End-Use Testing at BPA

2015 NERC-DOE FIDVR Workshop

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BPA End-Use Testing Lab

<< Temperature controlled chamber

Controllable power supply >>

Measurement System >>
Residential Air-Conditioner Tests

BPA, SCE and EPRI tested independently a number of single phase air-conditioners

Tests included voltage sags, ramps, oscillations, as well as frequency excursions

Learned in the first round:
- Residential air-conditioners stall for a sudden drop in voltage to 50%-60% of nominal in less than 3 electrical cycles
- Once stalled, residential air-conditioner remain stalled even when the voltage is recovered, until coolant pressure is equalized
- Thermal protection trips in 5 to 30 seconds
Test Findings:
Compressor Motor Steady-State Loading

- Compressor loading and stall voltage depend on the ambient temperature
- Compressor motors have high power factor ~0.97 when running
(a) Torque-Speed Curves

1 phase supply, 2 winding, capacitor-run motor

- Three phase motor elec. torque
- Single phase motor elec. torque
- Load torque
(b) Compressor Motors Inertia is Very Low

H = 0.03 – 0.05 seconds

E.g. 3.5-ton compressor motor:  
Weight: 4.6 kg
(c) Compressor Load Torque in very cyclical

It is very possible that the motor stalls at the next compression cycle.
Compressor Motor Tests – Power-Voltage Trajectories

*note motor load and stall voltage increase with temperature
Motors stall when voltage drops below $V_{\text{stall}}$ for duration $T_{\text{stall}}$

A fraction $F_{\text{rst}}$ of the aggregated motor can restart when the voltage exceeds $V_{\text{rst}}$ for duration $T_{\text{rst}}$
System Studies

Studies done with developed AC models were much more conservative compared to actual experience: the model indicated greater and wider FIDVR phenomenon compared to actual experiences

...Back to the drawing board...
BPA, John Undrill and Bernie Lesieutre found a “common mode failure” mode in SCE-BPA-EPRI testing - all voltage sags were sudden and applied at voltage waveform zero-crossing.

Additional testing done at BPA in collaboration with John Undrill and Bernie Lesieutre showed that air conditioners tend to be less prone to stalling when the fault is applied at the waveform peak, or voltage is ramped down instead of sudden steps down.
AC Stall, Instantaneous Voltage Dip

Previously thought

Zero Crossing

Peak

45°
AC Stall, 1 Cycle Ramp in Voltage Dip

Previously thought

Peak

Zero Crossing

45°
Next Steps

1. Update AC “performance” model

2. Add dynamic MOTORC model to composite load model

3. Continue benchmarking positive sequence models (GE PSLF and PSS®E) with point on wave models (PSCAD)
Thank You