Residential Air Conditioning and Heat Pump Response to Voltage Disturbances

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Leader Advanced Controls Development
Trane Residential

April 22, 2008

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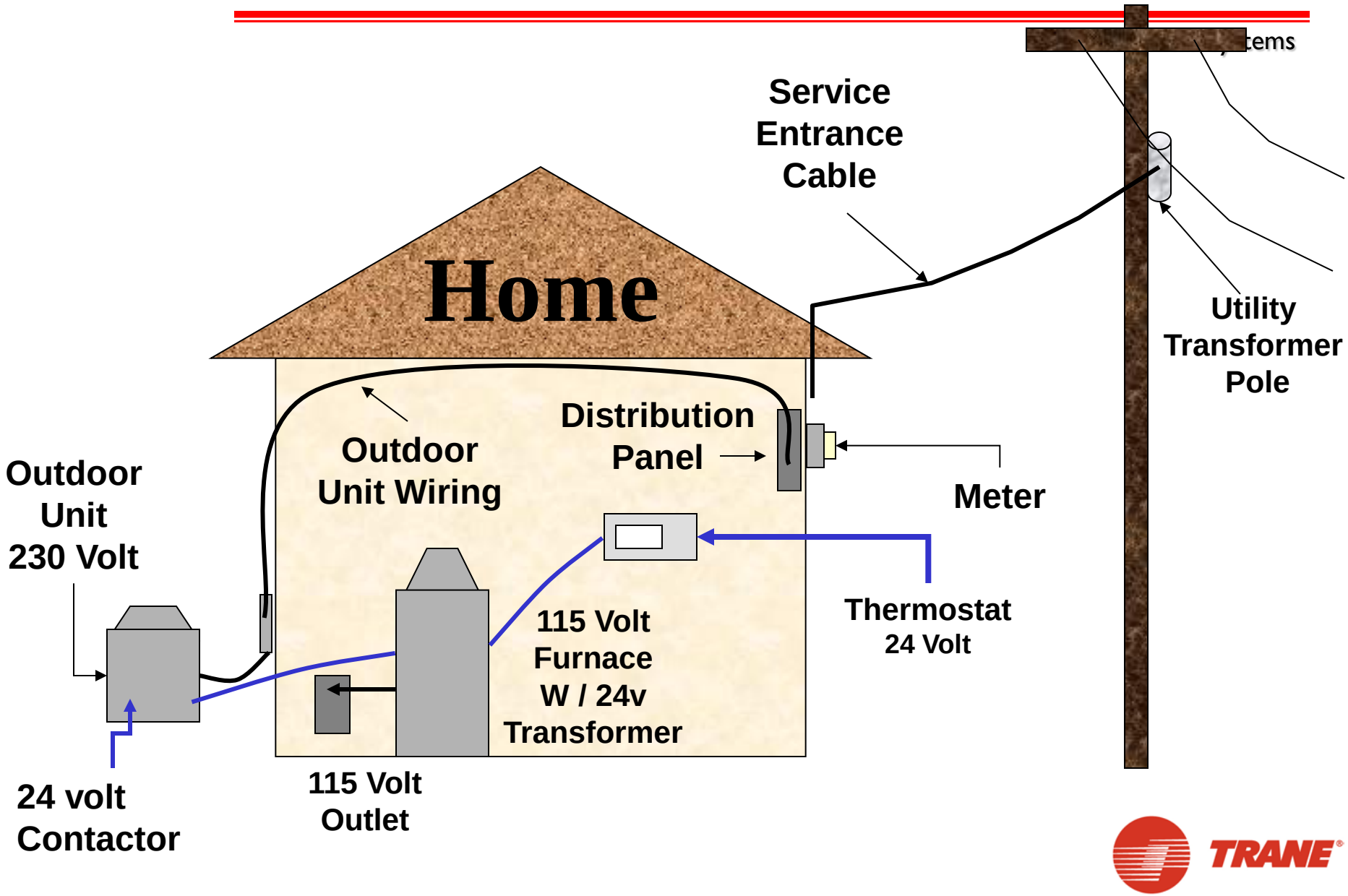
Residential Air Conditioning

