AEEM HVAC ENERGY VALVE

Prototype Design + Integrated Surge Protection Concept

A disconnect-adjacent HVAC energy monitor and adaptive supervisory controller designed to reduce avoidable HVAC energy use, detect performance degradation, and add a separately engineered surge-protective layer.

Prototype objective	Position
V0	Measure HVAC electrical + thermal behavior without interrupting compressor power
V1	Add low-voltage supervisory HVAC control after measurement is trusted
V2	Combine metering, diagnostics, supervisory control and a certified surge-protection stage
Installation concept	Adjacent to / upstream of the existing equipment disconnect; local disconnect remains accessible

1. Prototype Architecture

The first prototype should be measurement-first. Experimental electronics should not become the normal compressor disconnecting mechanism. Current sensing can be non-invasive, while any line-voltage measurement and enclosure work should use appropriately isolated, rated components and qualified installation practices.

V0 - Disconnect-Adjacent Monitor

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Panel / branch circuit
    |
    v
Existing HVAC disconnect ---- AEEM sensing enclosure
    |                  |- current sensing
    |                  |- voltage/power metering
    v                  |- temperature/humidity
Condenser / heat pump      |- local data + communications
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Measurement	Purpose
L1/L2 current + line voltage	True power, kWh, starts, steady-state load
Compressor/fan signatures	Identify operating state and abnormal electrical behavior
Supply + return air temperature	Estimate useful thermal response
Suction/liquid line temperatures	Trend refrigeration-side behavior without claiming diagnostic certainty
Outdoor temp + indoor temp/RH	Normalize performance for weather and latent load
Thermostat call state	Associate energy use with commanded operation
Cycle time / cycles per hour	Detect short cycling and poor recovery behavior

Core learned metric: energy consumed per useful thermal result under comparable weather, humidity and starting indoor conditions. This is an operating-performance index, not a claim that the device changes the compressor's intrinsic COP or SEER rating.

V1 - Supervisory Control

After V0 establishes trustworthy baselines, V1 adds an isolated low-voltage control bridge. Normal optimization should act through thermostat/equipment control signals rather than repeatedly removing 240 V power. Functions can include minimum off-time, minimum run-time, setback/recovery optimization, pre-cooling or pre-heating, tariff-aware scheduling, humidity-aware operation, and user-defined peak avoidance.

2. Integrated Surge Protection

Yes: the product can double as surge protection - if surge protection is explicitly designed, tested and certified as a separate function. A monitor, relay or controller is not automatically a surge protector. A surge-protective device contains non-linear protective components that limit transient overvoltage by diverting surge energy away from downstream equipment.

UL Solutions identifies UL 1449 as the principal safety standard used for surge protective devices (SPDs). For a permanently connected HVAC-adjacent product, the design team would need to determine the correct SPD type, voltage configuration, short-circuit current rating, voltage-protection rating, nominal discharge current and required upstream protection as part of certification.

Layer	Role
Branch-circuit overcurrent protection	Existing breaker/fuse remains the primary overcurrent protective device
AEEM surge stage	Clamps/diverts transient overvoltage; designed as an SPD function
AEEM measurement/control	Monitors energy and equipment behavior; does not substitute for the SPD
Existing HVAC disconnect	Remains the local servicing disconnect unless a future product is specifically listed to replace it
HVAC equipment	Downstream load receiving both monitoring and surge protection

Commercially this is valuable: the customer buys one outdoor HVAC-protection device that (1) protects against damaging transients, (2) measures actual energy, (3) learns system health, and (4) later enables adaptive savings. The surge-protection benefit exists from day one while the learning model is still accumulating data.

Design direction for V2

• Separate surge-protection PCB/module from metering and logic so surge events do not share sensitive low-voltage paths unnecessarily.

• Use status monitoring so the controller can report loss/degradation of the surge-protective element rather than silently leaving the condenser unprotected.

• Do not market 'surge protection' until the relevant configuration is tested/listed for that function.

• Keep the service disconnect function obvious and accessible; do not bury it inside software.

