

UNDERSTANDING OPEN NEUTRALS

A Technical White Paper for Electric Utilities,
Field Personnel, and Homeowners



Prepared by Kenick, Inc.

EXECUTIVE SUMMARY

An open neutral is one of the most misunderstood yet potentially destructive electrical failures found in residential electrical systems. Unlike a lightning strike or transient surge, an open neutral can create sustained overvoltage and undervoltage conditions that persist until the fault is corrected. The resulting voltage imbalance can damage appliances, destroy electronics, create fire hazards, and pose shock risks.

Electric utilities frequently receive customer complaints of flickering lights, lights that suddenly become unusually bright, appliances failing unexpectedly, or electronics being

damaged following storms or utility work. In many of these cases, the root cause is not a surge event but a failed or loose neutral conductor.

This paper explains:

- What an open neutral is
- Why it creates dangerous voltage imbalances
- Common causes
- Symptoms customers report
- Utility responsibilities
- Inspection and troubleshooting methods
- Preventative practices
- How open neutrals differ from transient surge events

INTRODUCTION

Modern homes rely on a split-phase 120/240-volt electrical service. The system provides two 120-volt legs that are 180 degrees out of phase with one another and share a common grounded neutral conductor.

Under normal operation:

- Line 1 to Neutral = approximately 120 volts
- Line 2 to Neutral = approximately 120 volts
- Line 1 to Line 2 = approximately 240 volts

The neutral conductor provides the return path for the imbalance between the two 120-volt legs and stabilizes voltage delivered to branch circuits.

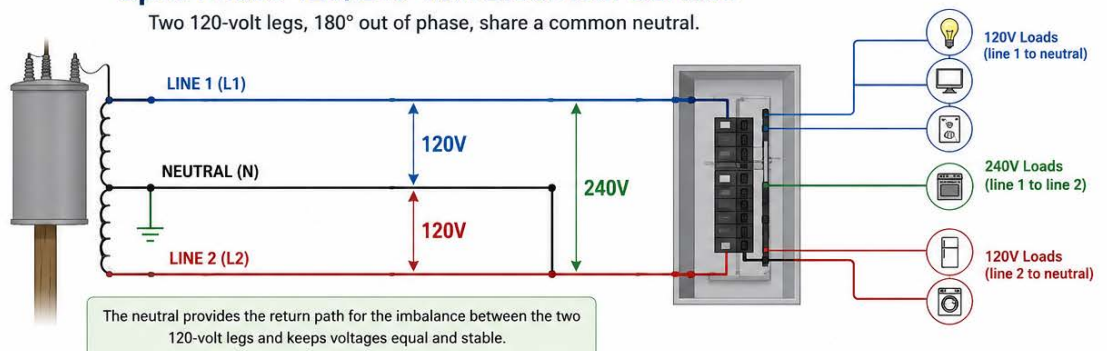
When this neutral conductor becomes loose or disconnected, the system can no longer maintain equal voltages. Instead, voltage is distributed according to the electrical load connected to each side of the panel.

The result can be one side receiving 80 volts while the opposite side experiences 160 volts—or even more extreme conditions.

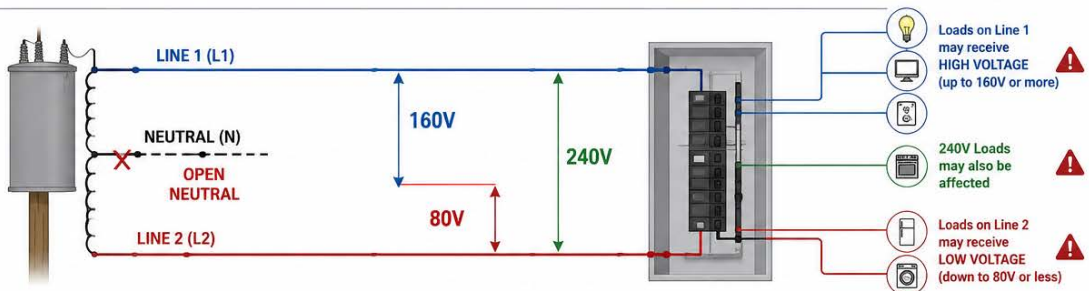
Split-Phase 120/240-Volt Electrical Service

Two 120-volt legs, 180° out of phase, share a common neutral.