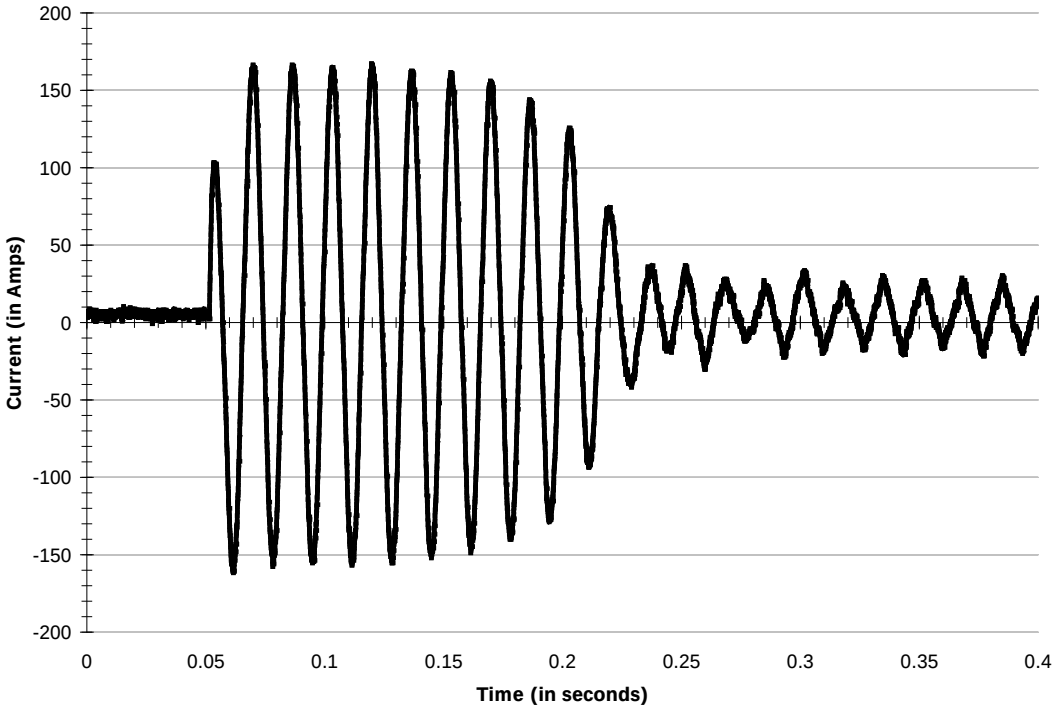


Air Conditioning Stall Criteria

- **Factors that effect a compressor stall condition**
  - Line voltage directly maps to motor torque
    - Higher the line voltage the higher the motor torque
  - Power Disturbance – Brown out condition - Compressor Stall
    - Probability increases with power interruption time
    - Probability increases with the percent voltage decrease
  - Differential pressure (DP)
    - DP increases in with outdoor temperature, (Heating or Cooling)
    - DP increases with system overcharging, coil blockage, age
    - Equalization of DP must occur to allow compressor to start
    - Time delay relays are applied to insure equalization improving starting after power interruption.
  - Compressor rotating inertia
    - Varies with different types of compressors and motors.
  - Compressor motor start kit application
    - Start kit increases starting torque
    - May assist during short brown out conditions

Background

- Residential air conditioners and heat pumps use electric motors driven compressors.
- During startup, the compressor motor draws high current from the power distribution system, which typically lasts for five to fifteen cycles.



Above is the startup current of a 4-ton Heat Pump Compressor.

