7313 William Barry Blvd.
N. Syracuse NY, 13212
United States
1-800-365-5525
info@icmcontrols.com

ICM CONTROLS®

COMPRESSOR PROTECTION IN PEAK HEATING SEASON.

ARE HIGH TEMPERATURES THE CAUSE OF FAILURE?

USA INNOVATION

www.icmcontrols.com

Executive Summary

When outdoor temperatures climb into the 90s and 100s, an air-conditioning or refrigeration compressor is asked to do some of its hardest work of the year. Systems run longer. Condensing temperatures rise. Electrical demand increases across buildings and utility distribution systems. Equipment that operated without an obvious problem in April can suddenly struggle in July or August.

But extreme outdoor temperature is rarely the entire story behind a failed compressor.

The more important question is often: What was happening electrically while the compressor was operating under peak load?

Low voltage, voltage imbalance, phase loss, rapid cycling, momentary power interruptions and surges can all become especially damaging when a compressor is already operating for extended periods. Compressor manufacturers themselves incorporate protection for conditions such as low voltage, locked rotor and excessive discharge temperature because these conditions can lead to equipment damage.

For contractors and electricians, this changes the conversation from simply replacing a failed compressor to understanding why it failed and what can be done to keep the replacement from experiencing the same conditions.

This paper explains the electrical risks that become more significant during peak summer operation, reviews real-world events involving air-conditioning compressors, and outlines practical protection strategies using voltage monitoring, anti-short-cycle controls and surge protection.

KEY IDEA

Peak heat increases operating stress. Power-quality protection helps keep abnormal electrical conditions from becoming compressor failures.

Why Summer Heat Is a Stress Multiplier

During hot weather, cooling equipment spends more time at high load. At the same time, utility systems, building distribution equipment, conductors, disconnects, contactors, and transformers may also be carrying heavier demand. A marginal condition that was invisible in spring can become a problem when the system is asked to start and run repeatedly under peak conditions.

This does not mean every summertime compressor failure is a “heat failure.” A grounded winding, locked rotor, open overload, or burned terminal describes the failure found in the field. It does not, by itself, establish the root cause.

What the compressor may experience

- Under voltage or brownout: voltage remains present but falls outside the compressor’s intended operating range.
- Rapid restart: power returns while the thermostat is still calling, and the compressor is commanded back on before an appropriate delay has passed.
- Three-phase abnormalities: phase loss, reversed phase sequence, or voltage/phase imbalance.
- Transient surge: a short-duration increased voltage event associated with lightning, switching, outages, or power restoration.
- High refrigeration load: dirty condenser coils, poor airflow, abnormal refrigerant conditions, or elevated head pressure add thermal and mechanical stress.

Low Voltage Can Stall a Compressor Quickly

Low voltage is dangerous because the equipment may remain energized while the motor can no longer start or run normally. Low supply voltage and locked-rotor conditions can also lead to damaging the compressor, that's why it's important to protect electronics and continuously monitor motor current and voltage in order to help identify these issues before further damage occurs.

In addition, when voltage falls significantly during compressor startup, the motor may not develop enough torque to accelerate normally. Instead of starting, it can stall.

A stalled compressor can draw very high current while producing little or no useful mechanical output. The result is rapid motor heating until an overload or another protective device opens the circuit.

Waiting for the internal overload to trip should not be considered the preferred first line of protection.

Research from Oak Ridge National Laboratory reports that modern air-conditioner compressor motors can stall in less than three electrical cycles when a fault causes voltage to sag to roughly 60%–70% of nominal. Once stalled, the motor can draw heavy current and generate heat while producing little useful mechanical work (Kueck et al.).

REAL-WORLD CASE 01 | SOUTHERN CALIFORNIA

A Summer Voltage Disturbance Stalled Residential A/C Compressors

Southern California Edison documented delayed voltage recovery following power-system faults and identified stalled single-phase air-conditioner compressors as the root cause in studied events. SCE's later test procedures identify August 5, 1997, as a significant event: system voltage dropped below 60%, many residential compressor motors stalled, reactive-power demand increased, and voltage recovery was delayed (Williams, Schmus, and Dawson; Robles, "Residential Air Conditioner with VFD Test Procedures").

FIELD LESSON: A momentary voltage problem can create a compressor problem that outlasts the original electrical disturbances.

