           | 10,000.0          | 100.0 |

Throat Transformers are typically Constant kVA  
Melt and Boost Transformers are Typically Hybrid kVA  
Forming Transformers are typically Constant Secondary Current

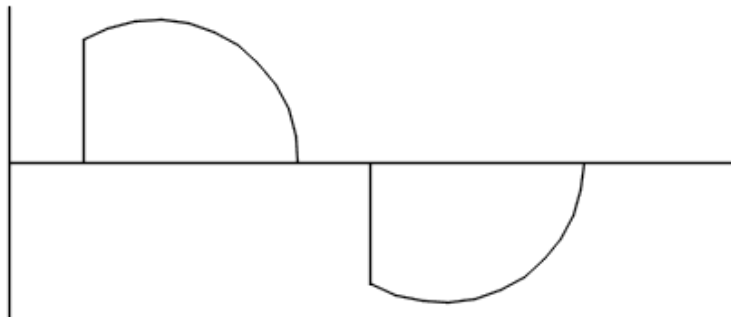
# Control Types - SCR



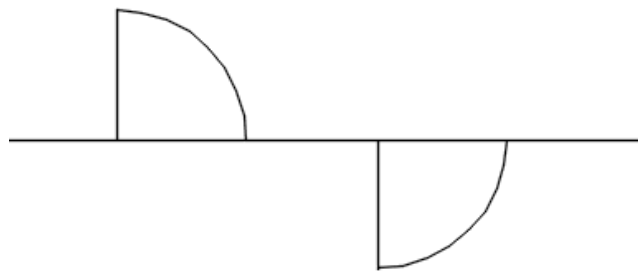
Control and Transformer Schematic



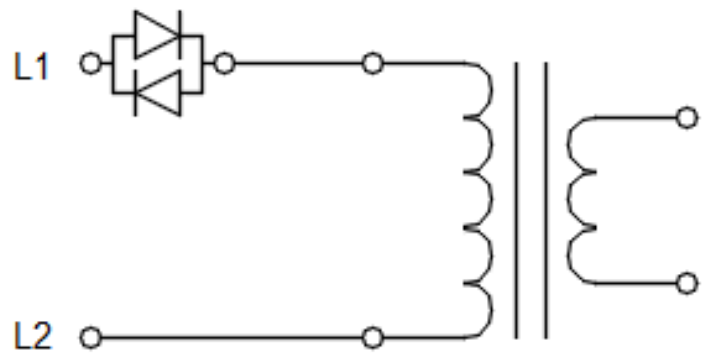
Full Sine Wave



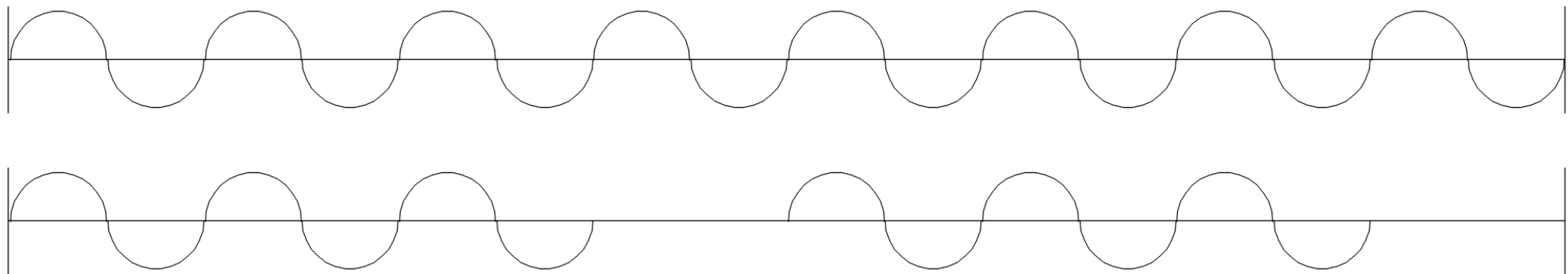
75% Sine Wave



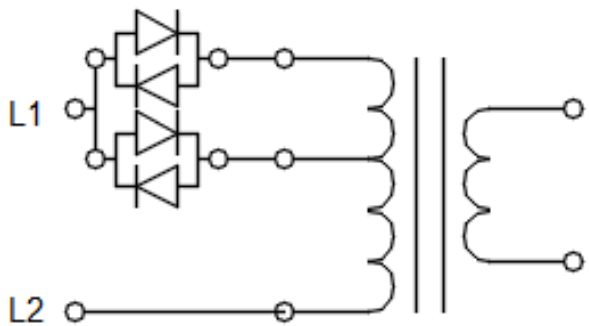
50% Sine Wave



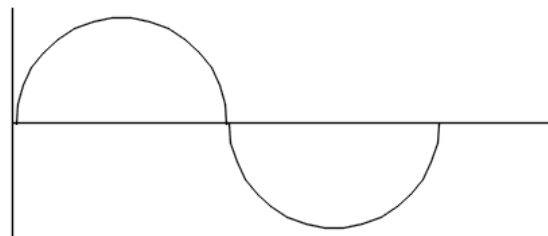
Control and Transformer Schematic



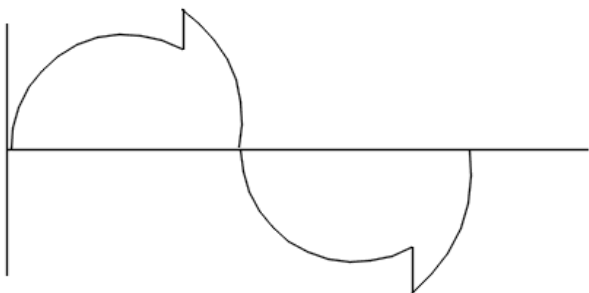
75% Burst Fire (3 Cycles On, 1 Cycle Off)