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A.O. SMITH

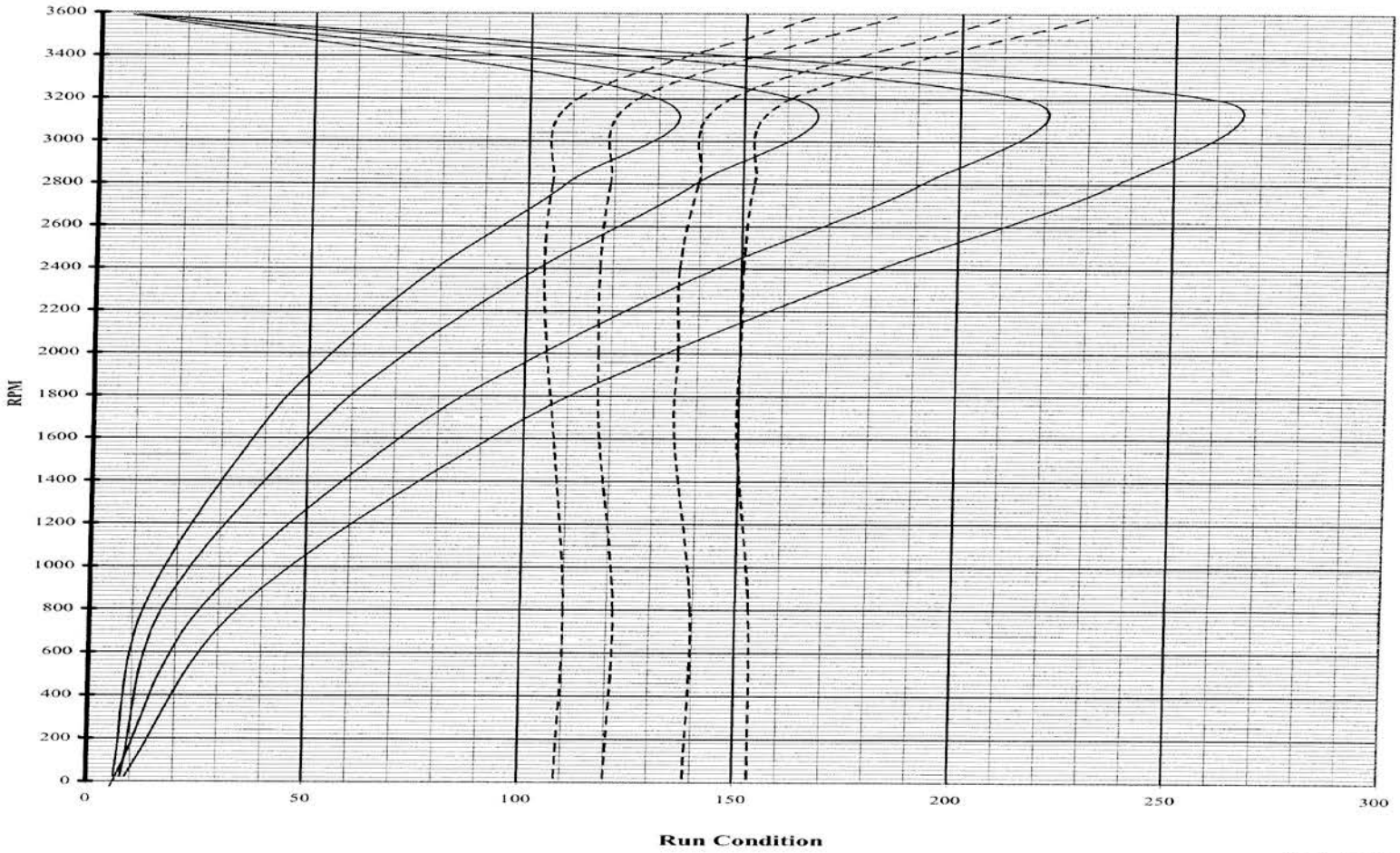
ELECTRICAL PRODUCTS COMPANY

C63205

GP303-EF1

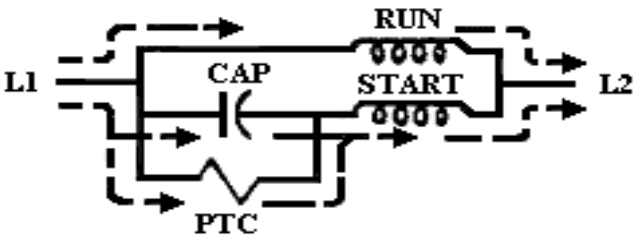
Model: SA3882	**EPTS:** 0443003A	**Crun:** 30	**Cstart:** 0
Date: 1/13/2005	**WTS:** 0443003	—— **TS**	- - - - **IS** (50X)
Customer: TRANE TYLER			

