METU

Electrical Safety

Electrical Safety

Definition

Electrical safety is the protection of personnel and equipment from electrical hazards arising from;

- outages, line openings,
- faults,
- severe weather conditions,
- other operational errors

Electrical Safety

Basic Definitions

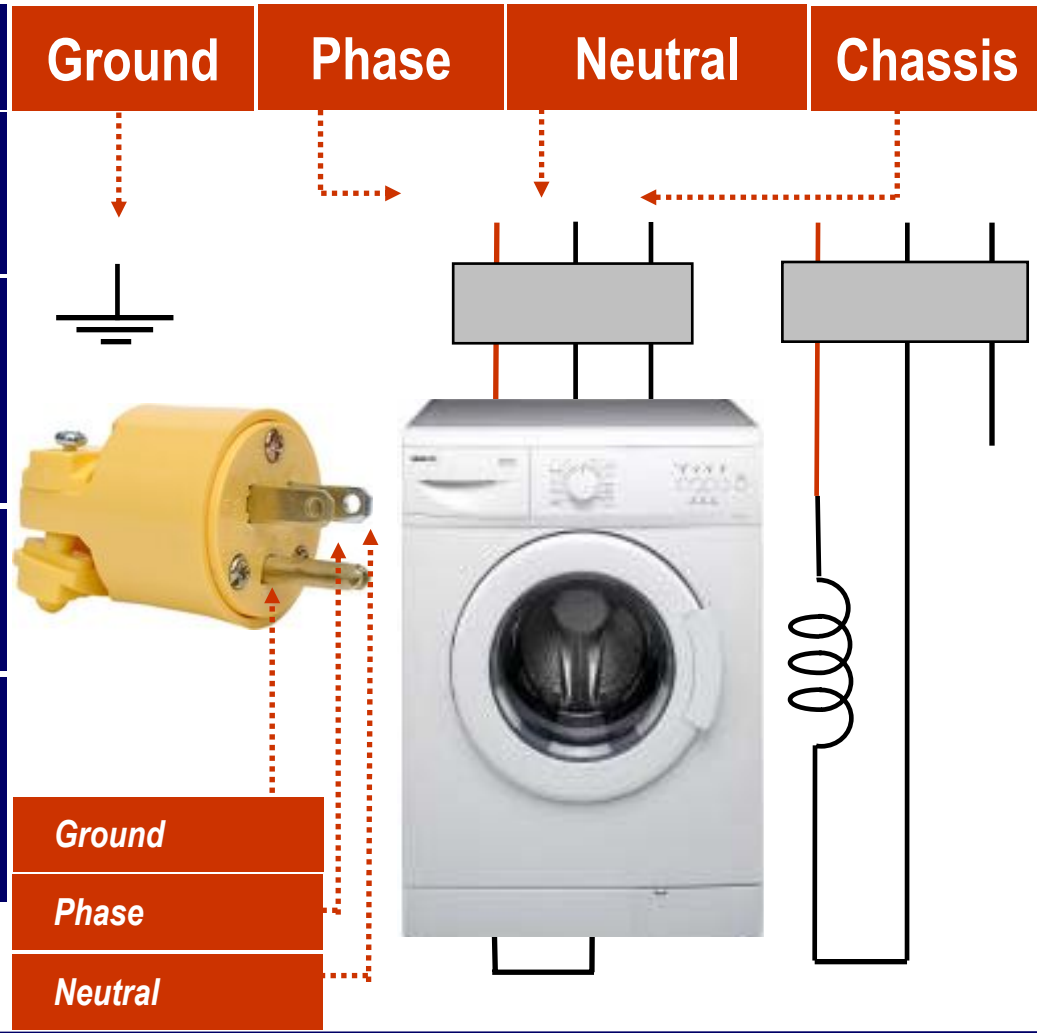
Phase, Neutral, Ground and Earth

Phase is the wire at which a phase voltage (220 Volt) exists

Neutral is the wire connecting the junction points of a star connected system

Chassis is the point on the metal cover of th electrical appliance

Ground, Earth is the point on the earth at which voltage is always zero



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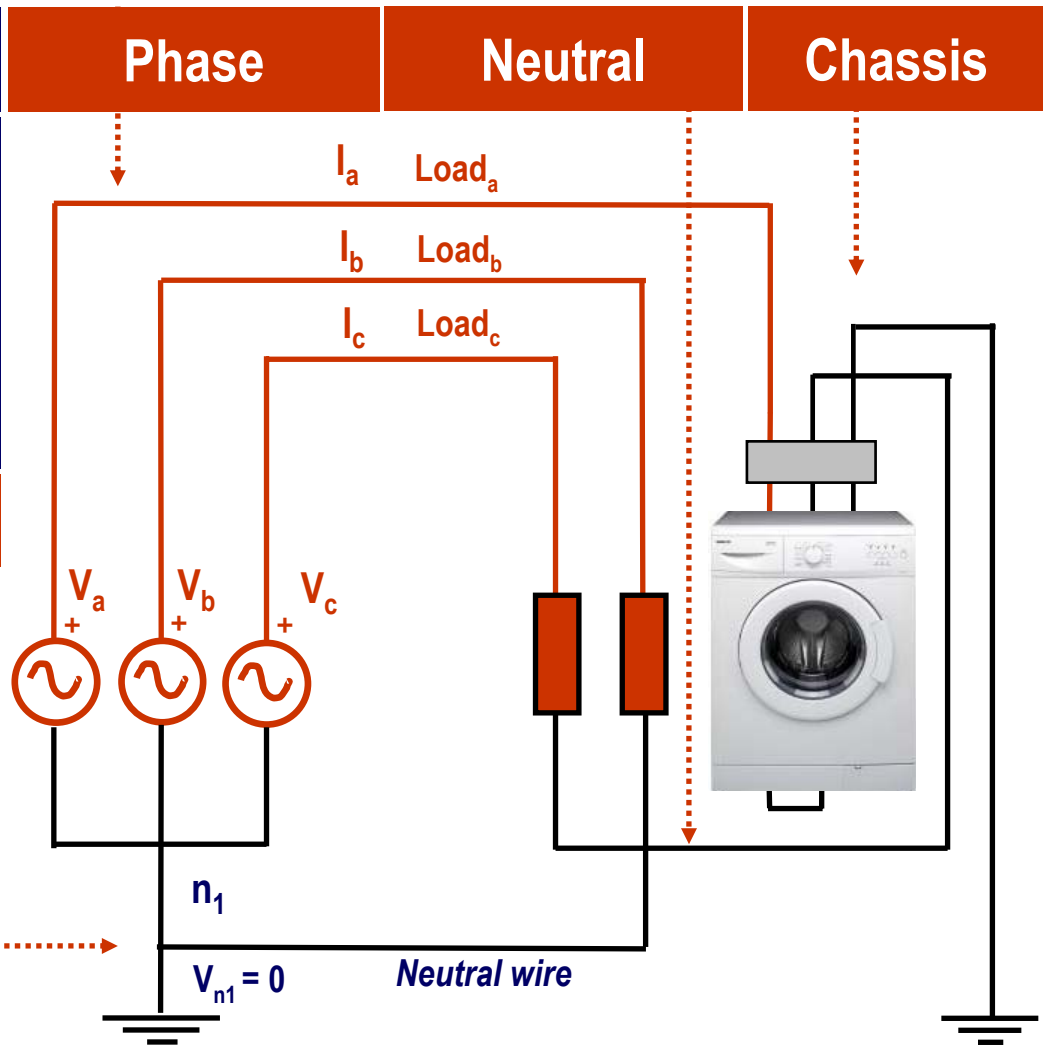
Grounding

Definition

Grounding is connecting a point to ground by a wire with zero or negligible resistance in order to make the voltage at that point zero, for safety purposes

Example: Grounded neutral



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Grounded and Ungrounded Neutral Points