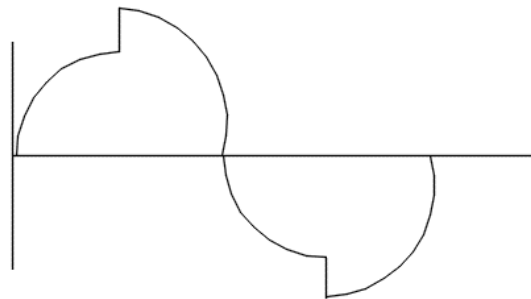
Control and Transformer Schematic



Full Sine Wave

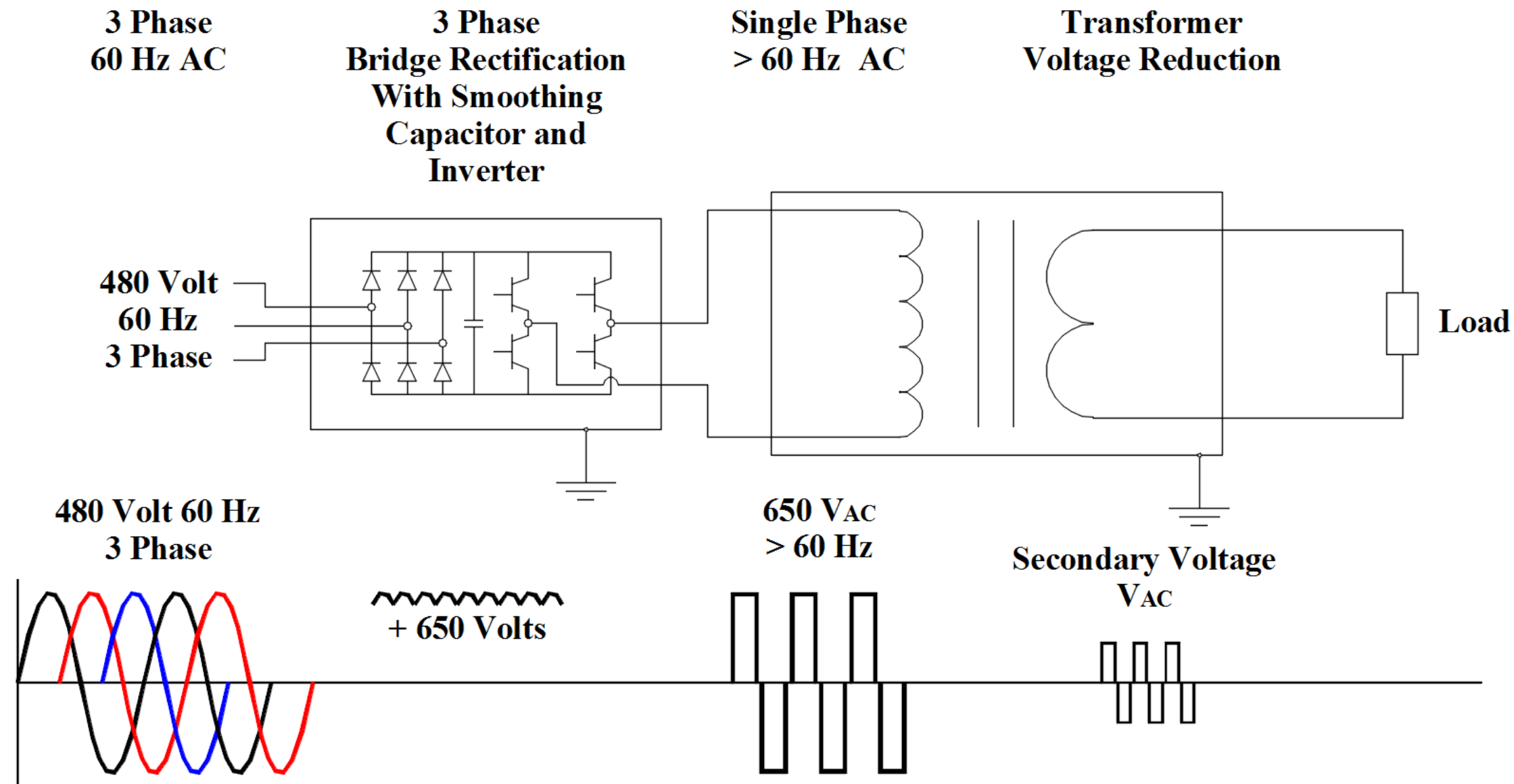


25% Second Tap

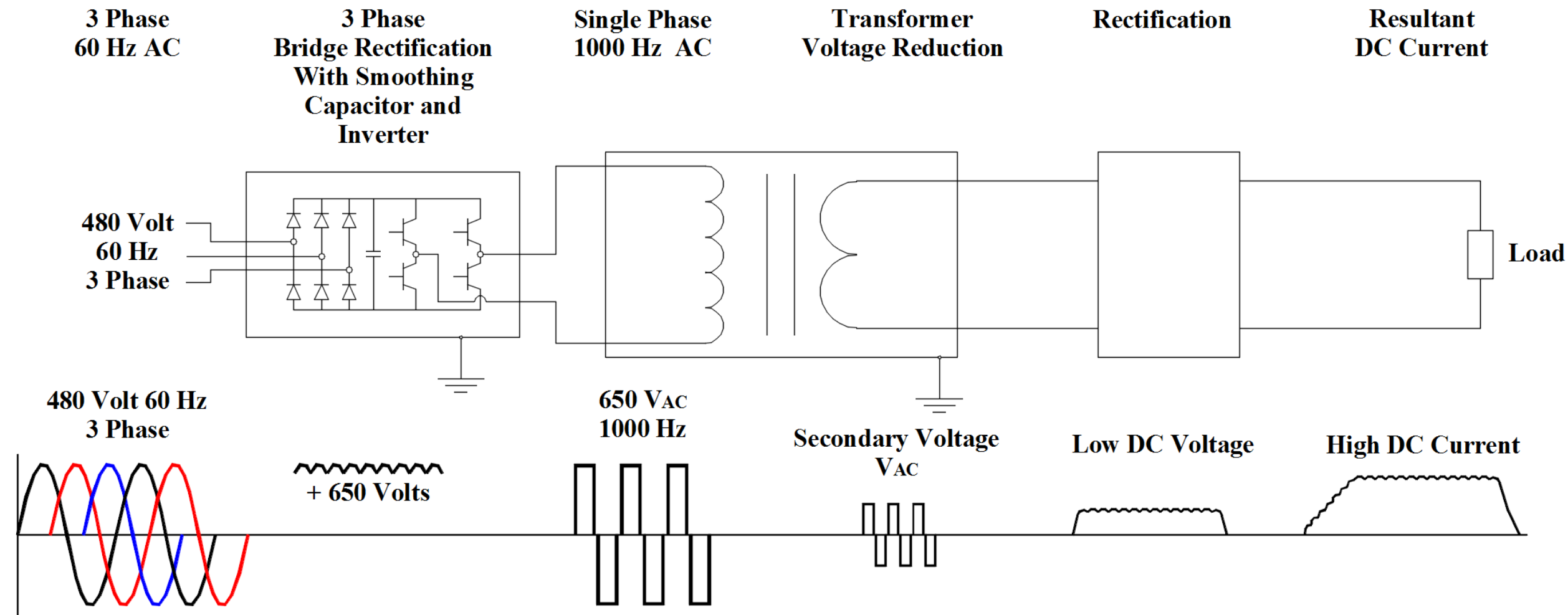


50% Second Tap

# Control Types - IGBT System Schematic – AC Output



# Control Types - IGBT System Schematic – DC Output



This type of system could be used for Radiant Heating (where the electricity does not go thru the glass material)

# Thermal Sensors



# Thermal Sensors

Heat affects all electrical components. Each breaker, control, transformer, wire, shunt, cable etc. all have a resistance or a loss associated with them. This loss is increased with temperature, so keeping the equipment in it's designed range is critical to consistent operation of a facility.