Three-Phase Systems Add Phase-Quality Risks

Commercial HVAC and refrigeration equipment introduces another important summer consideration: three-phase voltage imbalance. Three-phase equipment requires more than a quick check that "all three legs have voltage." Phase loss, phase reversal,and phase imbalance can create severe operating problems. It may also require checking incoming power, motor behavior, current transformers, and even installing a meter/recorder when the problem is intermittent.

A system can appear to have "about the right voltage" while still exposing a compressor to damaging conditions.

For example, measuring:

- L1 to L2
- L2 to L3
- L3 to L1

may reveal three voltages that individually look reasonable but are not sufficiently balanced with one another. That imbalance can produce a much greater imbalance in motor current and additional winding heat.

HVAC industry guidance has long warned that voltage imbalance exceeding roughly 2% can contribute to elevated winding temperatures and compressor motor overheating.

This is especially important during summer because the compressor may already be running for long periods.

For contractors and electricians, the important habit is to record all three line-to-line voltages under load and evaluate the readings as a set. A system can show voltages that look individually reasonable while still being unacceptably unbalanced for the connected equipment.

Single-Phase vs. Three-Phase Protection Matrix

Match the protection function to the failure modes that are credible for the application. More protection is not automatically better; correctly applied protection is better.

Protection Concern	Single-Phase	Three-Phase	Why it Matters During Peak Summer Heat
Under voltage / Brownout	Important	Important	Can contribute to difficult starts, stalling, abnormal current, and motor heating.
Over voltage	Important	Important	Can stress motors, capacitors, drives, controls, and insulation systems.
Surge Protection	Recommended	Recommended	Helps address short-duration transient events from lightning, switching, outages, and restoration.
Anti-Short-Cycle Protection	Important	Important	Prevents immediate restart after shutdown or a power disturbance.
Phase Loss	N/A	Critical	A missing phase can severely stress three-phase motors and equipment.
Phase Reversal	N/A	Critical	Incorrect sequence can cause improper operation of phase-sensitive equipment.
Voltage/Phase Imbalance	N/A	Critical	Unequal phase conditions can product unbalanced current and additional motor heating.
Fault History/Diagnostics	Helpful	Highly Helpful	Provides evidence when an intermittent event is gone before the service call.

Application examples with ICM Controls

Single phase: The ICM493 combines over/under voltage monitoring, anti-short-cycle protection, surge protection, a built-in 40A contactor, and retained history of the five most recent faults. The ICM493-60A provides the same protection concept with a 60A contactor for larger applications (ICM Controls, “ICM493”; ICM Controls, “ICM493-60A”).

Three phase: The 3VMS-60-208 monitors over/under voltage, phase loss, phase reversal, phase unbalance, and rapid short cycling; it also incorporates surge protection, a real-time clock for fault timestamps, and a separate three-pole 60A contactor (ICM Controls, “3VMS-60-208”).

Control-circuit option: For applications where a dedicated compressor-control delay is appropriate, the ICM206 provides brownout protection, prevention of low-voltage starts, and an adjustable 3–10 minute anti-short-cycle delay (ICM Controls, “ICM206”).

Surge Protection and Voltage Monitors Solve Different Problems

Surge protection is important, but contractors should understand what it does and what it does not do:
- A surge protective device is intended to address short-duration transients voltage spikes.
- A voltage monitor evaluates whether the incoming operating voltage remains within acceptable limits.
- An anti-short-cycle control regulates when the compressor is allowed to restart.

Those are three different functions.

A compressor may therefore be exposed to:

- A surge: A high-energy transient that can damage windings, circuit boards, drives or other electronics.
- A brownout or under voltage condition: Supply voltage remains present but falls outside the acceptable operating range.
- A rapid restart: Power returns and the compressor is commanded back on before an appropriate delay has passed.

Three-phase problems:
Phase loss, phase reversal or excessive voltage imbalance.

Installing only one type of protection does not automatically address all three conditions.

That is why compressor protection should be approached as a system rather than as a single component.

Practical Protection Strategy

The goal is not to add controls simply for the sake of adding controls. The goal is to identify which electrical failure modes are credible for the equipment and then select protection that addresses them.

Single-Phase Condensing Equipment

For valuable single-phase HVAC/R equipment, contractors should consider both voltage quality and surge protection.

Educational Point

Monitor the line voltage before allowing the compressor to operate. If voltage is outside the intended operating window, disconnecting the compressor is generally preferable to allowing it to struggle through an abnormal condition.

For applications that require dedicated transient surge protection rather than combined voltage monitoring, ICM offers single-phase surge-protection options including the ICM517A, ICM517A-Lite and related devices.