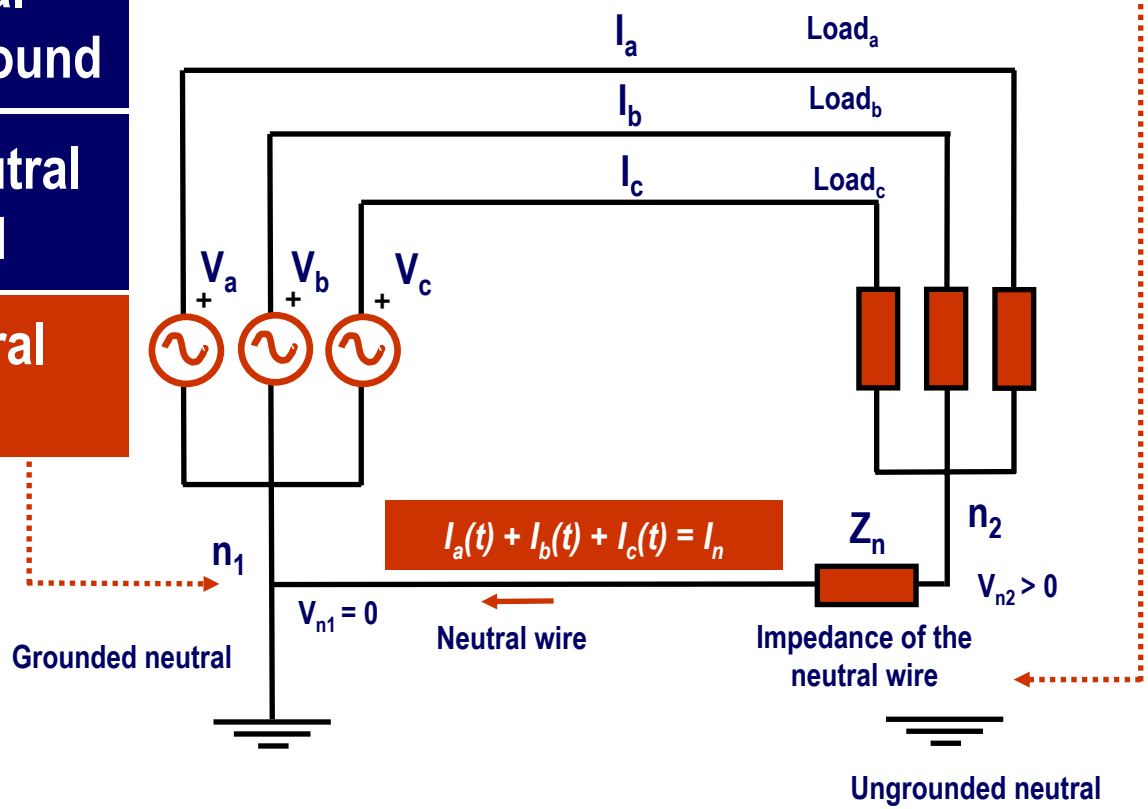
Definition

Grounded neutral is the neutral point connected directly to ground

Ungrounded neutral is the neutral point not connected to ground

Voltage at the grounded neutral point n_1 is always zero

Ungrounded Neutral



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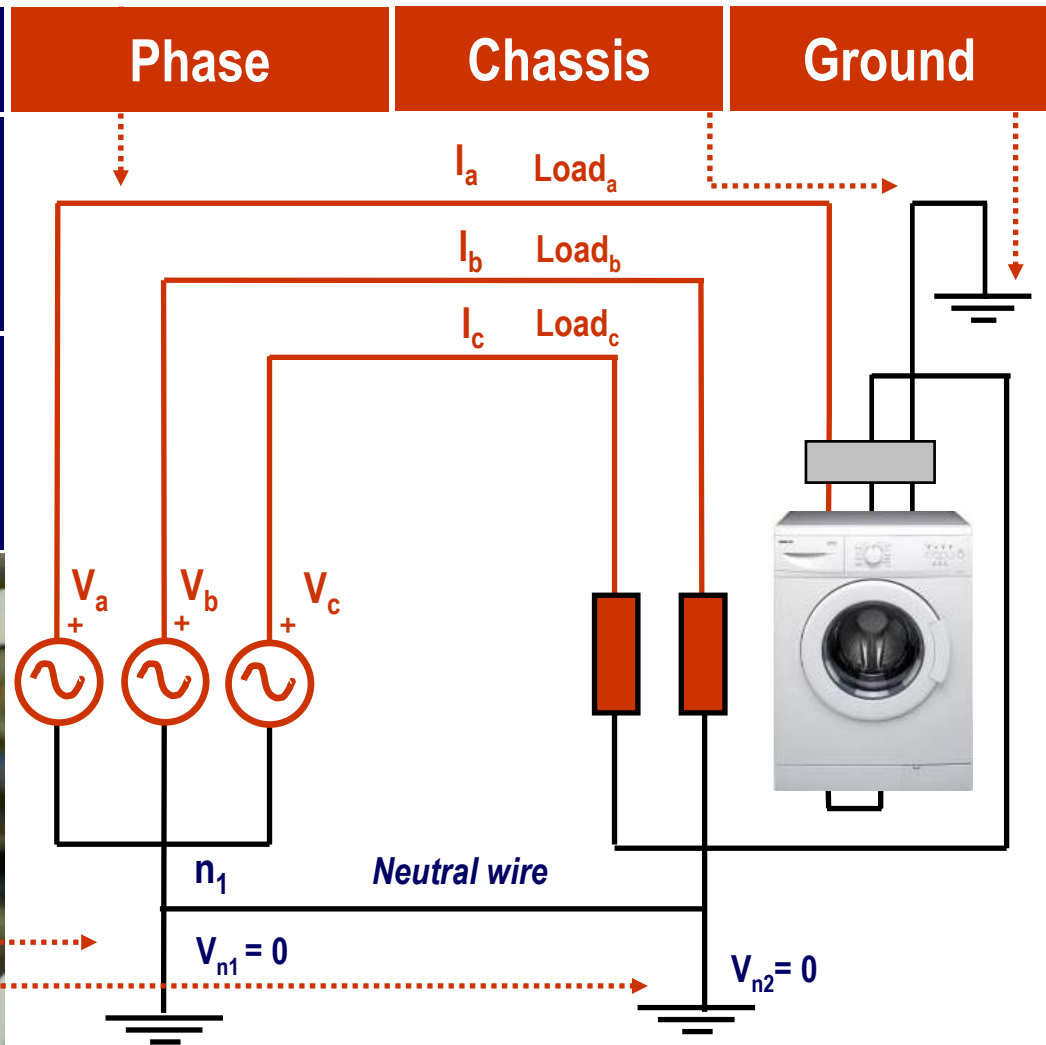
Grounding

Definition

Grounding the neutral points ***on BOTH sides*** of the neutral wire is essential

Voltage is zero everywhere on a neutral wire grounded on both sides



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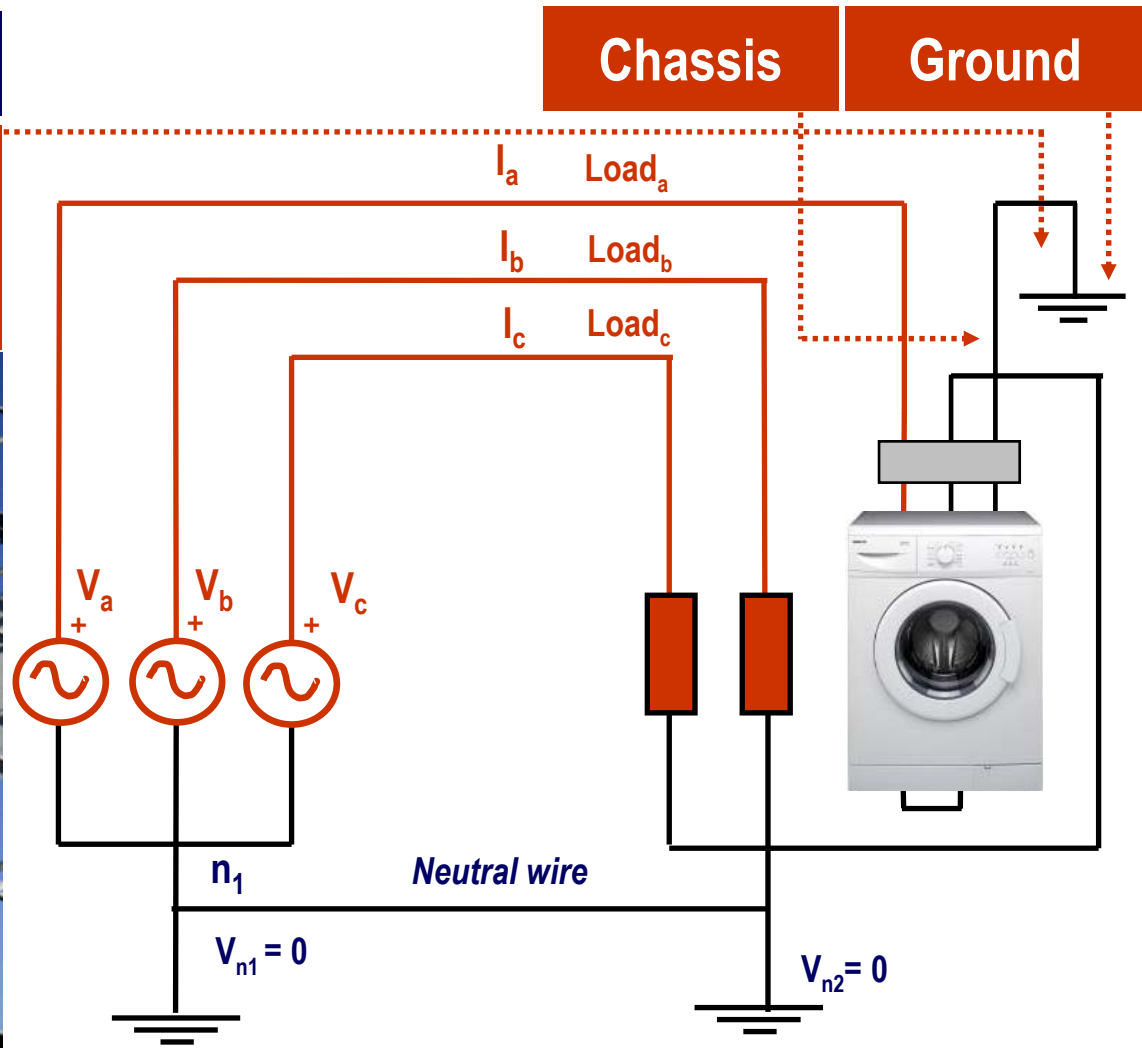
Grounding

Definition

Grounding the chassis of electrical appliances, such as washing machines is essential



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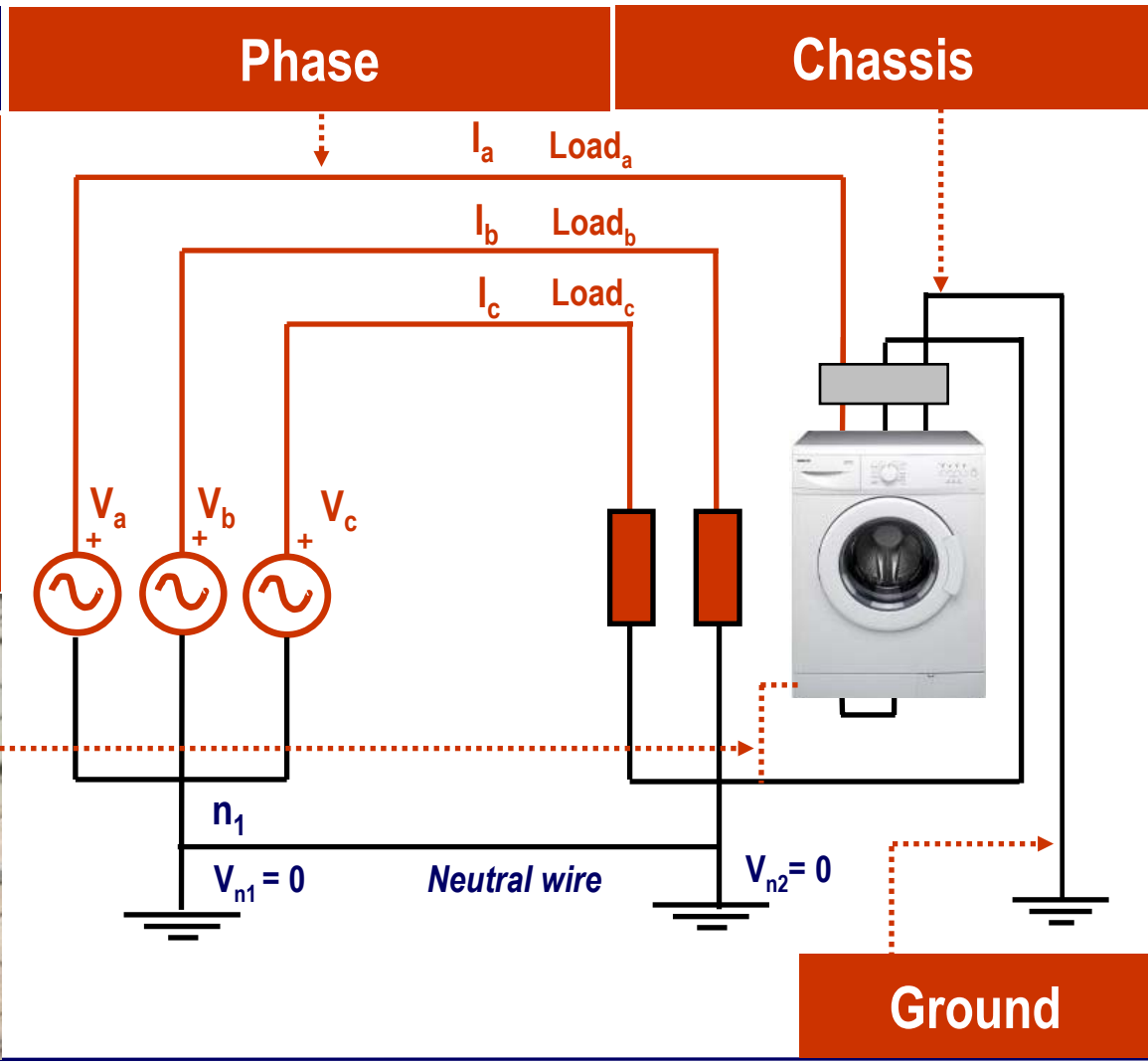
Grounding