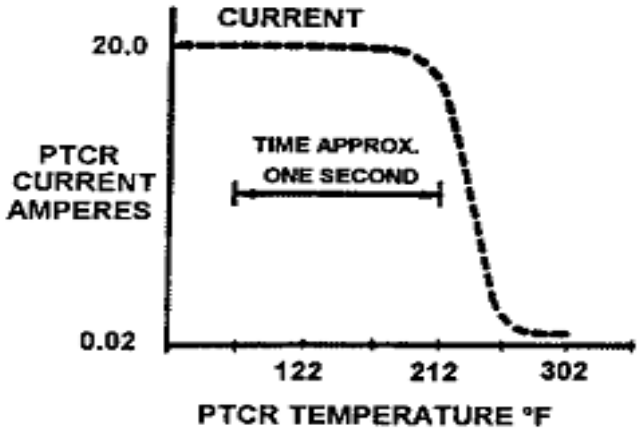
		1	2	3	4	5	
	===>						===>
Voltage	===>	180	200	230	253		===>



Compressor Start Assist Techniques

- For PSC motor driven compressors, there are two primary techniques used to increase the starting torque:
  1. Positive Temperature Coefficient (PTC) Thermistors
  2. Start Relay / Capacitors
- PTC thermistors are connected in parallel with the run capacitor as shown in the diagrams below.
- Start-assist products are sometimes used to reduce the start time thus reducing potential voltage flicker issues in residential HVAC systems.





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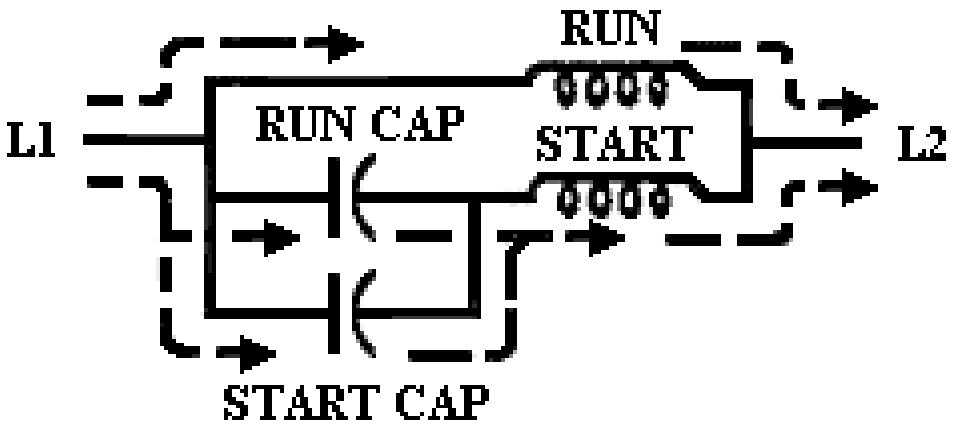
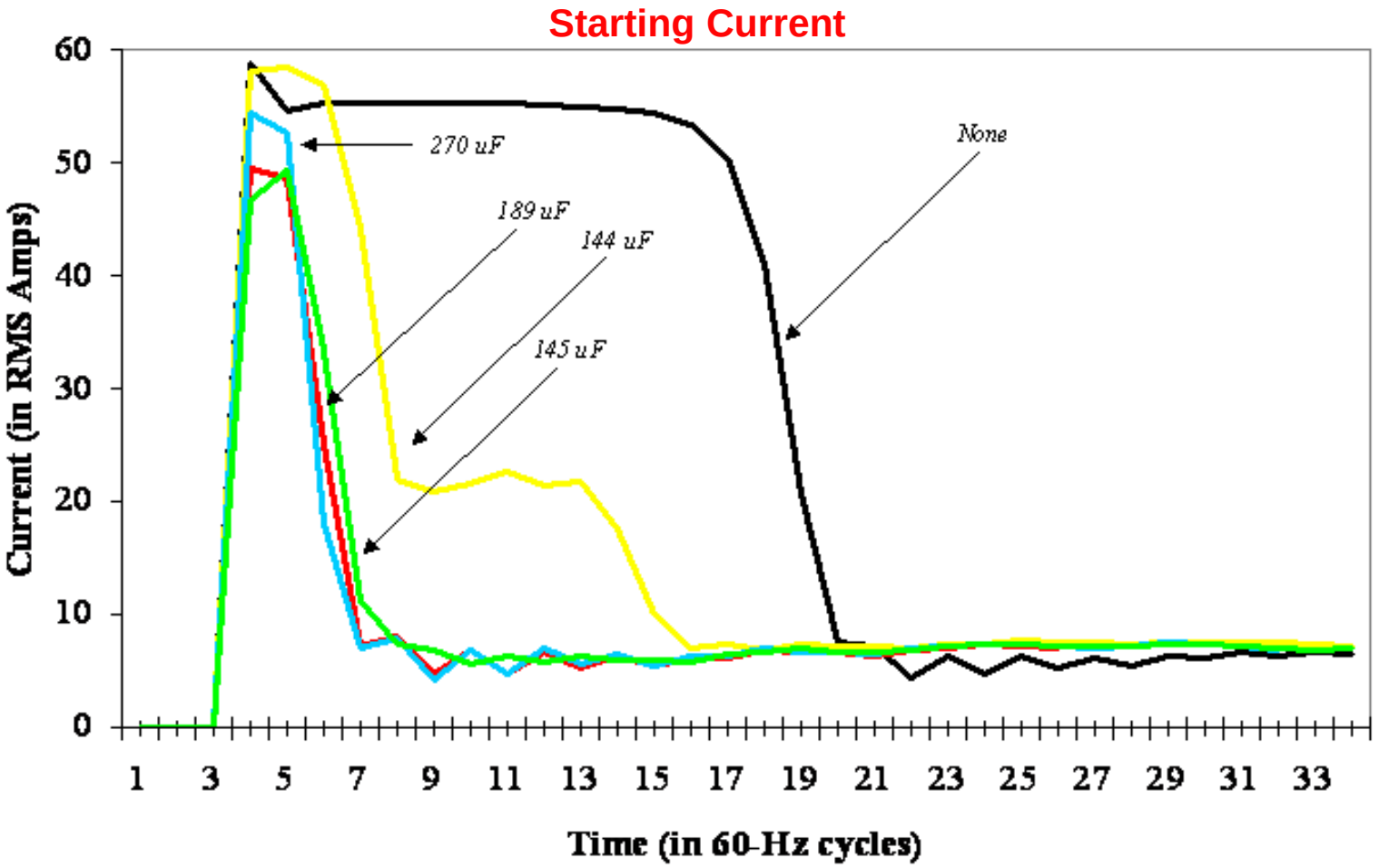
Compressor Start Assist Techniques