Why a Transformer, Breaker, Conductor, Control gets Hot:

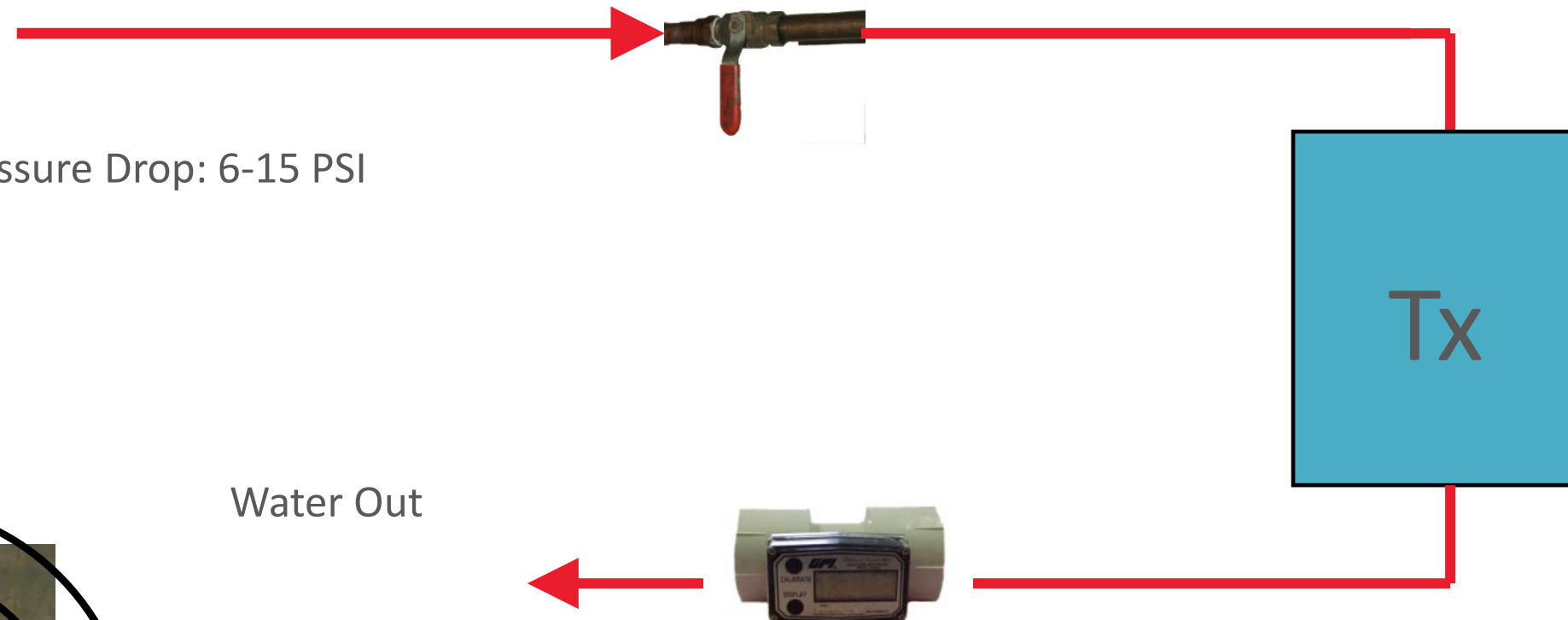
- Reaching it's rating
- High Harmonic Content
- Coupling to other structures
- Misfiring Control
- Cooling Requirement not met
  - Plugged Air Flow
  - Water Temp too High
  - Water Flow too Low

# Water Flow



Water flow must be measured in CLOSED LOOP  
NO open circuit bucket test

Typical Pressure Drop: 6-15 PSI



Water Out

Flow Meter is best means of protection  
(LPM/GPM) Must be inline with transformer  
Our universal manual specifies 50-micron filter

# Resources

[www.romanmfg.com/resources/](http://www.romanmfg.com/resources/)



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