Definition

Connecting the chassis of electrical appliances to the neutral point is strictly ILLEGAL (FORBIDDEN) due to safety reasons that will be described in the following pages



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Grounded and Ungrounded Neutral Points

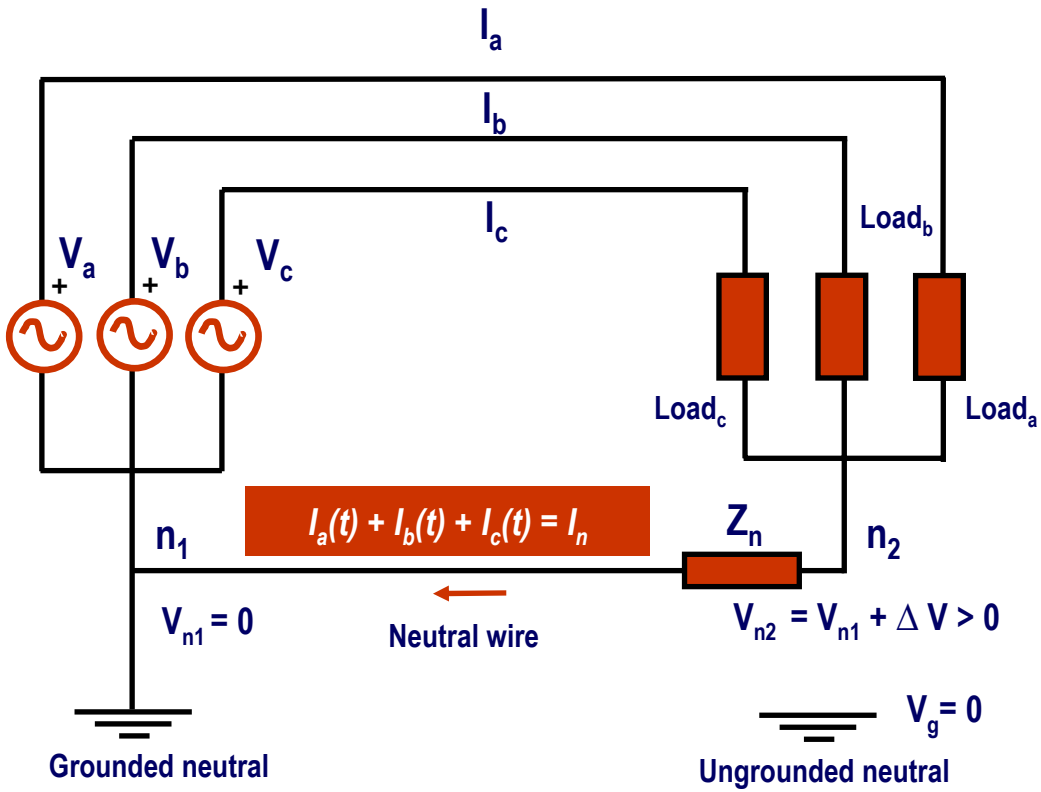
Voltage Rise on an Ungrounded Neutral Point

In case that the load is unbalanced, i.e. the phase loads; $Load_a$, $Load_b$, $Load_c$ draw unequal currents, their sum will not cancel, hence a current I_n will result in the neutral wire ungrounded on the load side

$$I_a(t) + I_b(t) + I_c(t) = I_n$$

Then, the voltage of node n_2 will rise to a level

$$V_{n2} = V_{n1} + \Delta V = I_n \times Z_n$$



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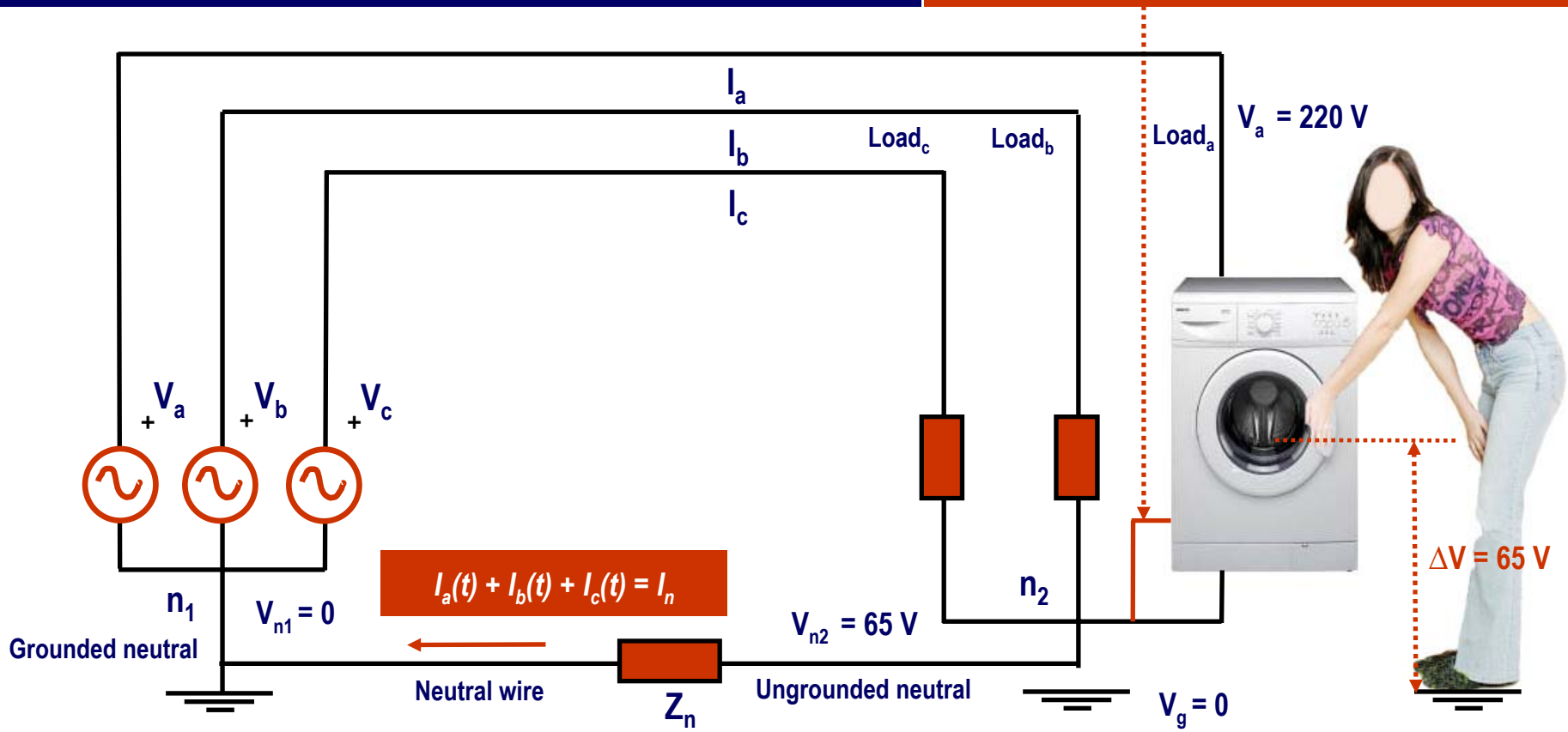
Why Connecting the Chassis to Neutral is Illegal ?

Voltage on the metal cover of household appliances may sometimes rise to dangerous levels due to ungrounded neutral wires

Metal cover of the washer is connected to neutral point the appliance



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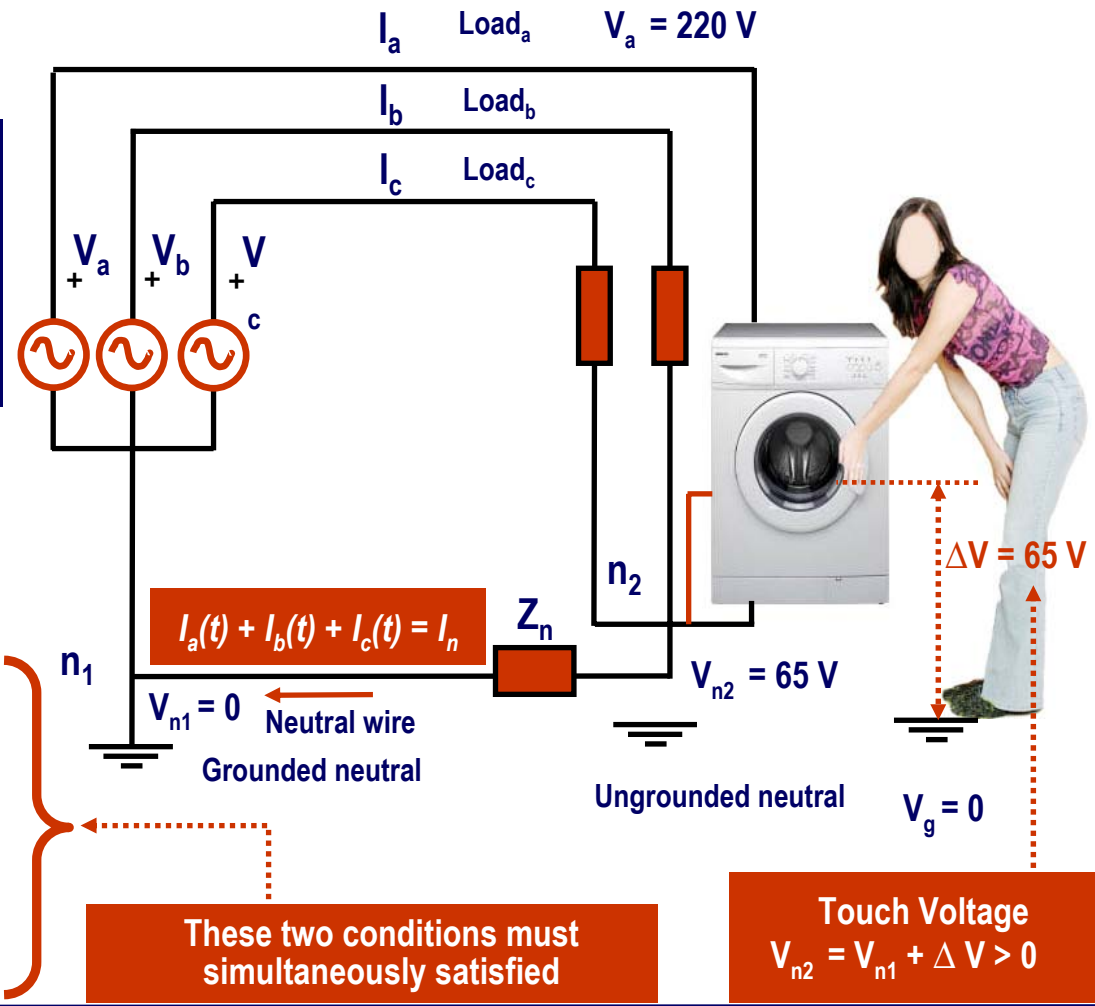
Touch Voltage

