ISLAND BREEZE TECHNICIAN CERTIFICATION PROGRAM

Inverter and Variable Speed Systems

MODULE A33 | ADVANCED SYSTEMS | PREREQ A32

The scene: A two-year-old variable speed heat pump, no-cool call, 109F afternoon. You hook gauges the way you have a thousand times. Suction is 142 psig and falling. Thirty seconds later it is 121. A minute after that, 96 and still moving. Superheat says 2F, then 14F, then 7F. A tech trained only on single speed equipment looks at those numbers and sees a system possessed: overcharged, then undercharged, then maybe a TXV hunting. None of that is happening. The compressor is ramping, changing speed on purpose, and every number on your manifold is chasing a moving target. Meanwhile the outdoor board has been holding the actual answer the whole time: a stored fault code pointing at a DC voltage problem from last night's monsoon storm. This module teaches you how these systems work, why your fixed-speed instincts mislead you on them, and the diagnostic order that gets to the truth: codes first, gauges last, and a capacitor bank you treat like a loaded weapon in between.

A32 taught you communicating systems: the four-wire serial bus, how the indoor and outdoor units negotiate, and how to commission and pair them. This module goes inside the box that bus talks to. Variable speed equipment is communicating equipment plus power electronics: a drive that converts incoming AC to DC and back to variable frequency AC, an inverter compressor that is secretly a three phase motor, and ECM blower motors with their own electronics. The diagnostic discipline from D26 still applies, the compressor is still innocent until a documented sequence proves it guilty, but the sequence itself changes, and one new safety rule sits on top of everything: the DC bus capacitors hold lethal charge after power is off, and you verify discharge before you touch.

Short Version

A variable speed system rectifies incoming AC to a high voltage DC bus (around 310 to 340 VDC on a 230V single phase supply, higher on boost designs), then chops that DC back into variable frequency three phase AC using pulse width modulation. That is why every inverter compressor is a three phase motor, even in a single phase house. Variable capacity means long, low speed runtimes: better humidity removal, smaller temperature swings, and big efficiency gains at part load. It also means your fixed-speed habits lie to you: gauges read garbage mid-ramp, there is no locked rotor inrush, and superheat and subcooling snap judgments are worthless until the system holds a known steady speed. The diagnostic order is fixed: fault codes and manufacturer service tools first, then a forced or stable test speed before any refrigerant judgment, then electrical work in safe order: power off, wait, and measure the DC bus down below 50 VDC before touching the board or compressor wiring. The DC bus capacitors hold a lethal charge after power-off; verifying discharge with your own meter is mandatory, every time. Drive faults, compressor faults, and sensor faults each leave different evidence; most "bad inverter boards" are misdiagnosed, and the manufacturer tech line, called with model, serial, fault history, and measured values in hand, is a diagnostic tool, not a surrender.

Key Values

ITEM	VALUE	NOTES
DC bus voltage, 230V single phase input	Roughly 310 to 340 VDC (line voltage times 1.414)	Measured across the DC bus test points or capacitor terminals; check the service manual for the exact spec
DC bus voltage, PFC boost designs	Can run 350 to 400 VDC by design	Power factor correction stage boosts above simple rectified value; a "high" reading may be normal, check the spec
Safe-to-touch DC bus threshold	Below 50 VDC and still falling, verified with your own meter	Never trust the bleed resistor, the wait time alone, or a discharge LED
Typical capacitor discharge wait	5 to 15 minutes after power-off, per the unit label	The label time is the minimum wait, not a substitute for measuring
Inverter compressor windings	Three phase: all three phase-to-phase readings equal, often under 2 ohms	Recall D26: zero your leads; at these resistances lead error condemns good compressors
Inverter compressor winding to ground	No continuity on an ohmmeter; megohm test per D26 rules	Pressure in the shell, never under vacuum
PWM output to compressor	Variable frequency three phase; a standard meter reading is approximate at best	Pulse width modulated waveform; clamp amps on all three legs are the more useful check
ECM motor winding resistance (motor half)	Under 20 ohms winding to winding, all three nearly equal	Measured at the motor plug with the module disconnected
ECM constant torque (X13 type) command	24VAC between the energized speed tap and common	No 24V at the tap means no call: board or wiring problem, not the motor
ECM constant airflow (variable speed) command	Line voltage always present, plus serial data from the board	Motor that is powered but never commanded is not a failed motor
Stabilization before charge judgment	10 to 15 minutes minimum at a fixed, known commanded speed	Use the manufacturer test or forced speed mode where available
Readings after a defrost cycle	Unstable for about 60 minutes	NIST measured two phase refrigerant lingering in the vapor line that long
Oil return cycle	Periodic commanded high speed run after extended low speed operation	Normal behavior; a few minutes of "racing" is not a fault
Soft start inrush	No locked rotor event; drive ramps frequency from near zero	Recall D26: LRA of 6 times run amps is a fixed-speed signature, absent here

ITEM	VALUE	NOTES
Phoenix surge season	Monsoon, July through September	Multiple simultaneous electronics failures on one system point to surge
ECM motor life in Phoenix dust	5 to 8 years typical	Versus 7 to 12 for PSC; dust and attic heat are the killers

Field Checklist

The inverter call order. Run it top to bottom; the whole point is that steps 1 and 2 happen before gauges and before any panel comes off the drive.