NORMAL OPERATION	
Voltages are balanced and stable.	
Line 1 to Neutral =	120V
Line 2 to Neutral =	120V
Line 1 to Line 2 =	240V



OPEN NEUTRAL CONDITION	
Neutral is loose or disconnected. Voltages become unbalanced and unpredictable.	
Line 1 to Neutral =	160V
Line 2 to Neutral =	80V
Line 1 to Line 2 =	240V



WHAT YOU MAY SEE

- Some lights become very bright
- Other lights dim or flicker
- Appliances may run poorly or fail
- Electronics can be damaged



Overvoltage
(Too Bright)



Undervoltage
(Too Dim)

WHY THIS HAPPENS

With the neutral open, the two sides of the system act like loads in series across 240 volts. Voltage divides according to the load on each side. As loads change, voltages change.



LIGHT LOAD
(High Resistance)
Gets More Voltage



HEAVY LOAD
(Low Resistance)
Gets Less Voltage



An open neutral is a dangerous condition that can damage equipment and create fire and shock hazards. If suspected, contact your utility or a qualified electrician immediately.

HOW AN OPEN NEUTRAL WORKS

The easiest way to visualize the problem is to think of the home's electrical loads becoming two resistors connected in series across a 240-volt source.

Instead of each side receiving:

120 V + 120 V

the voltage divides based on load impedance.

For example:

Heavy load side

- Electric heater
- Refrigerator
- HVAC blower

Meanwhile the opposite side:

- Television
- LED lighting
- Computer
- Microwave clock

May receive:

90 volts

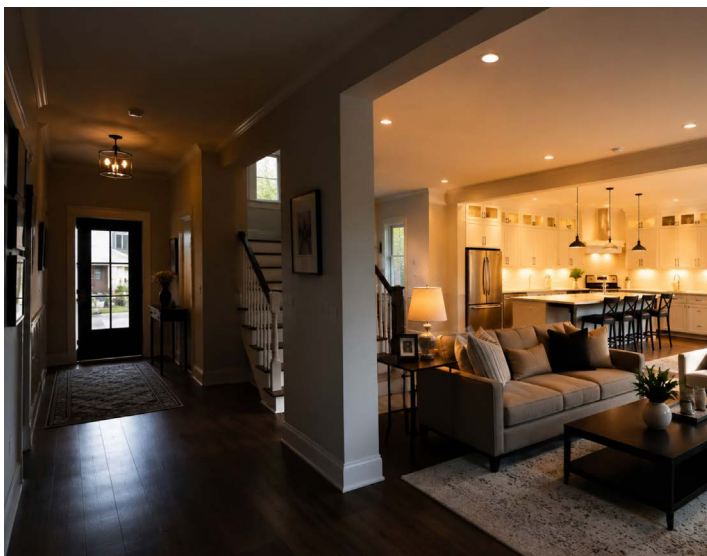
May receive:

150 volts

The total remains

240 volts.

Only the distribution changes.