Definition

"Touch Voltage" is the voltage difference between the surface of an electrical appliance and ground

"Touch Voltage" will appear on the surface of the electrical appliance when;

- the chassis is connected to the neutral point of the appliance,
- the chassis is ungrounded or the grounding wire is broken due to any reason



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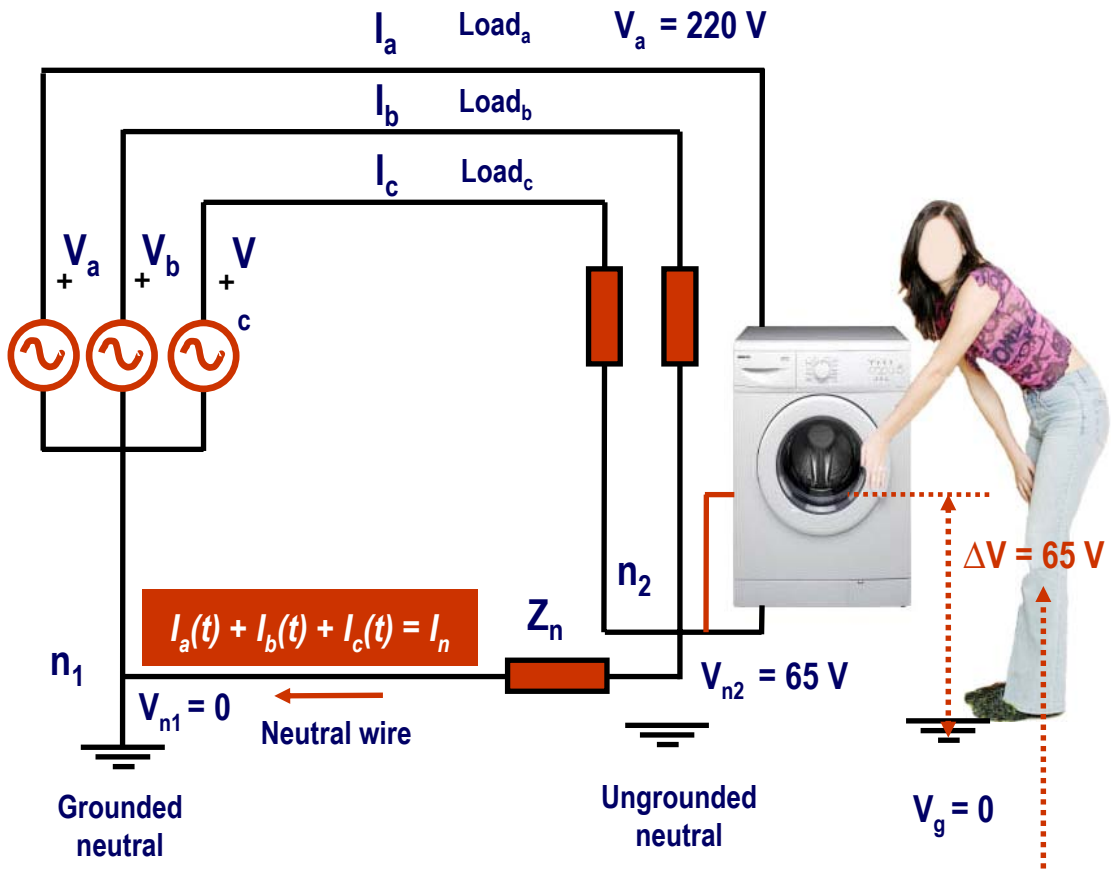
Touch Voltage

Definition

Touch Voltage may rise to dangerous levels, such as few hundred volts when the chassi of the appliance is

Touch Voltage at node n_2 will then be;

$$V_{n2} = V_{n1} + \Delta V$$
$$= V_{n1} + I_n \times Z_n$$
$$= 0 + I_n \times Z_n = I_n \times Z_n > 0$$



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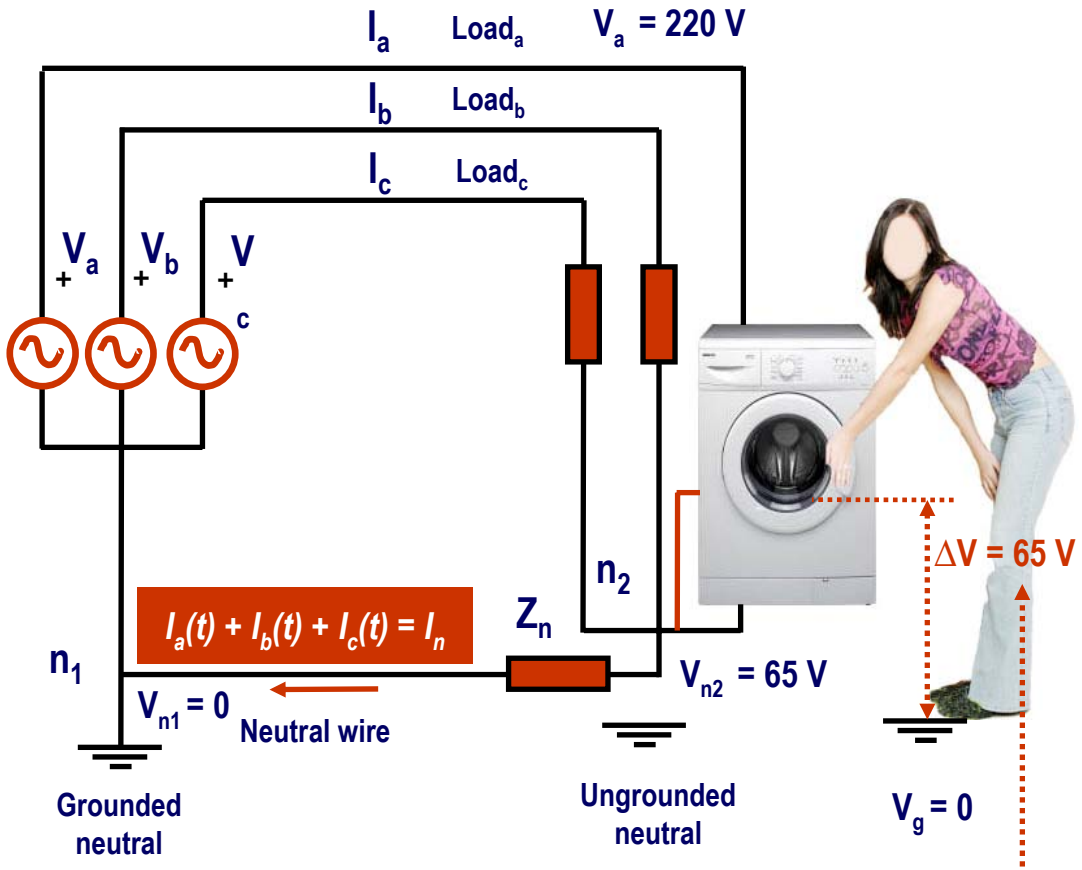
Touch Voltage

Fatal Level of Touch Voltage

Depending upon the values of Z_n and I_n, the resulting voltage V_{n2} may rise to a dangerous level, such as few hundred volts

Touch voltages above 65 Volts (AC) are fatal



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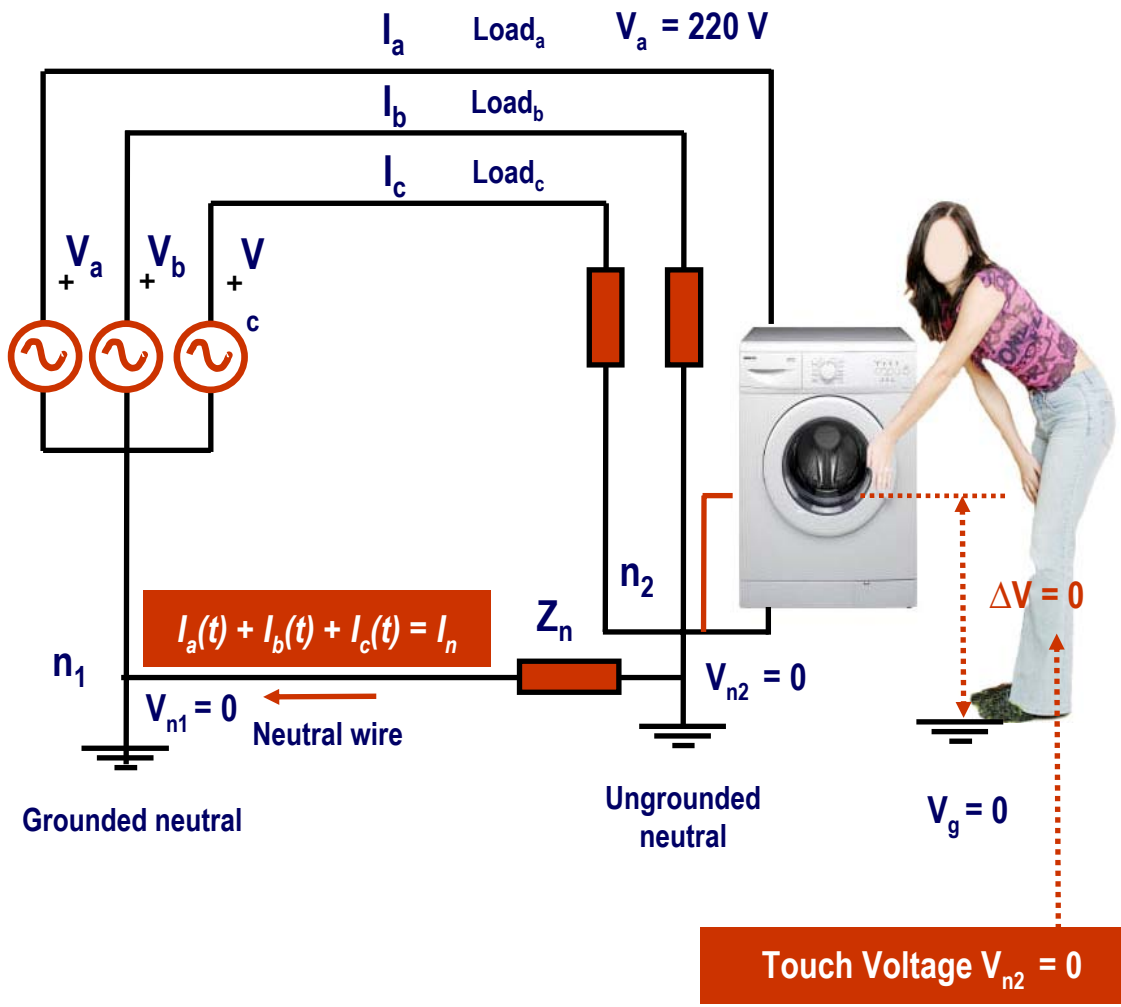
Solution for Eliminating Touch Voltage