Step 1: Codes and history first

1. Pull fault codes at the outdoor board display, indoor communicating control, or manufacturer service tool BEFORE cycling power. Cycling power can erase the evidence.
2. Photograph the code display and write down the fault history in order: the oldest code is often the cause, the newest the symptom.
3. Look up what each code means in the service manual for THIS model. Code families differ by brand (A34 covers brand specifics).

Step 2: Watch it run, on its terms

1. Initiate a call and watch the ramp: does the compressor start soft and climb, or attempt and trip? Note how far into the ramp any shutdown happens.
2. Enter the manufacturer test mode or forced speed mode if available, command a fixed speed, and let the system stabilize 10 to 15 minutes before judging any refrigerant reading.
3. No test mode? Wait for steady state operation and confirm with the service tool or board display that speed is holding before trusting superheat or subcooling.

Step 3: Power down and prove the bus is dead

1. Disconnect pulled, lockout on, label wait time observed (typically 5 to 15 minutes).
2. Meter on DC volts across the DC bus test points or capacitor terminals. Verify below 50 VDC and falling. If it is not falling, stop and wait; never bleed it with a screwdriver.
3. Only after the verified reading do hands go on the board, the compressor wiring, or the reactor.

Step 4: Electrical checks in order

1. Incoming supply: voltage at the unit within the nameplate window, connections tight, signs of surge (scorched MOVs, burned traces, swollen capacitors).
2. Board power supply stages: confirm the low voltage supplies the board makes for itself where test points are documented, fuses intact.
3. Compressor windings, power verified off and bus verified discharged: all three phase-to-phase readings equal (recall D26), no continuity to ground, megohm with pressure in the shell.

Step 5: ECM blower, if the complaint is airflow

1. Verify high voltage at the motor power terminals first.
2. Verify the command: 24V at the speed tap (constant torque) or confirmed data call from the board (constant airflow).
3. Power and command present, shaft free, motor does nothing: now you are allowed to talk about the motor or module. Windings under 20 ohms and equal at the motor plug points the verdict at the module.

Step 6: Verdict or phone call

1. Drive fault, compressor fault, or sensor fault: name which one the evidence supports.
2. Evidence ambiguous or the manual dead-ends: call the manufacturer tech line WITH model, serial, full fault history, and your measured values written down before you dial.

> **IB STANDARD**
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> Every inverter board condemnation at Island Breeze requires three things in the ServiceTitan job record before the part is ordered: the photographed fault code history, the measured DC bus voltage (and the discharge verification reading), and either a passed compressor winding check or the tech line case number confirming the board diagnosis. Boards are the most misdiagnosed part on variable speed equipment, and an undocumented board swap is a guess at the customer's expense.

Full Breakdown

Why the equipment changed: capacity that fits the load

A single speed system has two settings: everything and nothing. On a Phoenix design day at 112F it runs flat out and barely keeps up, which is what it was sized for. But most of the year the load is a fraction of design, and the single speed answer to a small load is short, repeated full-blast cycles. Every cycle wastes energy on startup, swings the indoor temperature a degree or two around the setpoint, and gives the coil only a short window to wring moisture out of the air before shutting off and letting some of it evaporate right back.

Variable capacity attacks all three problems by matching output to load. An inverter compressor can run anywhere from roughly a quarter of its capacity to slightly above its nominal rating, so on a mild day it settles into a long, quiet, low speed run that may last hours. The physics pays off three ways:

- **Efficiency at part load.** Slower compressor speed means lower refrigerant flow through the same size coils, so the coils are effectively oversized for the moment. Head pressure drops, suction rises, the compression ratio shrinks, and the compressor does dramatically less work per BTU moved. This is where the high SEER2 ratings on variable speed equipment actually come from: not magic, just small compression ratios at part load.
- **Humidity control.** A long low speed run keeps the indoor coil cold and the air moving across it slowly, which is the recipe for latent removal. Phoenix is a dry market most of the year, but during monsoon humidity this is the difference customers feel.

- **Comfort.** Capacity that matches load means supply air that runs nearly continuously and a room temperature that holds within a fraction of a degree instead of sawtoothing.