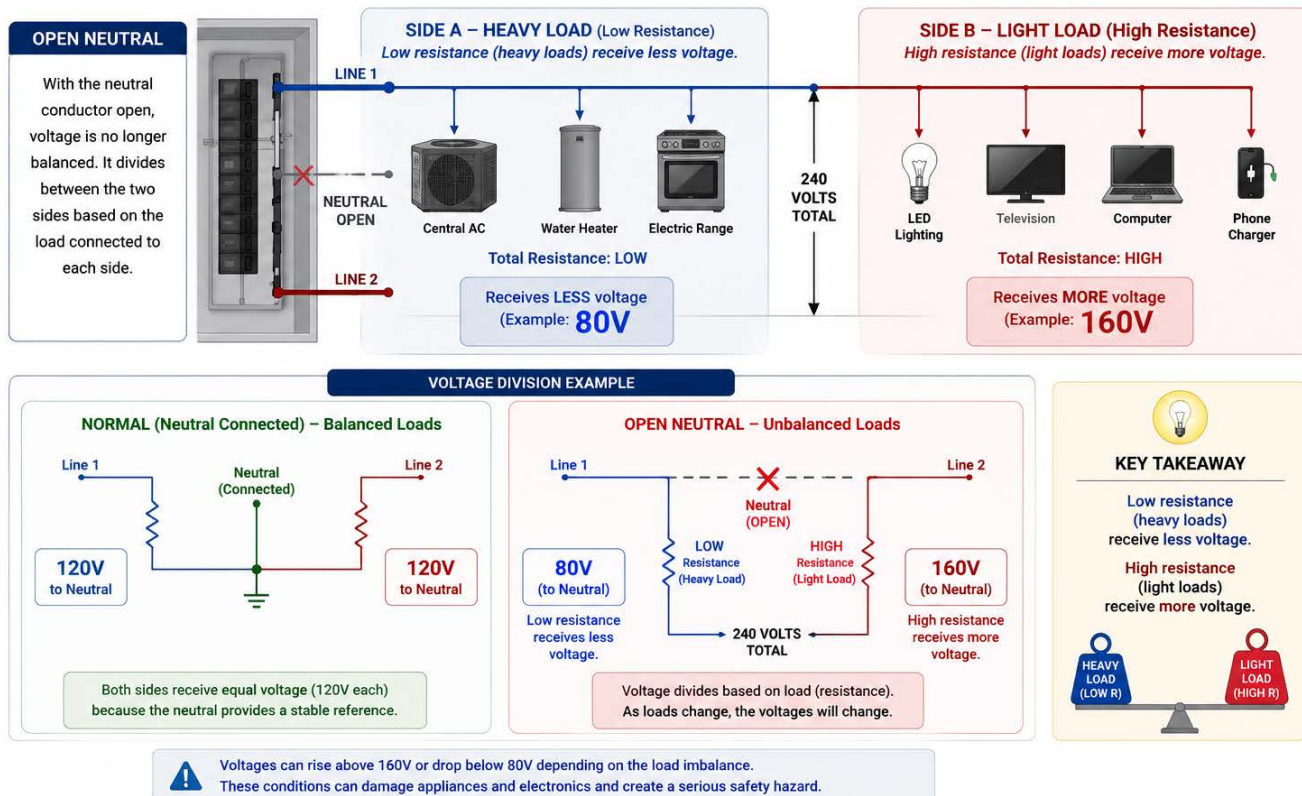
This is why homeowners frequently report:

"I noticed some lights getting brighter while others dimmed."

That observation is one of the classic indicators of an open neutral.

Open Neutral: How Voltage Divides Based on Load

When the neutral opens, the two sides of the system act like two resistances in series across 240 volts. Voltage divides based on the load (resistance) on each side.



WHY VOLTAGE CHANGES

According to Ohm's Law:

$$V = I \times R$$

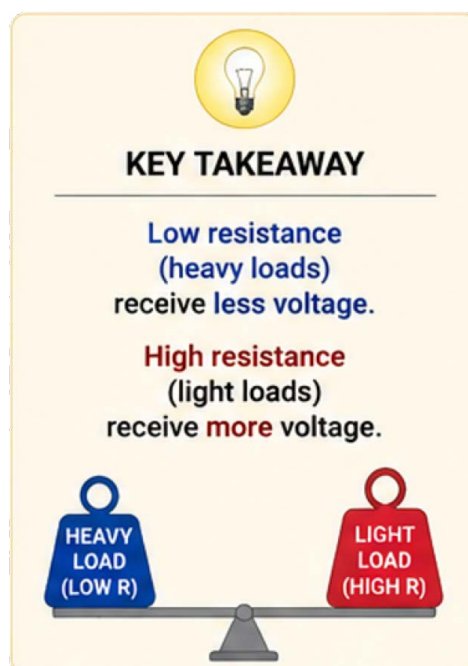
Voltage division in a series circuit is proportional to resistance.

When the neutral opens:

- Low resistance (heavy loads) receive less voltage.
- High resistance (light loads) receive more voltage.

As appliances cycle on and off, these voltages continuously change.

This creates unstable operating conditions throughout the home.



TYPICAL SYMPTOMS

Customers often report:

- Lights becoming brighter than normal
- Lights dimming when appliances start
- Flickering throughout the home
- Microwave display changing brightness
- Motors running slowly
- Electronics failing
- Burning smells
- Appliances repeatedly failing
- Multiple devices damaged simultaneously

Utilities frequently hear statements such as:

“When the air conditioner started, every light in the house changed brightness.”

“My lights got really bright before everything quit.”

These are classic open neutral symptoms.

COMMON CAUSES

Open neutrals may occur because of:

UTILITY SIDE

- Corroded service connections
- Broken neutral conductors
- Storm damage
- Vehicle pole impacts
- Loose transformer connections
- Failed underground neutral splices
- Damaged service drops

CUSTOMER SIDE

- Loose meter socket terminals
- Defective main breaker connections
- Loose panel neutral lugs
- Corroded service entrance equipment
- Improper electrical modifications
- Aging electrical systems

EQUIPMENT MOST AT RISK

The following equipment is especially vulnerable to overvoltage:

- Televisions
- Computers
- Routers
- Cable modems
- Wi-Fi equipment
- Smart appliances
- HVAC control boards
- LED lighting
- Microwave ovens
- Battery chargers
- Home automation systems
- Security systems

Many electronic power supplies begin experiencing damage well before 150 volts.

WHY ELECTRONICS FAIL

Most residential electronics use switching power supplies designed for approximately 120 volts.

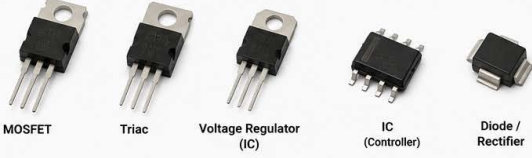
Sustained voltages exceeding design limits cause:

- Capacitor failure
- Semiconductor breakdown
- Overheating
- Insulation stress
- Premature aging
- Catastrophic component failure

Unlike a microsecond surge, these overvoltage conditions may last several minutes or even hours.

Capacitors and Semiconductors in Residential Appliances

These components are found in electronic control boards and power supply circuits in many home appliances.

CAPACITORS			SEMICONDUCTORS		
Store and release electrical energy, filter voltage, and help smooth power in electronic circuits.  Through-hole Electrolytic Capacitors Surface Mount Capacitors			Control the flow of electricity. They switch, regulate, amplify, or convert electrical power.  MOSFET Triac Voltage Regulator (IC) IC (Controller) Diode / Rectifier		
WHERE YOU FIND THEM IN HOME APPLIANCES • Power supplies, motor drives, control boards, LED drivers, and filters			WHERE YOU FIND THEM IN HOME APPLIANCES • Power conversion, switching, motor control, rectification, and regulation		
					
Refrigerator Control Board	Washing Machine Control Board	Air Conditioner Control Board	Refrigerator Inverter Board	Air Conditioner Outdoor Unit Board	Dishwasher Control Board
					
Microwave Oven Power Supply	LED Lighting Driver	Furnace Control Board	Microwave Oven Inverter Board	Induction Cooktop Power Board	Clothes Dryer Control Board
 WHY IT MATTERS Sustained overvoltage conditions—such as those caused by an open neutral—can overstress these components, causing premature failure or catastrophic damage to appliances and electronics.			LEGEND  Capacitors  Semiconductors		

FIRE AND SAFETY HAZARDS

Open neutrals can also create:

- Overheated conductors
- Loose connections becoming hotter
- Arcing
- Equipment overheating
- Increased fire risk

The National Fire Protection Association (NFPA) has long recognized poor electrical connections as contributors to residential electrical fires.