Solutions

Do either or both of the followings;

- **Ground the chassis of the electrical appliance by solidly,**
- **Ground the neutral wire solidly at both ends**

Solid grounding: Grounding by using a wire with zero or negligible resistance



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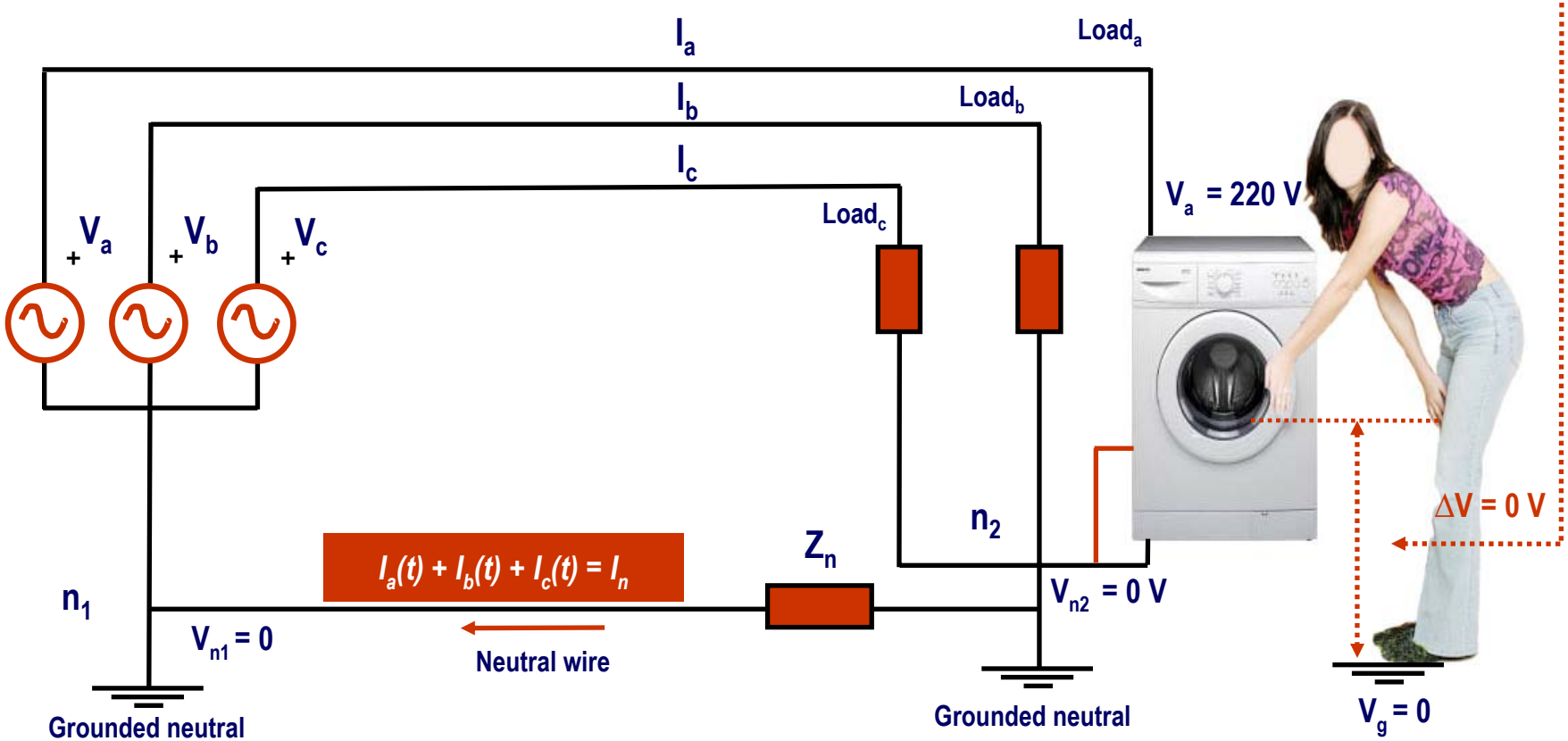
Solution for Reducing Touch Voltage in Household Appliances

Ground the neutral wire at the load terminals

Neutral voltage is now zero



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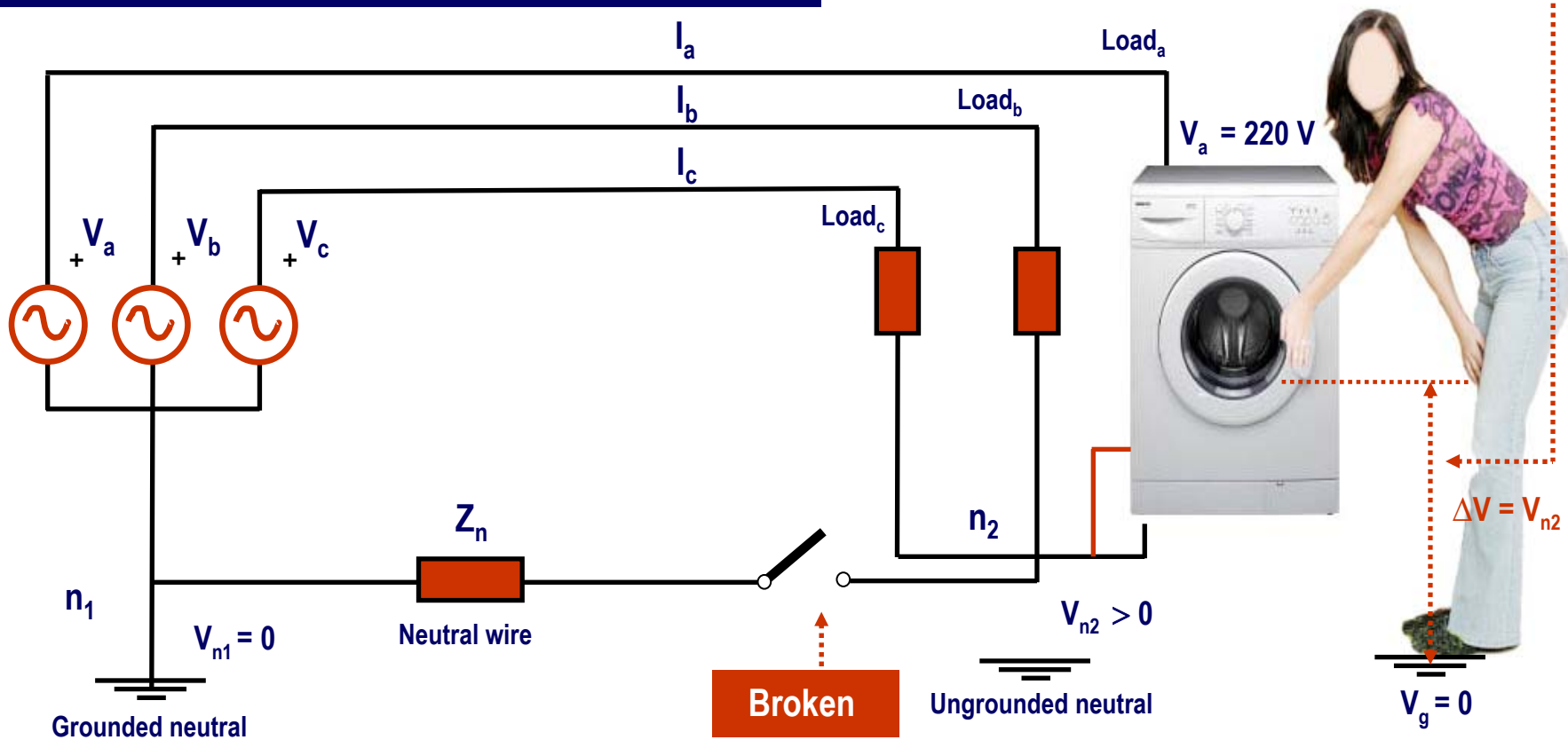
Breaking of the Neutral Wire

Sometimes neutral wire may be broken for any reason, yielding a voltage on the metal surface of the ungrounded electrical appliance