- Start Capacitors increase starting torque
  - Start capacitors are controlled by start relays or Potential (voltage sensing) relays
  - Start relays sense the compressor start winding voltage
  - As load increases the start winding voltage decreases
  - The start winding voltage decreases as speed decreases
  - At high load conditions and low line voltage conditions the start relay may connect the start capacitor to increase torque



Compressor start time



Short Cycle Protection

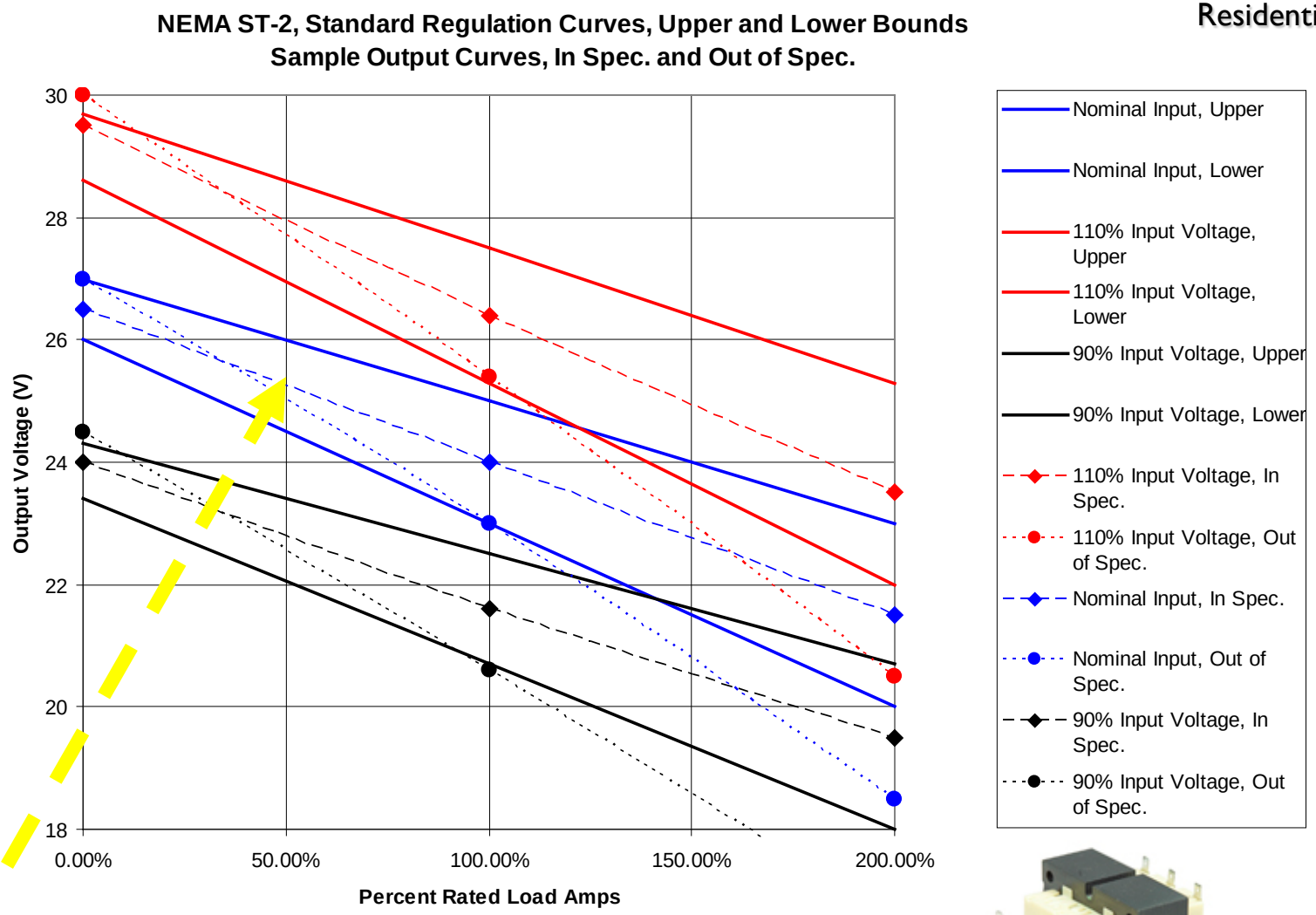
- Short cycle protection devices sense power interruption of the 24 volt power and inhibit compressor operation for a fixed period. (example 5-7 minutes.
- HVAC manufactures include short cycle protection in custom controls.
- Electronic thermostats may provide power interruption short cycle protection.
- Drop out sensing time varies from device to device. Optimum power off sensing time was selected at 50 msec or 3 line cycles.

Short Cycle Protection

- Controls sensing interruption time is easy but sensing voltage drop is problematic.
  - Short cycle protection devices sense power interruption of the 24 volt power. Optimum sense time 50msec or 3 line cycles.
  - Most HVAC controls do not sense the 230 volt line voltage. (UL, safety, and spacing concerns)
  - Sensing 24 volt control voltage does not map to line voltage very well. Transformer NEMA curves allows 23 to 26 volts with 230 or 115 volts input depending on load.
  - The normal operating range for 24 volt AC controls is 18 to 30 Volts AC including thermostats with various hold up times.
- Nuisance trips are a big concern for customer comfort and equipment reliability.




Control Transformer Regulation



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Relays and Contactors for Compressors

- A contactor or relay provides switching for compressor power.
- Typical contactors have 24 volt AC coils.
- Pick-up voltage is typically 75% of rated voltage or 18 volts maximum for a 24 volt nominal coil
- Drop out voltages vary and are typically 25-60% of rated voltage or for a 24 volt coil 6-15 volts.
- Some contactors are powered directly from the thermostat and some newer systems and heat pumps have a time delay associated with other controls.
- Assuming a 50% loaded typical 24 volt class II control transformer delivers approx. 6% higher voltage than nominal.
- AC line voltage for pick-up would be 75%-6% = 69% 159/230v
- AC line voltage for drop-out would be 19-54% 44-124v