The cost of those benefits is the subject of the rest of this module: a power electronics package between the breaker and the motor, and a system whose behavior no longer matches the fixed-speed instincts you built in the diagnostics track.

The drive chain: AC to DC to whatever AC the moment needs

The incoming power from the panel is fixed: single phase AC at line frequency, 60 cycles per second (Hertz, abbreviated Hz, the number of times the AC waveform repeats each second). A motor's speed follows the frequency feeding it, so fixed frequency means fixed speed. To vary the speed, the drive throws away the incoming frequency entirely and manufactures its own. It happens in three stages, and you should be able to sketch this chain from memory:

Stage 1: Rectification. A rectifier (a bridge of diodes, one-way valves for current) converts the incoming AC to DC. AC that swings positive and negative becomes lumpy one-direction DC.

Stage 2: The DC bus. A bank of large electrolytic capacitors smooths that lumpy DC into a stable high voltage reservoir called the DC bus. On a 230V single phase supply, the bus sits at the peak of the AC waveform: line voltage times 1.414, roughly 310 to 340 VDC. Many modern drives add a power factor correction stage (PFC, a boost circuit that draws current more smoothly from the line) that deliberately raises the bus higher, into the 350 to 400 VDC range. Know which design you are on before you call a bus reading high or low: the service manual states the expected value. The DC bus is also where the lethal hazard lives, and it gets its own section below.

Stage 3: Inversion. A set of fast power transistors (usually IGBTs, insulated gate bipolar transistors, switches that can turn hundreds of volts on and off tens of thousands of times a second) chops the DC bus into three output legs. By switching in a precise pattern, the drive builds three artificial AC waveforms, shifted apart from each other, at whatever frequency and voltage the control logic wants. The technique is pulse width modulation (PWM): the output is really a stream of fast DC pulses whose width varies, and the motor windings, which respond to the average, experience it as smooth AC. The high pitched whine you hear from inverter equipment is the PWM switching frequency, typically several kilohertz, singing in the windings.

Two field consequences fall straight out of this chain:

Every inverter compressor is a three phase motor. The drive makes three phase power from scratch, so the motor gets the better motor: three phase machines are simpler (no start winding, no run capacitor, no start relay), smoother, and more controllable. The house's single phase supply is irrelevant past the rectifier. This is why your D26 winding expectations change: no C, S, R with a sum check. Instead, three identical windings, and **all three phase-to-phase resistance readings should be equal**, often under 2 ohms on residential inverter compressors. Zero your meter leads (recall D26: at these resistances, lead error and a corroded terminal can fake a fault), and check each winding to ground exactly as before. The megohm rules from D26 carry over untouched: 500V DC, pressure in the shell, never under vacuum.

Your voltmeter cannot honestly read the drive output. The compressor leads carry PWM pulses, not a clean sine wave. A standard meter, even a true RMS meter, gives an approximation that varies with the meter and the switching frequency. Do not condemn anything based on "weird voltage" at the compressor terminals. The useful field measurements are the DC bus voltage (a clean DC value the meter reads honestly), clamp amps on the three compressor legs (which should be present and roughly balanced when the drive is driving), and the drive's own reported values through the service tool.

The DC bus: treat it like a loaded weapon

Here is the sentence to memorize before anything else in this module: **the DC bus capacitors hold a lethal charge after the power is off, and you verify discharge with your own meter before you touch anything.**

A capacitor is a storage device. The run capacitors you have discharged since F1 store enough energy to bite. The DC bus capacitors on an inverter board are a different class: hundreds of volts DC across a large capacitor bank, enough stored energy to stop a heart, and no contactor or disconnect between that stored charge and the board you are about to put your fingers on. Pulling the disconnect stops the refill; it does nothing to the charge already in the bank.

Drives include bleed resistors intended to drain the bus over several minutes, and the unit label states a wait time, typically 5 to 15 minutes. Here is why neither one is good enough on its own: bleed resistors fail open, and when one does, the bus holds its charge for hours. A failed bleed resistor produces no symptom you can see. The label wait time assumes the bleed circuit works. So the rule is layered, and every layer is mandatory:

1. **Disconnect pulled and locked out.** Power verified off at the line side, the F1 habit.
2. **Wait the labeled time.** The wait is the minimum, not the verification.
3. **Measure the bus yourself.** Meter on DC volts, across the marked DC bus test points or, where there are none, across the capacitor bank terminals per the service manual. You want **below 50 VDC and still falling**. Watch it move; a reading that is low and dropping is a discharging bus, a reading that is high and frozen means the bleed circuit is dead and you wait, re-measuring, however long it takes.
4. **Never short the bus to discharge it.** A screwdriver across a charged DC bus is an arc flash, a destroyed board, and a tech who got lucky if that is all it is. If a manufacturer documents a discharge procedure through a resistor for their board, that procedure and only that procedure is acceptable; the default is to let the bleed circuit work and verify.