3. Adaptive Learning and Expected Savings

Elapsed time	Adaptive state	Expected impact
0-3 days	Fingerprinting	No optimization claim; establish electrical and cycle signatures
4-7 days	Weather normalization begins	Early anomaly detection; little credited savings
7-14 days	Useful personalized model	Conservative supervisory optimization can begin
14-30 days	Active optimization	Runtime/recovery/peak strategies become household-specific
30-60 days	Stable personalized baseline	Most recurring adaptive savings should be visible
90+ days	Seasonal refinement	Stronger weather and seasonal fault baselines

Target mature operating savings for suitable homes: 5-12% of HVAC electricity/cost. This is a development target, not a guaranteed consumer claim. The box itself does not improve the refrigeration cycle's intrinsic efficiency; savings come from avoiding unnecessary runtime, better recovery timing, peak/tariff coordination, and identifying fixable degradation.

Monthly HVAC spend	5% target	8% target	12% target
$100	$5	$8	$12
$200	$10	$16	$24
$350	$17.50	$28	$42
$500	$25	$40	$60

Fault-mediated savings should be reported separately. If AEEM detects a dirty coil, airflow restriction, electrical degradation or another verified service issue, any post-repair energy reduction is a maintenance-recovery benefit rather than direct controller efficiency.

4. Prototype Hardware and Build Gates

Prototype subsystem	Rough prototype allowance
Controller + local storage/comms	$20-$60
Split-core current sensing	$20-$60
Isolated voltage / real-power metering	$30-$80
Temperature + humidity sensing	$25-$60
Low-voltage HVAC input/control interface	$25-$75
Outdoor-rated enclosure, terminals, protection	$40-$100
Surge-protection development module/components	$40-$150
Prototype total before certification/labor	~$200-$585

Go / No-Go Gates

Gate	Pass condition
Metering	Energy and operating-state detection are accurate enough to support savings claims
Learning	Weather-normalized model becomes stable without excessive false alarms
Control	Equivalent comfort is maintained while measured HVAC kWh falls
Safety	No nuisance interruption; loss of controller does not create unsafe compressor behavior
Surge stage	Independent test/certification path demonstrates intended SPD performance
Economics	Hardware + installation produce a plausible consumer payback in the target segment

Recommended first physical build: V0 measurement enclosure with space, connector provisions and firmware architecture reserved for V1 supervisory control and V2 surge-protection integration. Do not prototype mains switching or surge clamping on a live HVAC branch circuit without appropriately rated hardware and qualified electrical practices.

5. Product Position and References

The strongest consumer position is not 'an optimizer that also happens to surge protect.' It is an **HVAC protection + intelligence appliance**: surge protection provides immediate equipment-protection value; diagnostics begin immediately; adaptive energy optimization improves as the device learns the home.

Proposed product stack

Day 1	Surge protection status + live HVAC electrical monitoring
Week 1	Cycle fingerprinting + abnormal start/runtime alerts
Weeks 2-4	Conservative adaptive runtime/recovery optimization
Months 1-2	Stable household-specific energy-performance model
Long term	Predictive service + tariff/peak coordination + future AEEM node functions

References / design basis

• UL Solutions - Surge Protection Device Testing and Certification Services: UL 1449 certification/testing framework for SPDs.

• UL Solutions - Guide to Power Strips and Surge Protectors: explains that a surge protector includes a clamping/diversion element protecting downstream equipment.

• NFPA - NFPA 70 (National Electrical Code) development materials: benchmark electrical installation framework; HVAC disconnect requirements remain applicable to final product installation.

• ENERGY STAR - Smart Thermostats: field-performance framework establishes that adaptive HVAC control can generate measurable heating/cooling savings.

• U.S. Department of Energy - residential HVAC controls, diagnostics and smart-home energy-management research.

Engineering note: final product claims, SPD type, installation point, conductor configuration, enclosure rating, SCCR, VPR, nominal discharge current, disconnect implementation and required certifications must be established by the final electrical design and applicable code/listing review.