EPRI Voltage Disturbance Occurrence

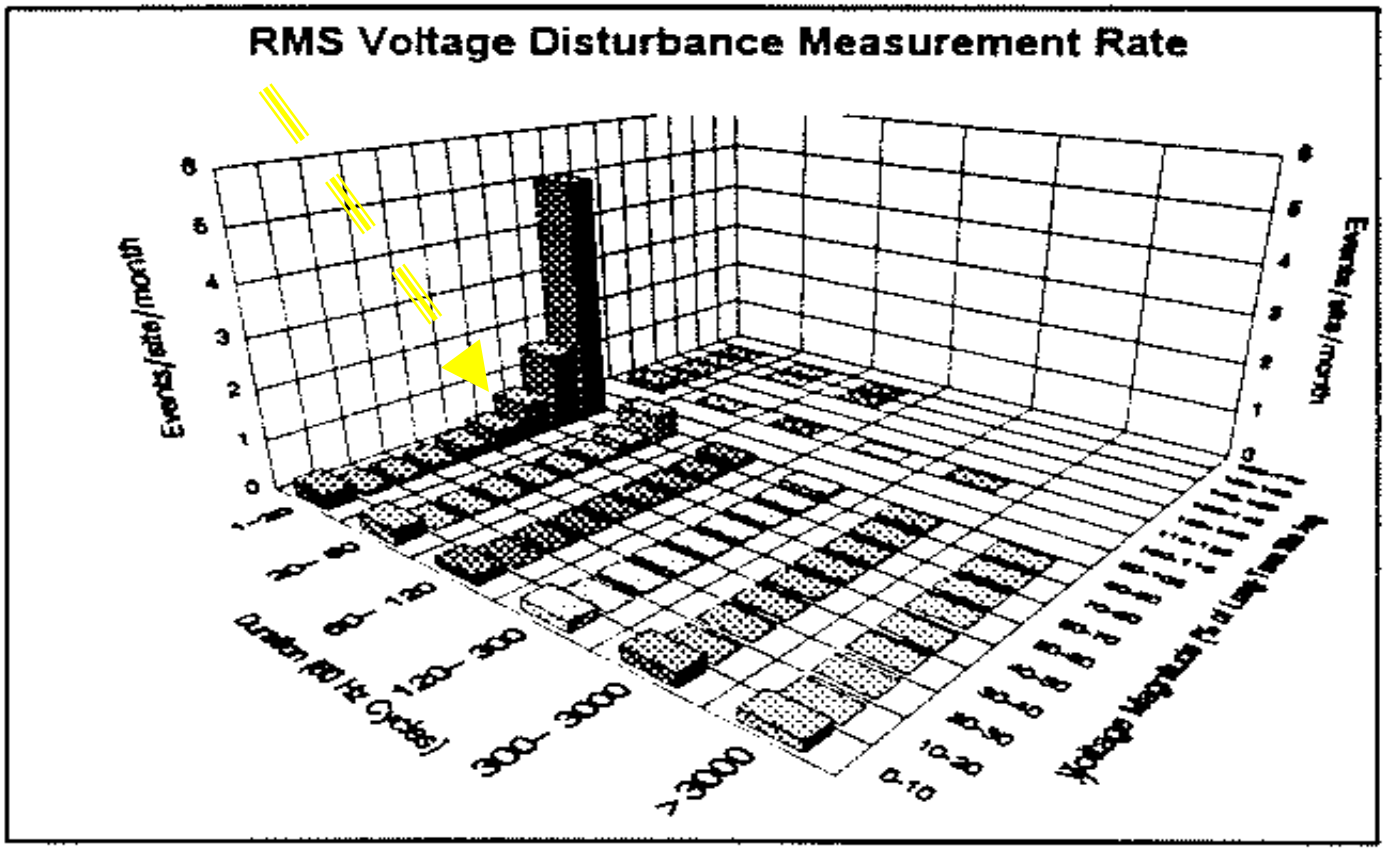

Figure 4: Two-variable histogram of the voltage magnitude and duration of all RMS Variations measurements, normalized on a per site per month basis; all EPRI monitors - 1/6/93 to 1/6/94

Conclusions

- The residential HVAC compressor protection system relies on the motor overload for primary protection and has shown to be a reliable system.
- Existing Air Conditioners and heat pumps over 3-5 years old may not have any short cycle protection.
- Electro mechanical thermostats have no short cycle protection.
- Electronic thermostats provide short cycle protection (various methods)
- Some new equipment has short cycle protection that detects only the loss of power.
- Existing controls are 24 volts and do not directly sense line voltage.
- The very large installed base of equipment dictates a field installed solution to be effective.
- The solution should monitor line voltage and provide a off delay with random restarts. This control feature could be added to load management controls.

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