One more habit: capacitors can recover a small residual voltage after discharge (charge migrates back out of the dielectric, the insulating layer inside the capacitor). It will not be lethal after a verified discharge, but it is the reason you re-verify if you walked away from an open drive and came back ten minutes later.

> **IB STANDARD**
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> DC bus discharge verification is a recorded step on every Island Breeze inverter job, not a private habit. The job record gets the measured bus voltage after wait time, with a photo of the meter. Any tech found working on an open drive without a logged discharge verification is pulled from inverter work until retrained. There is no second version of this rule.

ECM blower motors: two families, one discipline

The indoor half of variable speed equipment is the ECM blower (electronically commutated motor: a brushless DC motor whose own onboard electronics, the module, do for the blower exactly what the inverter drive does for the compressor: rectify line AC to a DC bus and switch it into the motor windings). ECMs come in two families, and knowing which one you are facing decides your test sequence:

Constant torque (the X13 family). The simpler, cheaper ECM, common on mid-tier equipment. It receives line voltage at its power terminals full time, and it runs when it sees a 24VAC command on one of its numbered speed taps (each tap programmed at the factory to a torque level, which the motor holds regardless of static pressure, within limits). Think of it as a smart PSC replacement: thermostat-style 24V signals in, programmed torque out.

Constant airflow (the true variable speed family). The premium ECM. Line voltage full time, but the command is serial data from the equipment board, the same communicating philosophy as A32. The board asks for CFM; the module measures how hard the motor is working and adjusts speed continuously to deliver that CFM against whatever static pressure the duct system imposes. This is the motor that masks duct problems by muscling through them, drawing more watts the worse the ducts are (recall D25: a constant airflow ECM on bad ducts does not lose airflow, it loses efficiency and life expectancy).

The test discipline is the same for both families, and it exists because most condemned ECMs are not bad. The motor cannot run without three things, and you verify them in order:

1. **High voltage.** Line voltage at the motor's power terminals, matching nameplate (120 or 240). Some 240V motors have a jumper configuration; check it. No line voltage is a supply problem upstream, not a motor.
2. **The command.** Constant torque: 24VAC between the energized speed tap and common while there is a call. Constant airflow: confirm via the board's diagnostics or service tool that a CFM demand is active. **No command means no call, and a motor that was never asked to run is not a failed motor.** The fault is the board, the thermostat circuit, or the wiring.
3. **The motor itself, split from its module.** Power and command verified, shaft spins freely by hand (seized bearings are a motor verdict on their own), and still nothing: disconnect power, then separate the module from the motor and ohm the motor windings at the plug. **All three winding-to-winding readings under 20 ohms and nearly equal, with no continuity to the shell**, means the motor windings are healthy and the verdict lands on the module. An open, shorted, or grounded winding condemns the motor half. On many ECMs the module is replaceable separately, which turns a correct diagnosis into a cheaper, faster repair.

Two field notes worth keeping: ECMs hate unstable high voltage, so the same monsoon surges that kill inverter boards kill ECM modules, and a board-plus-blower double failure after a storm is a surge signature, not a coincidence. And ECMs in Phoenix live 5 to 8 years against 7 to 12 for PSC, mostly because dust packs the module heat sink and the motor cooks in a 140F attic; cleaning the module's cooling path during maintenance is real service, not ritual.

Ramping: why the system lies to your gauges

A fixed speed compressor gives you a step function: off, then 100 percent, with pressures settling to a readable state in a few minutes. An inverter system gives you a moving picture, and every habit you built reading the settled state will betray you while it moves.

Soft start. The drive ramps frequency up from near zero, so there is no locked rotor inrush, no 6-times-run-amps spike, no hard click and shudder. The familiar LRA diagnostics from D26 simply do not exist here. A drive that detects trouble during the ramp quietly aborts and logs a code instead of tripping a breaker, which is why the fault history holds evidence your clamp meter never saw.

The ramp itself. After start, the control ramps speed over several minutes while it hunts for the output the load needs, and during that hunt suction, head, superheat, and subcooling are all in motion. The numbers are not wrong, they are just answers to a question that keeps changing. **You cannot make fixed speed snap judgments mid-ramp.** A suction pressure that would scream "low charge" at 100 percent speed is unremarkable at 40 percent speed. Superheat readings swing as the EEV (electronic expansion valve, the computer controlled metering device on most of this equipment) chases the moving target right alongside you.