Neutral voltage is now nonzero



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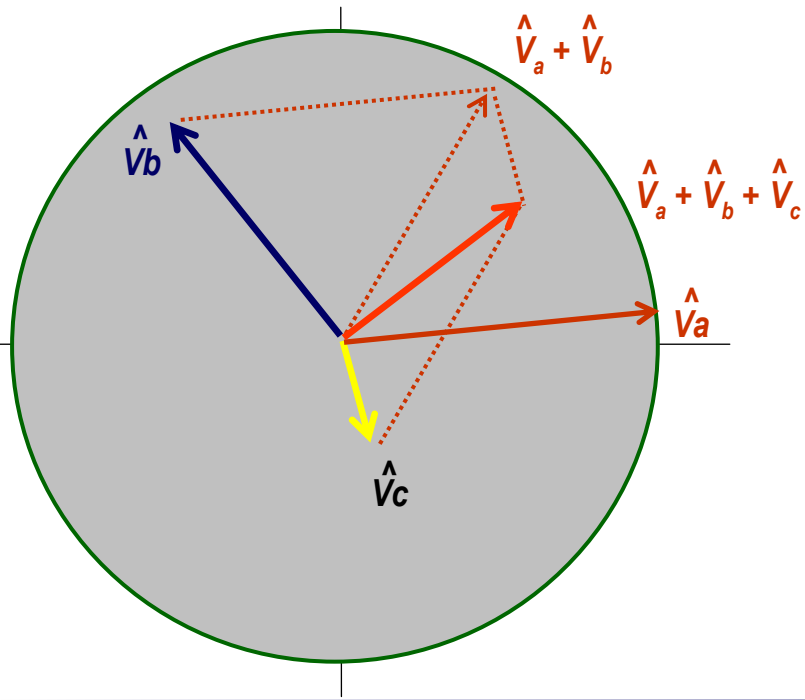
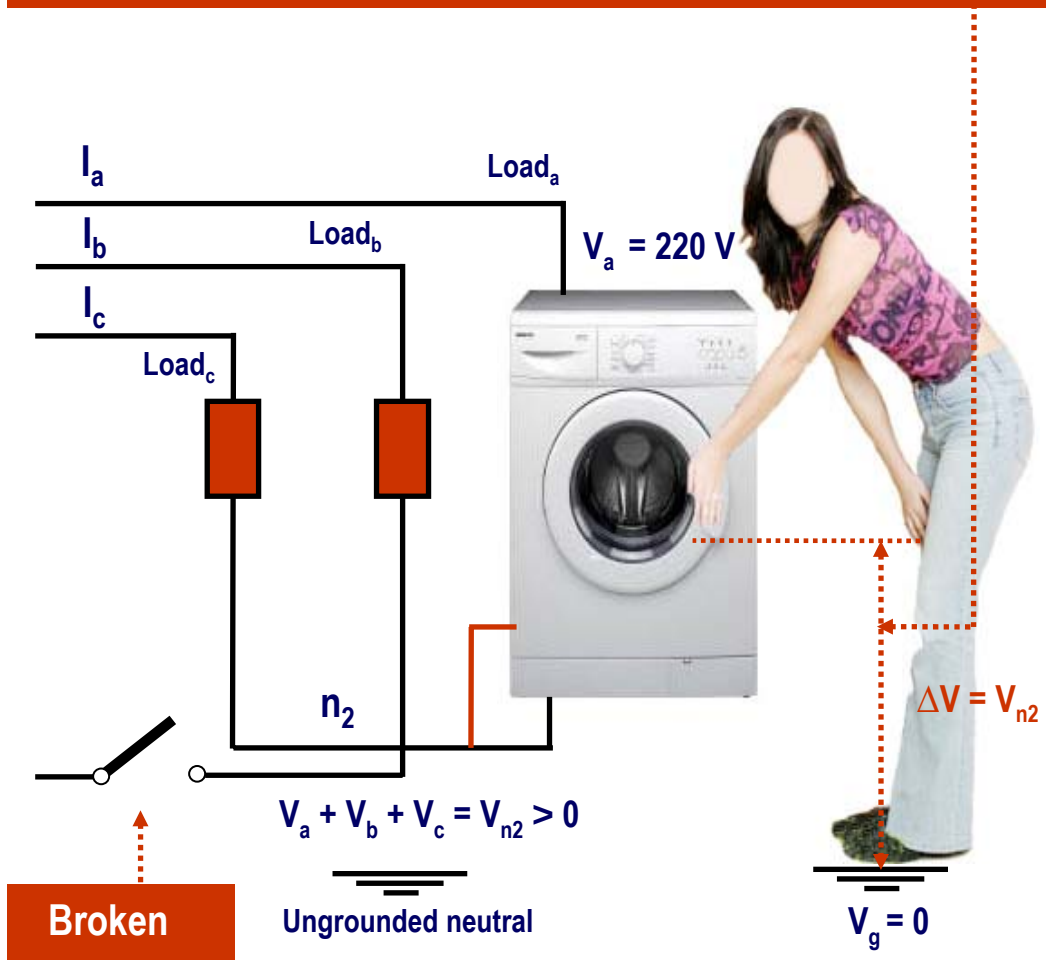
Why the Voltage on an Ungrounded Neutral is nonzero ?

Since the load voltages are unbalanced, sum of voltages is no longer zero.
The resulting voltage V_{n2} appears on the metal surface of the electrical appliance



Neutral voltage is now nonzero



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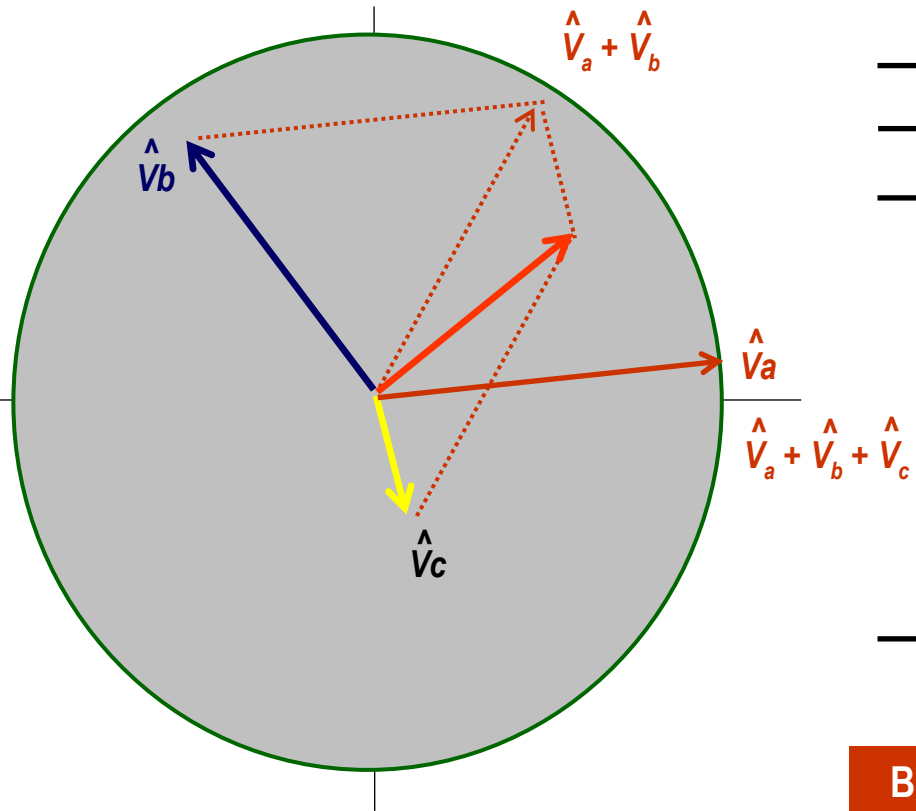
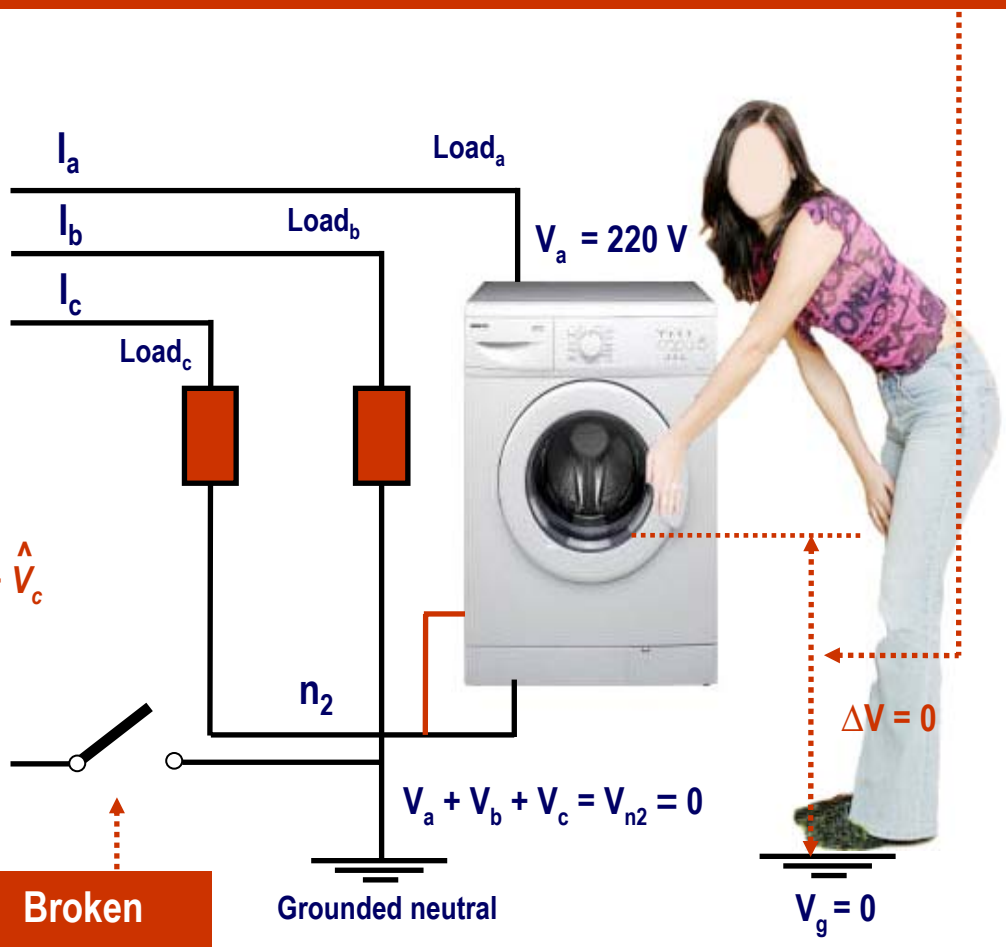
Solution for Reducing Touch Voltage in this case

Ground the neutral wire at the load terminals

Neutral voltage is now zero





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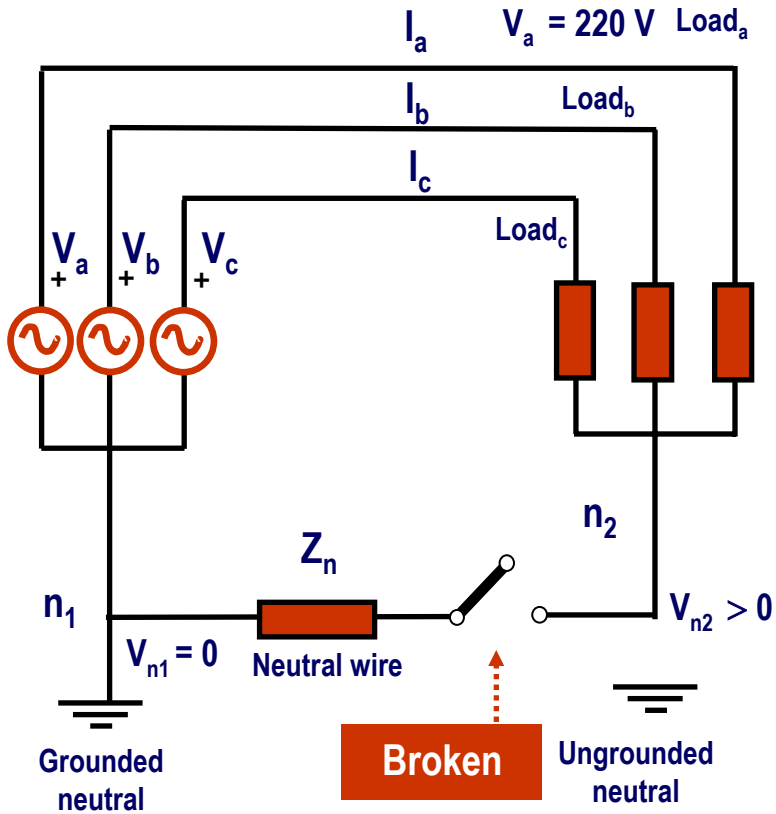
Why does Neutral Line break ?

Power lines may always break due to severe weather conditions



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Why does Neutral Line break ?

Due to severe weather conditions

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Why does Neutral Line break ?