Three-Phase Equipment Requires More Than a Voltage Reading

Three-phase rooftop units, chillers, refrigeration systems and other commercial equipment should be evaluated for: over voltage, under voltage, phase loss, phase reversal, voltage imbalance, rapid restarting, and transient surges.

ICM’s current 3VMS-60-208 and 3VMS-60-480 protection platforms combine line-voltage monitoring and surge protection for three-phase applications. The integrated ICM450A+ PLUS monitors over/under voltage, phase loss, phase reversal and phase imbalance while also providing anti-short-cycle functionality and fault history information. That last capability, fault history, can be particularly useful for service.

Intermittent electrical problems are often difficult to diagnose because the technician arrives after the event has disappeared.

A unit may be operating normally when the service truck arrives at 9:00 a.m. even though it experienced repeated voltage problems during the previous afternoon's peak demand.

Protection that also records fault information gives technicians another diagnostic tool.

The conversation can move from:

"The compressor stopped yesterday." to: "The equipment was disconnected because a specific electrical condition occurred."Which is a much more useful starting point.

Field Case: A Grounded Compressor During Extreme Summer Heat

REAL-WORLD CASE 02 | CRYSTAL LAKE, ILLINOIS

A maintenance visit became an emergency A/C replacement

Four Elements Service Heating & Cooling documented a July 2026 service visit during a period of extreme heat in Crystal Lake, Illinois. The air conditioner was found inoperative, and testing confirmed that the compressor was shorted to ground. The contractor reported outdoor temperatures above 100°F and replaced the failed system (Four Elements Service).

The case does not prove that outdoor heat alone caused the internal electrical failure. That limitation is important. A summer failure should trigger a root-cause investigation that includes voltage, current, connections, starting components, condenser condition, airflow, refrigerant conditions, cycling history, and available fault records.

FIELD LESSON: The failed compressor tells you what happened. Good diagnostics determine why.

Diagnose the Cause, Not Just the Failed Part

Before condemning a compressor, determine whether the observed failure is the primary defect or the final result of another problem. Repeatedly replacing the compressor without correcting abnormal voltage, poor heat rejection, bad connections, inadequate restart delay, or phase problems can expose the replacement to the same stress.

- Measure supply voltage with the equipment operating under load.
- On three-phase equipment, record all three line-to-line voltages and investigate imbalance.
- Inspect disconnects, breakers/fuses, contactors, terminals, and splices for overheating, corrosion, or loose connections.
- Measure operating current and investigate repeated overload trips or difficult starts.
- Verify condenser airflow, coil condition, refrigerant conditions, and manufacturer operating limits.
- Review fault history when protection or OEM controls provide it.

Peak Summer Compressor Protection Checklist

Use this checklist during preseason maintenance, peak-season service calls and repeat compressor-failure investigations.

1 | CHECK THE POWER SUPPLY	
	Measure line voltage with the equipment running under load, not only while idle.
	Compare measured voltage with the equipment manufacturer’s acceptable operating range.
	For three-phase equipment, record all three line-to-line voltage measurements.
	Calculate voltage imbalance where applicable.
	Investigate significant voltage drop between the electrical source and the equipment.
	Check for evidence of recurring brownouts, utility disturbances or power-quality complaints
2 | INSPECT THE ELECTRICAL PATH	
	De-energize equipment following applicable electrical safety procedures before physical inspection.
	Inspect disconnects, breakers/fuses, contactors, terminals and splices.
	Look for discoloration, heat damage, pitting, corrosion or loose connections.
	Verify conductor and over current-protection sizing against equipment requirements.
	Inspect capacitors and starting components where applicable.
	Look for evidence of previous electrical or surge damage.
3 | CHECK COMPRESSOR OPERATION	
	Measure compressor operating current and compare it with manufacturer data and actual operating conditions.
	Investigate repeated internal-overload trips.
	Listen and test for difficult, delayed or failed starts.
	Determine whether the compressor has been rapidly cycling.
	Check for abnormal compressor temperature or unusual noise.
	If the compressor has failed, determine whether it is open, grounded, mechanically locked or otherwise electrically compromised before assuming the compressor itself was the root cause.
4 | CHECK THE REFRIGERATION SIDE	
	Inspect and clean the condenser coil as required
	Verify condenser-fan operation and airflow.
	Check refrigerant conditions using manufacturer-prescribed procedures.
	Investigate abnormal suction/discharge condition and high head pressure.
	Confirm operation is within the manufacturer’s guidelines.
5 | VERIFY THE PROTECTION STRATEGY	
	Single phase: over/under-voltage, surge protection, restart delay, and fault history as appropriate.
	Three phase: add phase loss, phase reversal, and phase/voltage imbalance protection.
	Confirm any external protection complements rather than conflicts with OEM controls.
	Use fault records to help diagnose intermittent events.