The discipline: force or wait for a known speed. Most manufacturers provide a test mode, charge mode, or forced speed function through the board or service tool that locks the compressor at a defined speed, usually full or a stated percentage. That mode exists precisely so charging targets in the service manual mean something. Enter it, let the system stabilize 10 to 15 minutes, and only then compare superheat and subcooling to the manual's targets for that mode. No test mode available? Let the system reach steady state on its own and confirm through the service tool or board display that speed is holding before you judge anything. The charging targets themselves come from the service manual for the specific model, not from the generic fixed-speed targets you memorized; a variable speed system in a low speed state can run numbers that would fail a fixed speed system while being perfectly healthy.

Oil return cycles. At low speed, refrigerant velocity in the lines drops, and oil that should ride the refrigerant back to the compressor starts settling in the piping. The control knows this and periodically commands a few minutes of high speed running to sweep the oil home. A customer who reports "it suddenly races for no reason, then calms down" is describing a feature. So is the tech who watches their stable test reading suddenly scramble: check whether an oil return event fired before chasing a ghost.

Defrost on variable speed heat pumps. D29's defrost fundamentals carry over, but variable speed machines manage frost more gradually: they can raise compressor speed to hold capacity as frost builds, and some run defrost at controlled speeds rather than a fixed-speed slam. The NIST measurement to burn in: after a defrost cycle, readings stay unstable for about 60 minutes because two phase refrigerant lingers in the vapor line. Heating season charge judgments on any heat pump, and doubly on a variable speed one, wait for a stable run well clear of a defrost event.

Diagnosing without the old cues: the inverter call order

Strip away the fixed speed cues (LRA, contactor click, settle-and-read gauges) and what remains is actually a cleaner discipline, because inverter equipment self-reports. The order matters more than anything else in this module:

1. Fault codes before everything, and before power cycling. The board logged what happened, with more context than you will ever reconstruct from gauges: which protection acted, at what point in the ramp, how many times. On some platforms a power cycle clears the history, so the code pull happens before you touch the disconnect. Photograph the display, write the codes in order, and read the history like a story: the oldest code is often the disease, the newest the symptom. Decode them against the service manual for this exact model; brand code families are A34's territory, but the habit of codes-first is universal.

2. The manufacturer service tool is a gauge set for the drive. Most platforms expose live data through the communicating control, a plug-in service tool, or an app: compressor commanded versus actual speed, DC bus voltage as the drive sees it, EEV position, every sensor reading. Two minutes of live data answers questions that an hour of manifold-watching cannot, including the killer question on intermittent calls: what did the system see at the moment it tripped?

3. Sensor faults: cheap parts, expensive misdiagnoses. The control runs on its sensors: outdoor ambient, coil temperatures, discharge temperature, suction pressure transducers. A drifted or failed sensor makes the control do strange things with a healthy refrigerant circuit (limit speed, abort ramps, run endless protective logic) and the symptom looks like a drive or compressor problem. Sensor checks are fast: compare each sensor's reported value against a reading you trust (your thermometer on the same line, resistance versus the thermistor table in the manual). Run them before any expensive verdict.

4. Power quality and the input side. Verify supply voltage at the unit under load against the nameplate window, inspect for surge evidence (scorched metal oxide varistors, the sacrificial surge clamping parts; burned board traces; swollen or vented capacitor tops), and check the incoming connections. Drives are the most voltage-sensitive equipment on the truck, and many "board failures" are the supply's fault.

5. The bus and the board, in safe order. Power down, lockout, wait, **verify discharge below 50 VDC**, then work. Measure what the manual documents: bus voltage during operation if test points are accessible safely (many boards expose marked test pads), fuses, the board's own low voltage power supplies where the manual gives test points. A drive whose control logic boots, reports codes, and communicates has a working power supply stage; one that is completely dark with good incoming power and good fuses is telling you where to look.

6. The compressor, last and by the old rules adapted. Bus verified discharged, compressor leads disconnected from the drive: three phase-to-phase readings, **equal, low, and compared against published values**; winding to ground on the ohmmeter; megohm per D26 (pressure in the shell, never under vacuum, cold oil caveat intact). A shorted or grounded inverter compressor can take the drive's output stage with it when it fails, so on any failed-drive finding, the windings get checked before the new board goes in. Installing a new board onto a shorted compressor executes the new board at first start.

7. Drive fault versus compressor fault versus sensor fault: the discrimination. The three families leave different evidence. A **sensor fault** shows as a sensor reading that disagrees with your reference instrument, usually with codes pointing at the sensor circuit. A **compressor fault** shows in the windings: unequal, open, shorted, or grounded readings with the drive disconnected, or a compressor that fails mechanically (will not rotate, no pumping at commanded speed with the drive proven). A **drive fault** is what remains when the supply is proven, the sensors are proven, the windings are proven, and the drive still will not produce balanced output: no amps on the three legs at command, codes pointing at the drive's own protections (overcurrent at zero ramp, bus undervoltage with a healthy supply, IGBT or module faults), or visible board damage. Notice the structure: the board is condemned by elimination plus evidence, never by default. That ordering is the whole defense against the industry's quiet epidemic of replacing good inverter boards.