Due to severe weather conditions

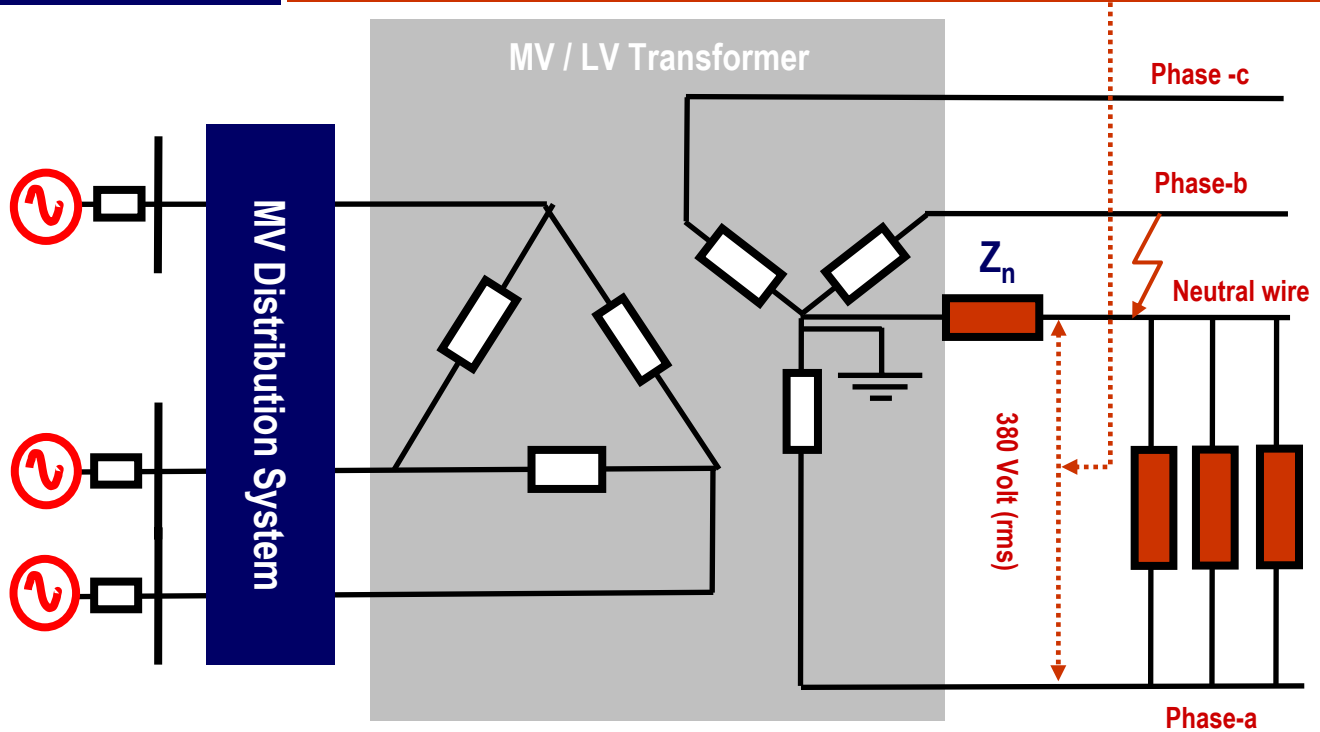
Electrical Safety

Overvoltages

As a result of sudden line-to-ground short circuit on phase-b, the phase and neutral wires are shorted, raising the voltage at neutral wire to that of phase-b

Neutral wire is grounded at the transformer side, but not at the load side, hence, the voltage across the loads becomes;

$$V_{load} = V_{phase} = V_a - V_b = V_{line} = 380 \text{ Volts}$$



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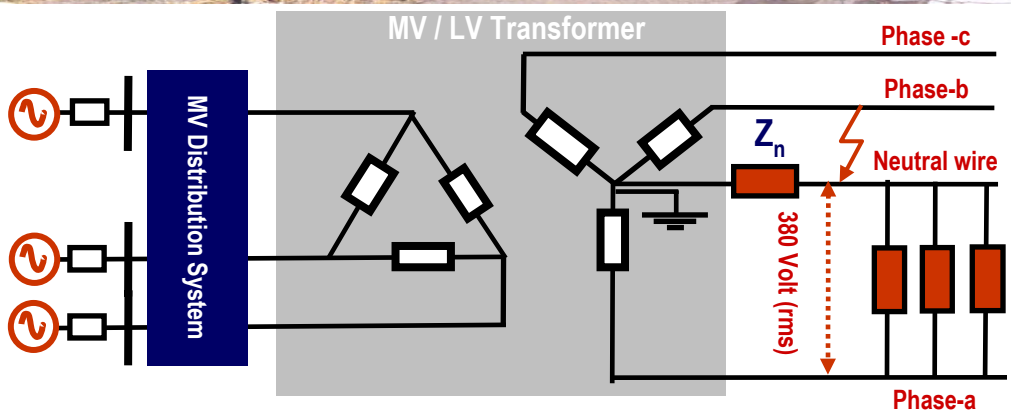
Damages due to Overvoltages

Overvoltage at the load terminals may yield;

(a) Burning and destruction of expensive electrical and electronic equipments,
(b) Fire,
(c) Weakening and failure of electrical insulation in the equipments,
(d) Explosion,
(e) Fatal consequences arising from fire, smoke, and electric shock (cardiac arrest)

Overvoltage in Adana Çimsa 154/34 kV Substation



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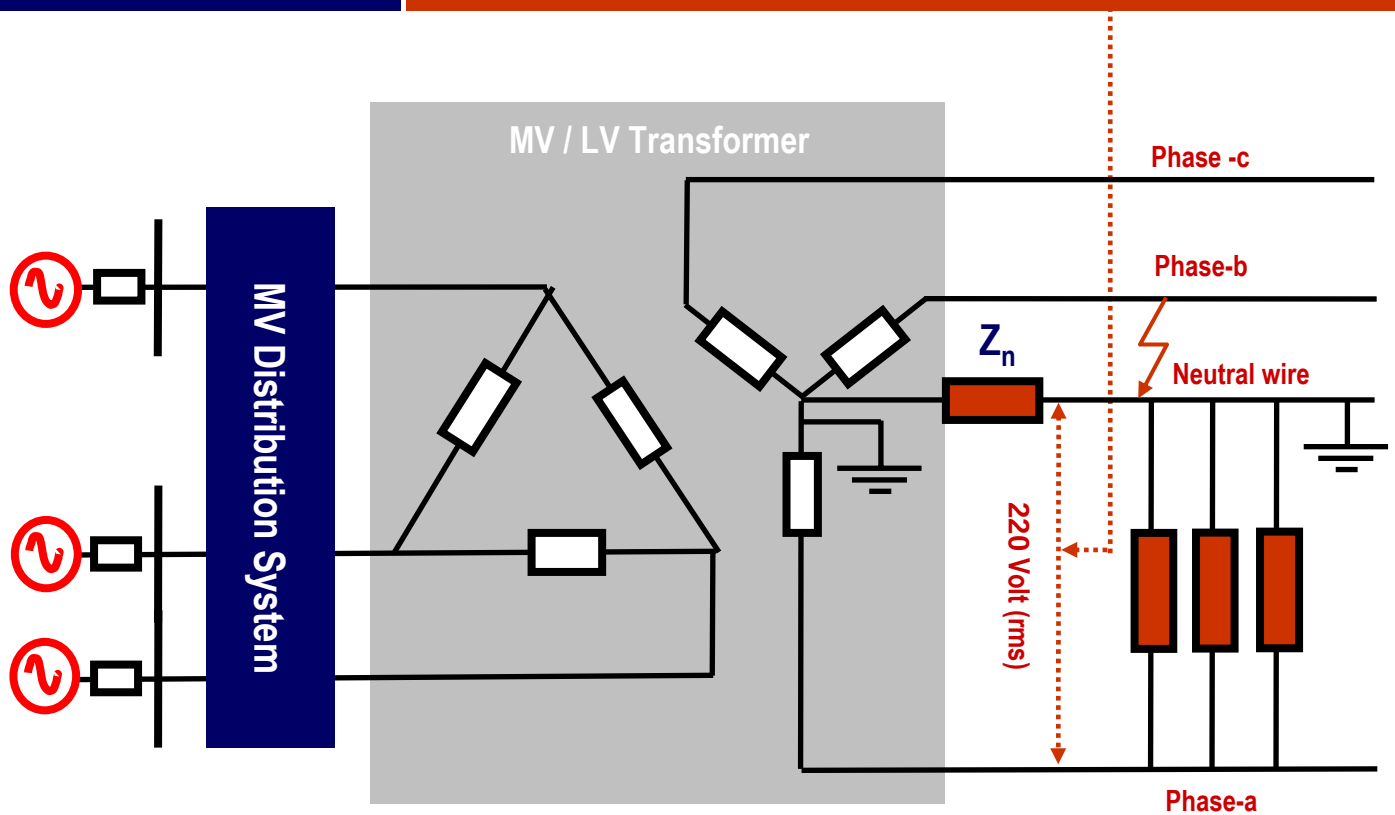
Solution for Reducing Overvoltages

Ground the neutral wire at both ends in order to make the voltage at the neutral wire zero

Voltage across the laods now becomes;