Protection as a Design and Service Discipline

Compressor protection is not a single accessory decision. It is a design and service discipline that connects electrical quality, controls, refrigeration conditions, and diagnostics. Contractors reduce callbacks when they identify the cause instead of only replacing the failed part. Electricians improve reliability when they evaluate voltage at the equipment under real load. Engineers and OEMs can reduce exposure by designing protection and diagnostics into the equipment architecture rather than adding them only after field failures appear.

ICM Controls' role in that process is most useful when it is application-driven: identify the failure mode, understand the OEM protection already present, and apply the appropriate monitoring, delay, phase supervision, and surge-protection functions. The objective is not to add controls for their own sake. The objective is to keep abnormal electrical conditions from reaching the compressor long enough to become expensive failures.

For contractors and technicians

Use protection as part of the diagnostic conversation. A recorded under voltage, phase, or restart fault can shorten troubleshooting time and provide a defensible explanation for why a unit was taken offline. When no fault history exists, document measured voltage, current, temperatures, and refrigeration conditions so the next service call starts with evidence rather than assumptions.

For engineers and OEMs

Treat compressor protection as a coordinated system. Define acceptable voltage windows, restart behavior, phase supervision, surge strategy, and fault reporting alongside contactor ratings, compressor operating envelopes, and control logic. Where OEM controls already provide protection, external devices should be selected and set so that trip thresholds and delays complement the equipment sequence rather than create nuisance cycling or conflicting resets.

For facility and asset owners

A repeat compressor failure is a reliability signal. Ask for the service record, measured electrical conditions, fault history, and the corrective action taken beyond replacement of the compressor itself. The cost of one additional diagnostic visit is small compared with repeated compressor replacement, lost cooling, product loss, tenant disruption, or emergency summer service.

Work Cited

Four Elements Service Heating & Cooling. “Same-Day AC Install: Restoring Cooling During a 100°F Crystal Lake Heat Wave.” Four Elements Service, 4 July 2026, https://fourelementservice.com/emergency-ac-installation-crystal-lake il-heat-wave/. Accessed 11 Aug. 2026.

ICM Controls. “3VMS-60-208.” ICM Controls, https://www.icmcontrols.com/product/3vms-60-208/. Accessed 11 Aug. 2026.

ICM Controls. “ICM206.” ICM Controls, https://www.icmcontrols.com/product/icm206/. Accessed 11 Aug. 2026.

ICM Controls. “ICM493.” ICM Controls, https://www.icmcontrols.com/product/icm493/. Accessed 11 Aug. 2026.

ICM Controls. “ICM493-60A.” ICM Controls, https://www.icmcontrols.com/product/icm493-60a/. Accessed 11 Aug. 2026.

Kueck, John D., et al. “Local Dynamic Reactive Power for Correction of System Voltage Problems.” Oak Ridge National Laboratory, Dec. 2008, https://www.ornl.gov/publication/local-dynamic-reactive-power-correction-system-voltage problems-0. Accessed 11 Aug. 2026.

Robles, Steven. “Commercial 3-Phase Rooftop Air Conditioner Test Report.” Prepared for Lawrence Berkeley National Laboratory by Southern California Edison, June 2015, https://certs.lbl.gov/publications/commercial-3-phase rooftop-air.html. Accessed 11 Aug. 2026.

Robles, Steven. “Residential Air Conditioner with VFD Test Procedures.” Prepared for Lawrence Berkeley National Laboratory by Southern California Edison, 2013, https://eta.lbl.gov/publications/residential-air-conditioner-vfd-test. Accessed 11 Aug. 2026.

Williams, B. R., W. R. Schmus, and D. C. Dawson. “Transmission Voltage Recovery Delayed by Stalled Air Conditioner Compressors.” IEEE Transactions on Power Systems, vol. 7, no. 3, Aug. 1992, pp. 1173–1181. Lawrence Berkeley National Laboratory, https://certs.lbl.gov/publications/transmission-voltage-recovery-delayed.html. Accessed 11 Aug. 2026.

Technical note: This white paper is educational and is not a substitute for equipment manufacturer instructions, electrical codes, jobsite safety procedures, or application-specific engineering. Always verify ratings, settings, compatibility, and installation requirements for the actual equipment being serviced or designed.