8. The tech line is a diagnostic instrument. On communicating variable speed equipment, the manufacturer's technical support line has access to engineering data, known failure patterns, and serial-number-specific history you cannot have. Calling is not failure; calling unprepared is. Arrive with: model and serial numbers off the nameplate, the full fault code history in order, your measured values written down (supply voltage, DC bus voltage, winding readings, sensor comparisons), and what you have already ruled out. That call takes ten minutes and routinely saves a misdiagnosed board, a denied warranty claim, or a second trip. Get the case number and put it in the job record.

> **PHOENIX FIELD NOTE**
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> Monsoon season, July through September, is when Phoenix kills inverter boards. Lightning and grid switching send surges down lines that fixed speed equipment shrugs off but drive electronics absorb with their MOVs, their rectifiers, and their capacitor banks. Learn the surge signature: multiple electronics failing simultaneously on one system (inverter board plus ECM module plus thermostat is the classic trio), failures clustered in the neighborhood after a storm night, scorched MOVs and tripped whole-home surge protection. After every confirmed surge event, inspect everything electronic on the system, not just the part that died loudest, and document the evidence: surge damage findings affect warranty conversations, and a customer whose drive died in a storm deserves to hear that surge protection exists. A variable speed system is the most surge-sensitive equipment we install, in the most surge-prone season in America, and the service records prove it every August.

What this module deliberately does not cover

Three boundaries, so you know where to look next. Brand-specific fault code tables, service tool menus, and platform quirks (which button sequence enters test mode on which board) are A34. Communicating bus wiring, pairing failures, and commissioning were A32; if the indoor and outdoor units are not talking at all, that is an A32 problem before it is an A33 problem. And the full fixed speed compressor condemnation sequence, including the megohm ladder and the internal overload trap, lives in D26; this module adapts it, but the documentation discipline and the innocent-until-proven framing are identical.

Common Mistakes

1. **Judging charge mid-ramp.** Suction, superheat, and subcooling are all moving targets while the compressor hunts for speed. The fix is procedural: test mode or confirmed stable speed, 10 to 15 minutes of stabilization, then compare against the manual's targets for that mode. Every other read is noise.
2. **Touching the drive without verifying DC bus discharge.** The capacitor bank holds lethal voltage after power-off, bleed resistors fail open, and the label wait time assumes the bleed works. Below 50 VDC and falling, on your own meter, every time. This is the one mistake in this module that can be fatal.
3. **Power cycling before pulling fault codes.** On some platforms the reset erases the stored history, which was the single best evidence on the job. Codes first, photo taken, then you may cycle power.
4. **Condemning the board by default.** "It does not run and the compressor ohms fine" is not a board diagnosis; it is an incomplete one. Supply proven, sensors proven, windings proven, drive evidence gathered, then the board. Misdiagnosed inverter boards are the signature warranty abuse of this equipment generation.
5. **Hanging a new board on an untested compressor.** A shorted or grounded compressor winding can destroy the drive output stage, and it will do it again to the replacement at first start. Windings get verified before any board is replaced, no exceptions.

6. **Condemning an ECM that was never commanded.** No 24V at the speed tap, or no data call from the board, means nobody asked the motor to run. Verify high voltage AND the command before any motor or module verdict, then split motor from module with the winding test (under 20 ohms, equal, no ground).
7. **Reading the PWM output with a voltmeter and trusting it.** The compressor leads carry chopped pulses, not sine waves, and meters give approximations. Use the DC bus reading, three-leg clamp amps, and the drive's own reported data instead.
8. **Treating oil return and defrost behavior as faults.** A commanded high speed burst after a long low speed run is the system sweeping oil home, and readings within about 60 minutes of a defrost are unstable by physics. Know the system's deliberate behaviors before declaring any of them a problem.
9. **Calling the tech line empty handed.** Model, serial, ordered fault history, and measured values, written down before you dial. An unprepared call wastes the one resource that can see engineering data you cannot, and a prepared one routinely saves the diagnosis.

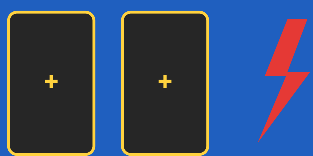
Module Visuals

DC BUS SAFETY

DC BUS SAFETY: THE CHARGE OUTLIVES THE POWER

The inverter capacitor bank holds a LETHAL charge after power-off

THE HAZARD



300+ VOLTS DC STORED

Pulling the disconnect stops the refill.
It does NOT touch the stored charge.

BLEED RESISTORS FAIL OPEN

No symptom, no warning. A dead bleed circuit holds the charge for HOURS.