$V_{load} = V_a - 0 = V_{phase} = 220$ Volts



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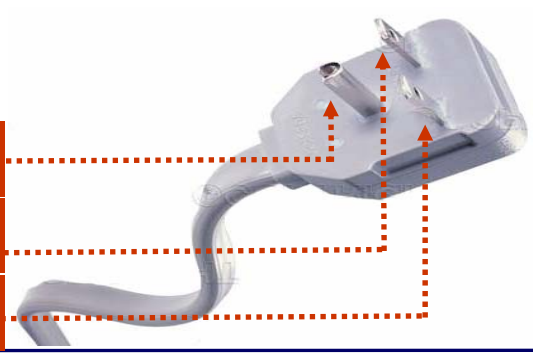
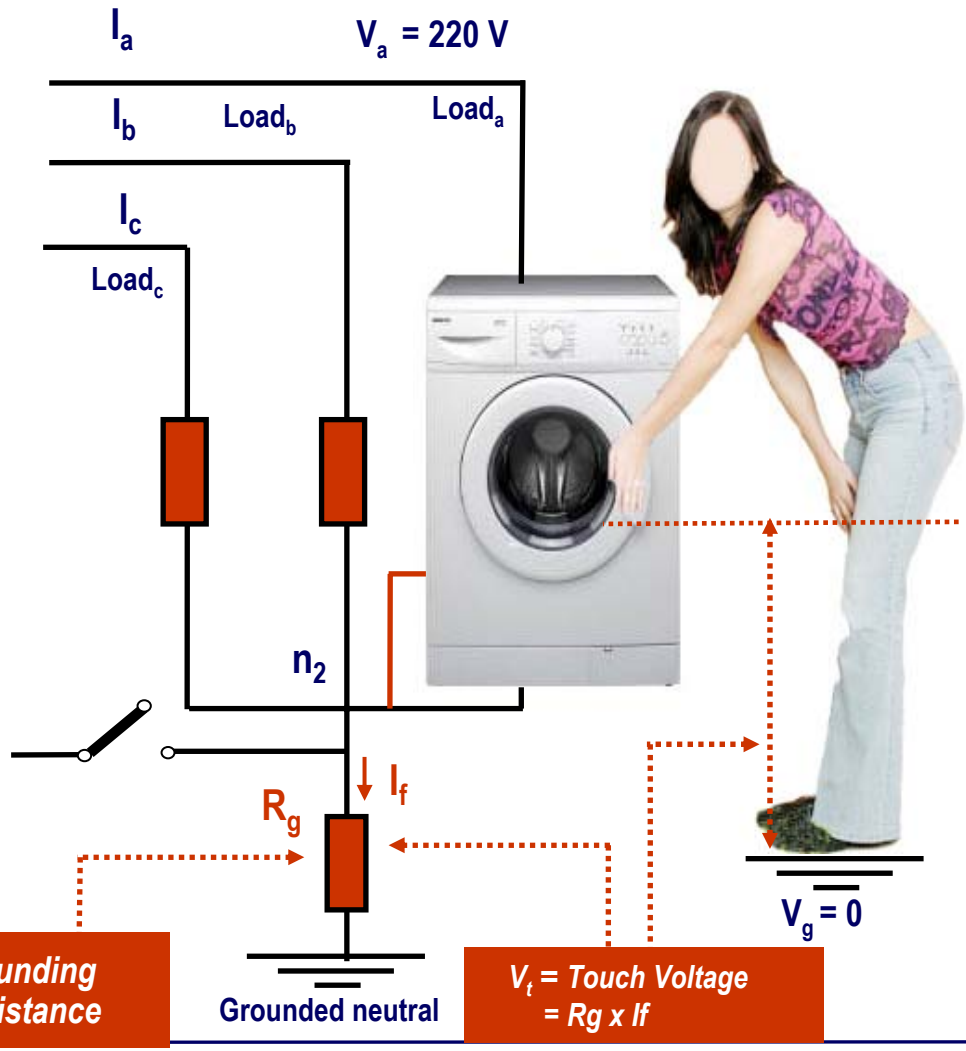
Grounding Resistance

Definition

Grounding resistance R_g is the total effective resistance between the metal cover of the equipment and ground

Grounding resistance must be near to zero or as low as possible in order to reduce the ***Touch Voltage***





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Calculation of Touch Voltage

Definition

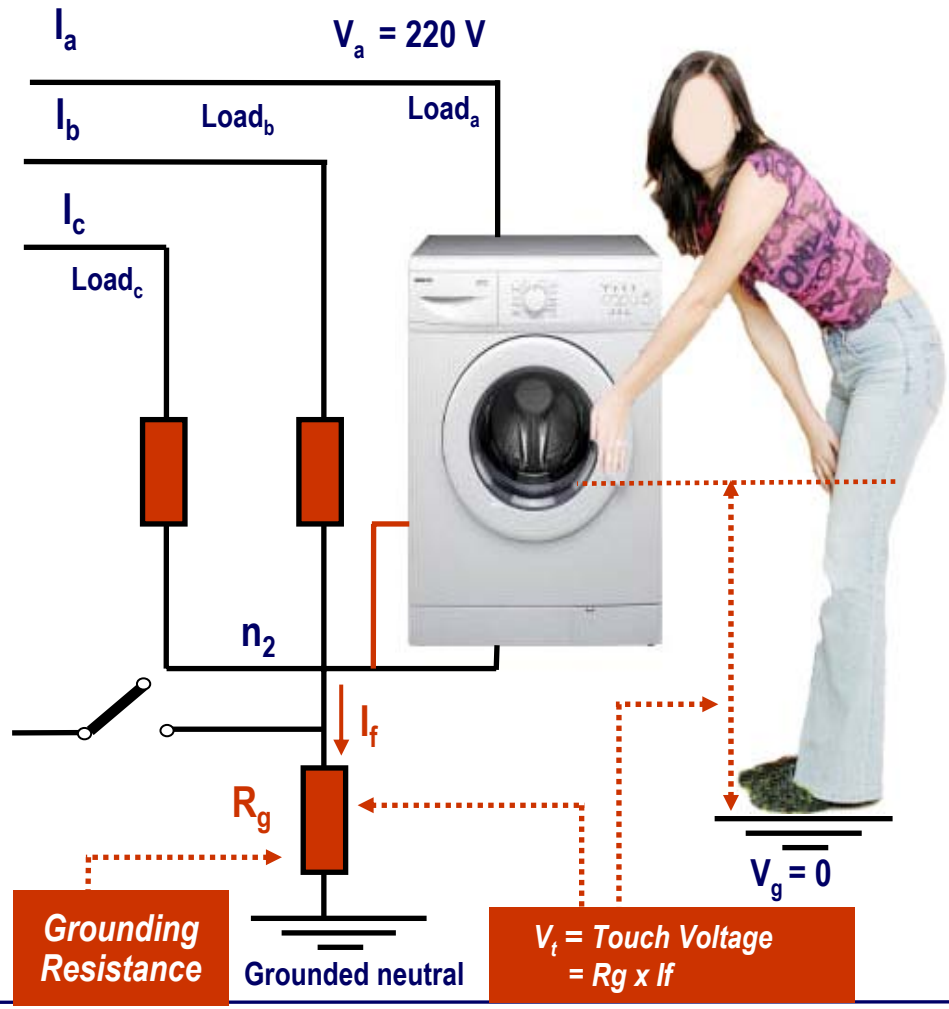
Touch Voltage **is the voltage appearing on the metal cover of the equipment when a line-to-ground type fault occurs in the equipment**

Touch Voltage **can be expressed as**

$$V_t = I_f \times R_g$$

where, V_t is the Touch Voltage,
I_f is the fault current,
R_g is the grounding resistance

Tolerable limit for AC Touch Voltage = 65 V



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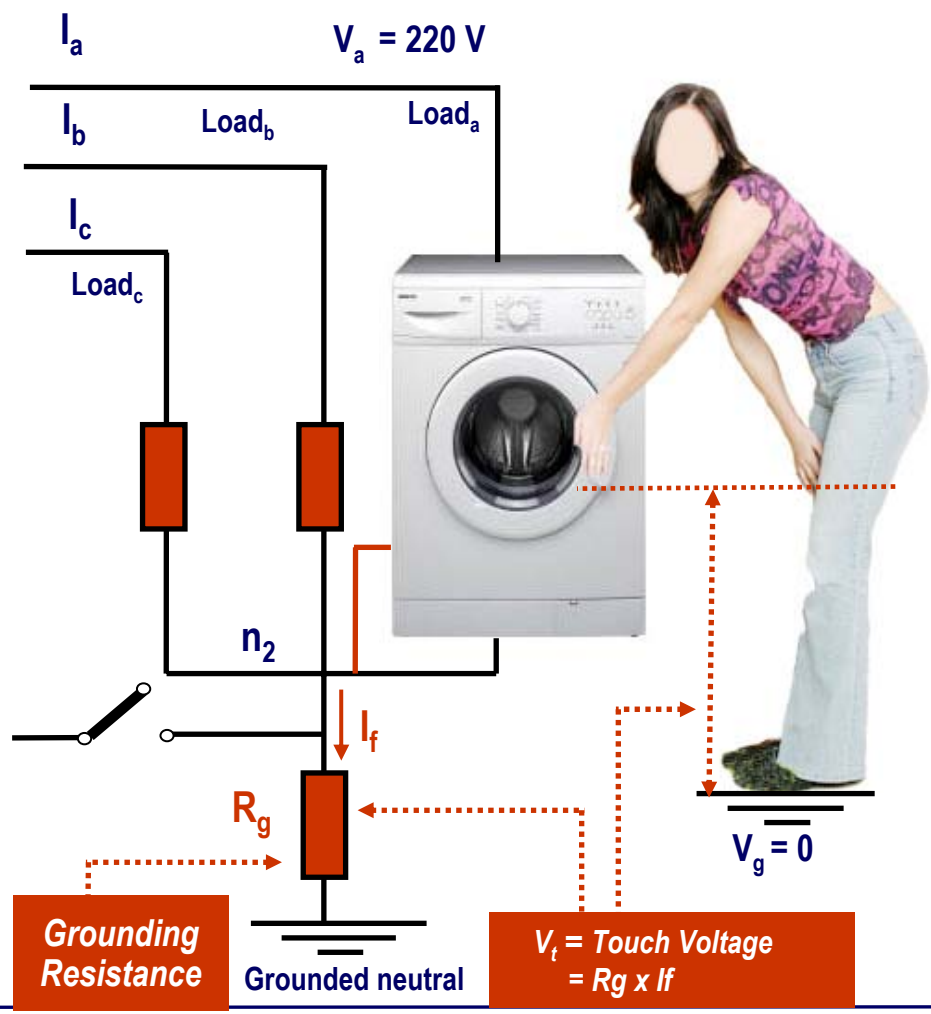
Solutions for Reducing Touch Voltage

Touch Voltage can be reduced by

(a) Reducing the resistance of the grounding wire, by increasing the cross section and/or reducing the length of the grounding wire,

(b) Making effective grounding, i.e. by using proper (copper) material for the grounding plate and/or rod, and burying them in a proper dept, choosing a proper (damp) location,

(c) Increasing the cross section of the wire, when the number and power rating of the equipment serviced by the common grounding wire is increased in time



Electrical Safety

"It's not voltage that kills, it's current!"

A common phrase heard in reference to electrical safety; *"It's not voltage that kills, it's current!"*

***If voltage presented no danger, no one would ever print and display signs saying: "*DANGER -- HIGH VOLTAGE !"**

The principle that *"current kills"* is essentially correct.

It is electric current that burns tissue, freezes muscles, and fibrillates hearts.

Electrical Safety

Reaction of Human Body against Electrical Current

BODILY EFFECT	DIRECT CURRENT (DC)	60 Hz AC	10 kHz AC
Slight sensation at hand(s)	Men = 1.0 mA	0.4 mA	7 mA
	Women = 0.6 mA	0.3 mA	5 mA
Perception threshold	Men = 5.2 mA	1.1 mA	12 mA
	Women = 3.5 mA	0.7 mA	8 mA
Painful, but voluntary muscle control still maintained	Men = 62 mA	9 mA	55 mA
	Women = 41 mA	6 mA	37 mA
Painful, unable to let go of wires	Men = 76 mA	16 mA	75 mA
	Women = 51 mA	10.5 mA	50 mA
Severe pain, difficulty in breathing	Men = 90 mA	23 mA	94 mA
	Women = 60 mA	15 mA	63 mA
Heart fibrillation after 3 seconds	Men = 500 mA	100 mA	
	Women = 500 mA	100 mA	

Electrical Safety

Hey, my boy,
Be careful about electrical safety

He, he, he