Residential AC Compressor
Low Line Voltage Behavior

DOE Workshop 22 April 2008

Jay Jayanth
Hung Pham
Emerson Climate Technologies
AC Compressor Under-Voltage Stall

• Background
  – SCE & Other Utilities Have Reported Instances Of Residential AC Units Stalling When Line Voltages Dip Fast Due To Grid / Feeder Faults. When Large Numbers Of Units Stall At The Same Time, The Grid Voltage Does Not Recover Quickly After The Fault Has Been Cleared Due To The Excessive Reactive Power Demand From The Stalled AC Units. The Fear Is That This Localized Delayed Voltage Recovery Can Spread Very Rapidly To Other Areas On The Grid Leading To Wide-Spread Voltage Collapse.

• Presentation Objective
  – Share Basic Compressor Design Attributes That Drive Its Behavior Under Low Voltage Conditions
Residential Scroll Compressor

- Discharge
- Suction
- Compression Mechanism
- 1-Phase Motor
  - Stator
  - Rotor
- Thermal Protector
Speed-Torque Curves As f (Voltage)

Residential Single-Phase Compressor Motor

Lower Voltage
Compressor Motor Current As f (Voltage, Load)

Compressor Motor Current (amps)

1.5-Ton Compressor

Compressor Stalling Domain

Typical Designed Protector Trip Point

Max Operating Current (UL MCC)

Rated 230v Voltage

Tcond Tamb
(30° delta T)

155° 125°
145° 115°
125° 95°
100° 70°

Compressor Motor Voltage

Compressor Motor Current As f (Voltage, Load)

Compressor Motor Voltage

140 150 160 170 180 190 200 210 220 230 240 250

Compressor Motor Voltage

145° 115°
125° 95°
100° 70°

1.5-Ton Compressor
Typical Motor Protector Drivers / Response

Tuned To Trip
If Motor Winding Temperature > Safe Operating Temperature (eg. 285°F)

Motor Current

Locked Rotor / Stall Regime

Overload Regime

Loss Of Cooling Regime

Time To Trip

1 Sec 3 Sec 15 Min >15 Min

4-6x \( I_{\text{rated}} \)

\( I_{\text{rated}} \)

4-6x \( I_{\text{rated}} \)

Aux Wdg \( I^2R \)

Main Wdg \( I^2R \)

Location Ambient

Aux Wdg \( I^2R \)

Main Wdg \( I^2R \)

Location Ambient

Aux Wdg \( I^2R \)

Location Ambient

**Not to scale**
Actual Response To Slow Voltage Changes (Secs)
Response To Fast Voltage Transients (Cycles)

Compressor @ 45/145° Tevap/Tcond

- Voltage: 170v
- Current: 27A

Motor Stalls 7.0 secs Later

Protector Trip 12 cycles
Summary

• **Compressor Motor Designed To**
  – Meet Max-Load Torque (Typical 115° - 125°F Outdoor Ambient) At Low Line Voltage Condition (Typical 187VAC)
  – Start At Low Line Voltage Condition (Typical 187VAC)

• **Current Protection Leads To Observed Behavior Under Low Voltage Conditions**
  – Time To Trip Protector When Rotor Stalls Is In Seconds
    • 3 to 15 Secs
  – Protector Trip Actuation Is Thermally Driven
    • Not Designed To Respond To “Transient” Low Voltage Dips < 1 Sec

• **No Known Commercially-Available Solution Today**
  – Can Be Developed