High and frozen reading = wait and re-measure

1. DISCONNECT PULLED, LOCKED, TAGGED

Power verified off at the line side, both legs. The F1 habit, unchanged.

2. WAIT THE LABELED TIME (typically 5 to 15 min)

The wait is the minimum. It assumes the bleed circuit works. It is not proof.

3. MEASURE THE BUS YOURSELF

Meter on DC volts, across the marked bus test points or cap terminals.

BELOW 50 VDC AND STILL FALLING before you touch.

4. NEVER SHORT THE BUS TO DISCHARGE IT

A screwdriver across a charged bus is an arc flash and a dead board.

RE-VERIFY if you walked away and came back. Capacitors recover a small residual voltage after discharge.

IB rule: the discharge verification reading is photographed into the job record on every inverter job. No exceptions.

ECM BLOWERS: TWO FAMILIES, ONE TEST DISCIPLINE

An ECM is a brushless DC motor plus its own onboard drive (the module)

CONSTANT TORQUE (X13 family)

The smart PSC replacement on mid-tier equipment

POWER: line voltage, present full time

COMMAND: 24VAC at a numbered speed tap (measure tap to common)

BEHAVIOR: holds programmed torque per tap

No 24V at the tap = no call.
That is a board, thermostat, or wiring fault,
NOT a motor fault.

CONSTANT AIRFLOW (variable speed)

The premium ECM on communicating equipment

POWER: line voltage, present full time

COMMAND: serial data from the board (a CFM demand, not a tap)

BEHAVIOR: delivers commanded CFM against whatever static the ducts impose

Masks duct problems by working harder:
more watts, hotter module, shorter life (D25 recall).

THE TEST ORDER BEFORE ANY ECM IS CONDEMNED

1. HIGH VOLTAGE
Line voltage at motor power terminals

2. THE COMMAND
24V at tap, or data call confirmed

3. SHAFT + SPLIT THE HALVES
Spins free, then motor vs module test

MOTOR WINDINGS AT THE PLUG (module off)

Under 20 ohms winding to winding, all three nearly equal,
no continuity to the shell = healthy motor

Verdict lands on the MODULE

OPEN, SHORTED, OR GROUNDED WINDING

OL, unequal, or any reading to the shell,
or a seized shaft that will not spin by hand

Verdict lands on the MOTOR

INVERTER DIAGNOSTIC FLOW

THE INVERTER CALL ORDER

Codes first, bus verified dead, board condemned by elimination plus evidence

Some platforms erase history on reset: never power cycle first

1. PULL FAULT CODES + HISTORY
BEFORE cycling power. Photograph. Oldest code = the story.

↓

2. SERVICE TOOL + WATCH THE RAMP
Live data; note where in the ramp it fails. Test mode for any charge call.

↓

3. SAFETY GATE: POWER OFF + VERIFY DC BUS DISCHARGE
Lockout. Wait the labeled time. Measure the bus yourself:
BELOW 50 VDC AND FALLING before hands go in. Every time.

↓

4. SUPPLY + SURGE EVIDENCE
Voltage in window, tight lugs, scorched MOVs, swollen caps, burned traces

↓

5. SENSORS vs YOUR INSTRUMENTS
Cheap parts first: thermistor tables, transducer vs gauge, harness plugs

↓

6. COMPRESSOR WINDINGS (drive disconnected)
Three phase: all equal, low ohms, none to ground, megohm per D26

Never hang a new board on untested windings: a shorted compressor kills the replacement at first start

↓

SENSOR FAULT
Sensor disagrees with your reference instrument; codes point at the sensor circuit