UTILITY RESPONSE

Utilities should treat reports of:

- Bright and dim lights
- Flickering throughout the home
- Simultaneous appliance failures as potentially urgent service issues.

Field personnel typically inspect:

- Service drop
- Meter socket
- Weatherhead
- Neutral conductor
- Transformer connections
- Secondary connections

If utility equipment is confirmed satisfactory, customers should be advised to

contact a licensed electrician immediately.

DIAGNOSING AN OPEN NEUTRAL

Typical measurements include:

Normal:

- L1-N = 120 V
- L2-N = 120 V
- L1-L2 = 240 V

Possible Open Neutral:

- L1-N = 90 V
- L2-N =150 V
- L1-L2 =240 V

The key indicator is that line-to-line voltage remains near 240 volts while the individual line-to-neutral voltages fluctuate significantly.

OPEN NEUTRALS VS. POWER SURGES

These events are often confused but differ significantly.

OPEN NEUTRAL vs. ELECTRICAL SURGE

Understanding the Key Differences

CHARACTERISTIC	 OPEN NEUTRAL	 ELECTRICAL SURGE
 DURATION	Seconds to hours	Microseconds (millionths of a second)
 VOLTAGE CONDITION	Sustained overvoltage and undervoltage	Transient overvoltage
 PRIMARY CAUSE	Loose, damaged, or disconnected neutral conductor	Lightning strikes or switching events
 VOLTAGE BEHAVIOR	Continuously changes as electrical loads change	Very brief, high-energy impulse
 TYPICAL SYMPTOMS	Bright and dim lights, flickering, appliance malfunction	Sudden equipment damage, often with no visible warning
 CORRECTIVE ACTION	Locate and repair the failed neutral connection	Install surge protective devices (SPDs) to limit transient voltage
 PRIMARY RISK	Prolonged overvoltage can destroy appliances and electronics	High-energy transient can puncture insulation and damage sensitive electronics

Surge protection devices are designed to limit transient overvoltages. They

are not intended to correct or stabilize voltages caused by an open neutral condition.

PREVENTION

Utilities can reduce open neutral incidents through:

- Routine inspection of aging infrastructure
- Proper torque on neutral connections
- Corrosion prevention
- Infrared inspections
- Storm hardening
- Scheduled replacement of deteriorated service conductors
- Preventive maintenance programs

Customers should:

- Report unusual light brightness immediately.
- Never ignore flickering throughout the house.
- Contact the utility before assuming appliance failure.
- Have aging electrical panels inspected by qualified



electricians.

CONCLUSION

Open neutral conditions represent one of the most serious sustained voltage abnormalities encountered in residential electrical systems. Because symptoms often mimic other electrical problems, they can go unrecognized until significant damage has occurred.

For electric utilities, educating customers about the warning signs of an open neutral can reduce equipment damage, improve customer satisfaction, and help field personnel identify hazardous service conditions more quickly.

Understanding the distinction between transient surges and sustained voltage imbalance is equally important. Both can damage sensitive electronics, but each requires a different approach to mitigation.

Questions?

Please contact us if you have questions about this article or a particular issue that you need help with.

Solutions@kenick.com

1-800-362-9997

Kenick remains committed to helping electric utilities educate customers about electrical safety and protecting homes from transient surge events through proven surge protection solutions.

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