Residential Air Conditioning and Heat Pump Response to Voltage Disturbances

Robert Helt
Leader Advanced Controls Development
Trane Residential

April 22, 2008
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.
A.O. SMITH
ELECTRICAL PRODUCTS COMPANY

Model: SA3882  EPTS: 0443003A  Crun: 30  Cstart: 0
Date: 1/13/2005  WTS: 0443003
Customer: TRANE TYLER

Voltage 1 2 3 4 5

180 200 230 253

Run Condition

Page 1 of 4
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.
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

Starting Current

Current (in RMS Amps)

Time (in 60-Hz cycles)
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.
• 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.
Residential Systems

Control Transformer Regulation

NEMA ST-2, Standard Regulation Curves, Upper and Lower Bounds
Sample Output Curves, In Spec. and Out of Spec.

- Nominal Input, Upper
- Nominal Input, Lower
- 110% Input Voltage, Upper
- 110% Input Voltage, Lower
- 90% Input Voltage, Upper
- 90% Input Voltage, Lower
- 110% Input Voltage, In Spec.
- 110% Input Voltage, Out of Spec.
- Nominal Input, In Spec.
- Nominal Input, Out of Spec.
- 90% Input Voltage, In Spec.
- 90% Input Voltage, Out of Spec.
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
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.