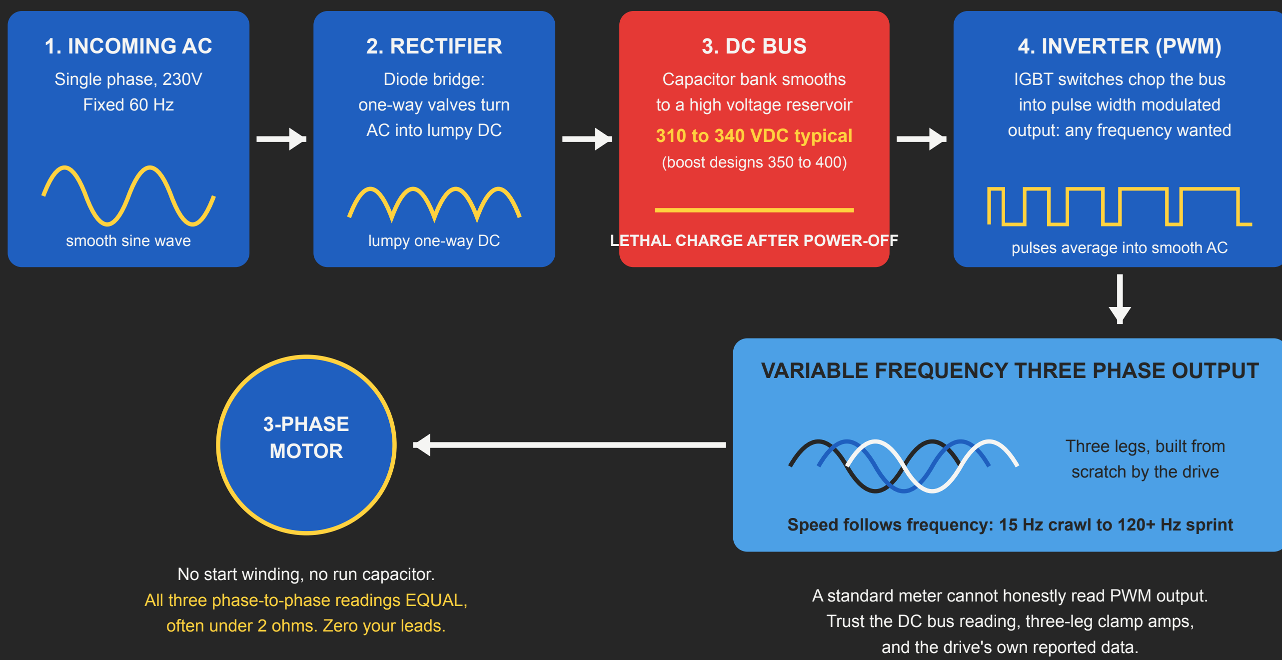
COMPRESSOR FAULT
Unequal, open, shorted, or grounded windings with the drive off, or no pumping at a proven commanded speed

DRIVE FAULT (by elimination)
Supply, sensors, windings all proven; no balanced output on the three legs; drive-protection codes or visible damage

Evidence ambiguous? Tech line, PREPARED: model, serial, fault history in order, measured values. Get the case number.

THE INVERTER DRIVE CHAIN: AC TO DC TO VARIABLE AC

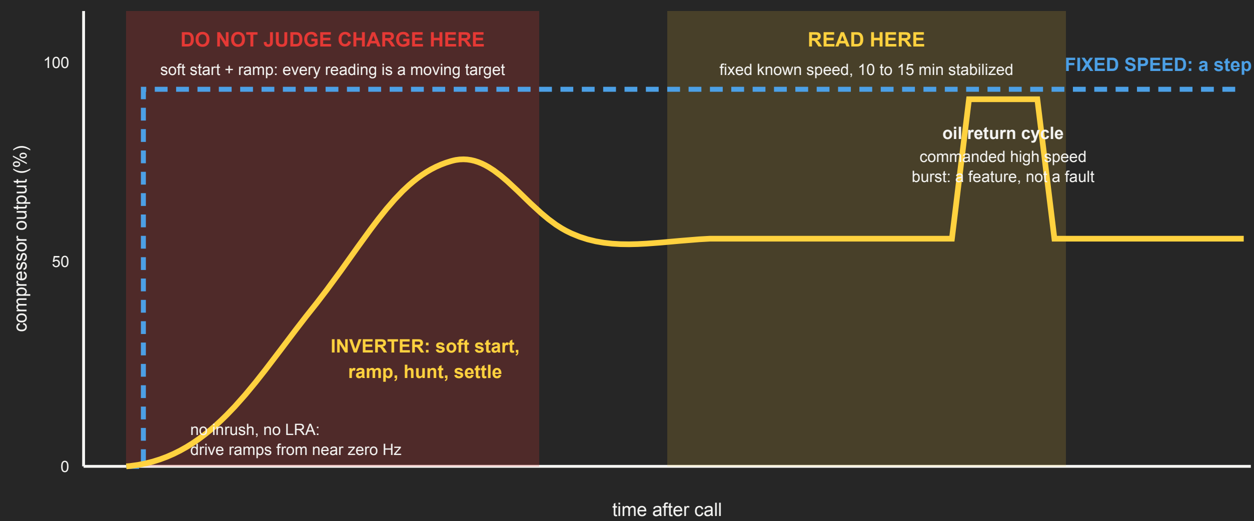
Why every inverter compressor is a three phase motor, even on a single phase house



RAMPING VS FIXED SPEED

RAMPING vs FIXED SPEED: WHEN GAUGES TELL THE TRUTH

Compressor output over time after a call for cooling



MID-RAMP READINGS LIE

Suction, head, superheat, subcool all move with speed.
A "low charge" number at 40% speed can be normal.
Fixed-speed snap judgments do not transfer.

THE DISCIPLINE

Test mode or forced speed, stabilize 10 to 15 minutes,
judge against the manual's targets for that mode.
After a defrost: unstable for about 60 minutes.