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 accidents

Electrical Safety

Basic Definitions

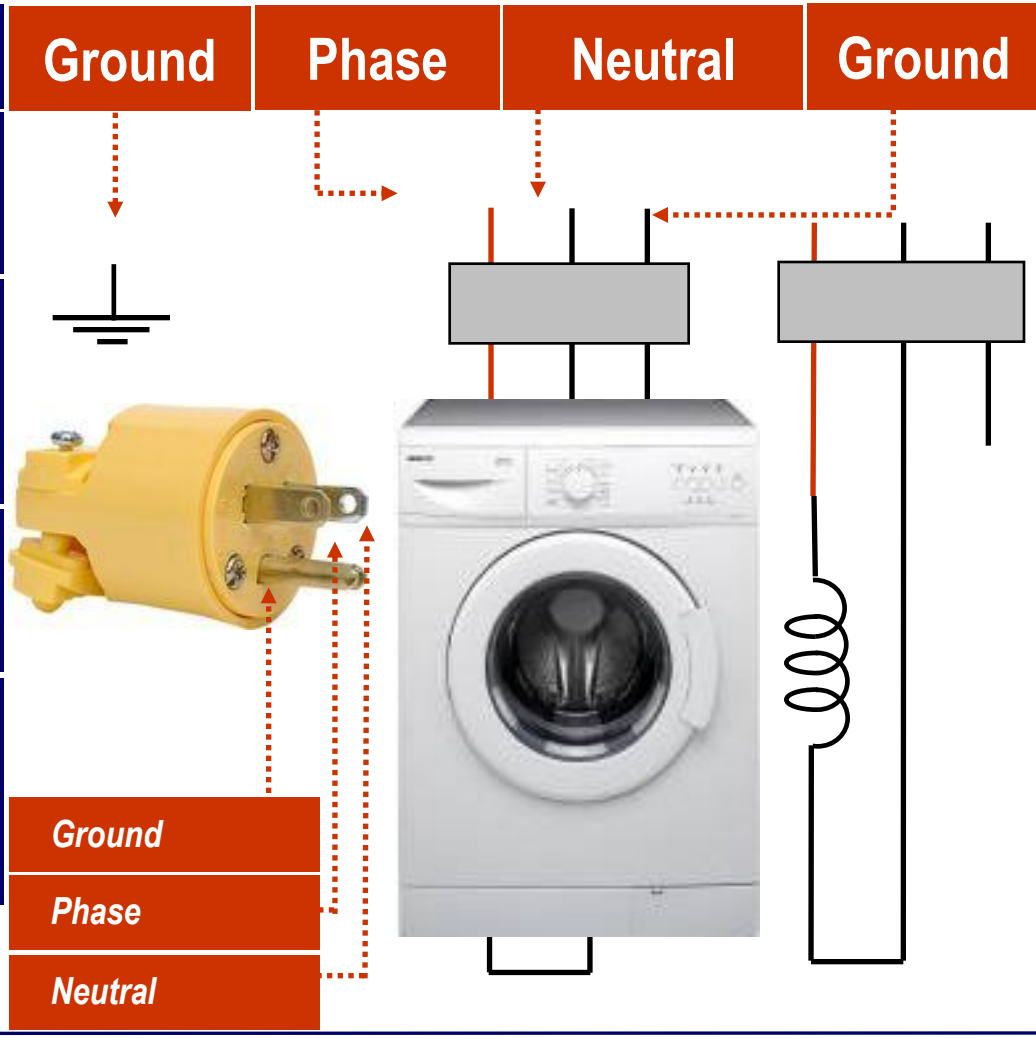
Phase, Neutral, Ground and Earth

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 the electrical equipment

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



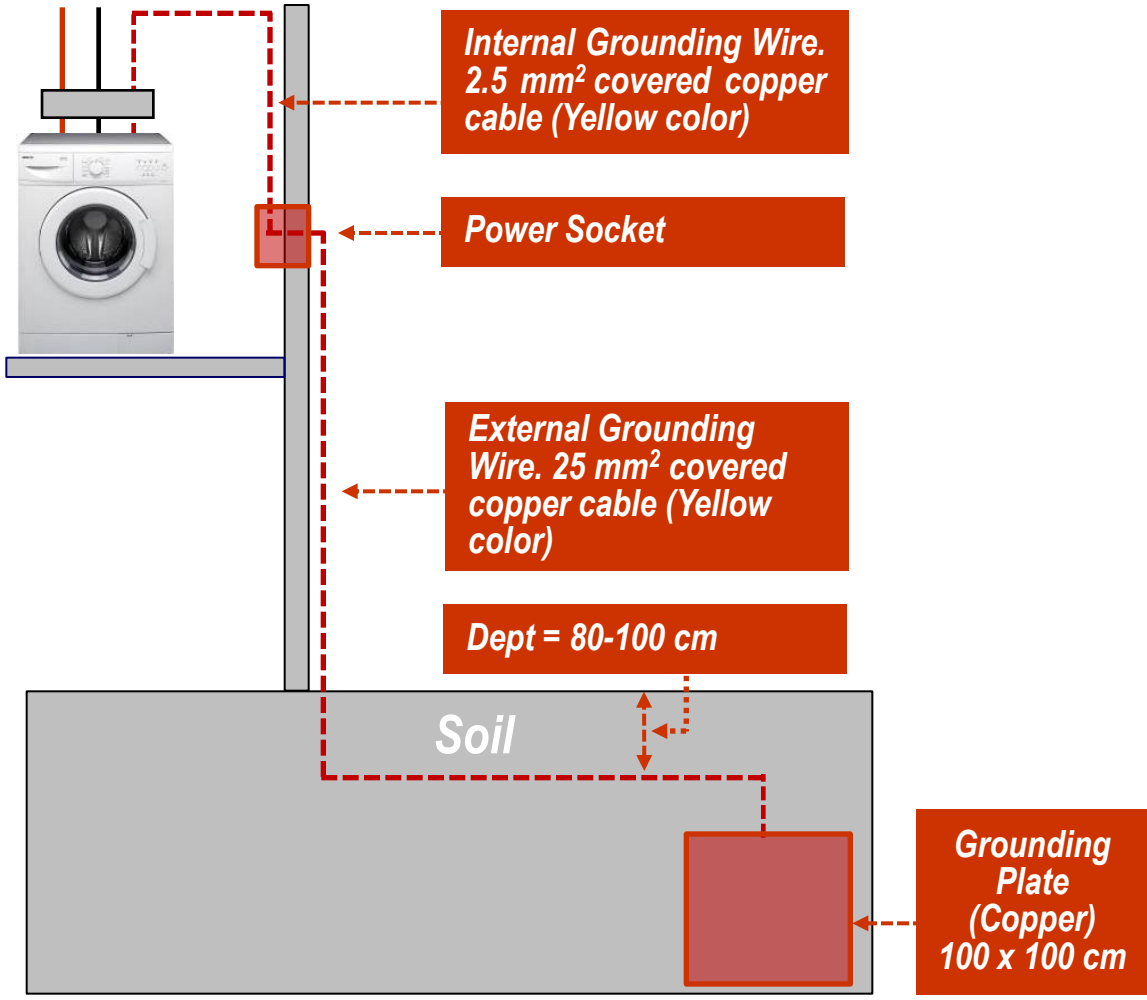
Electrical Safety

Grounding

Definition

Grounding is connecting the metal cover of an electrical equipment to ground by a wire with zero or negligible resistance, in order to make the voltage at the surface of the equipment zero, for safety purposes

Direct (Solid) Grounding is grounding of an equipment by a wire with zero resistance



Electrical Safety

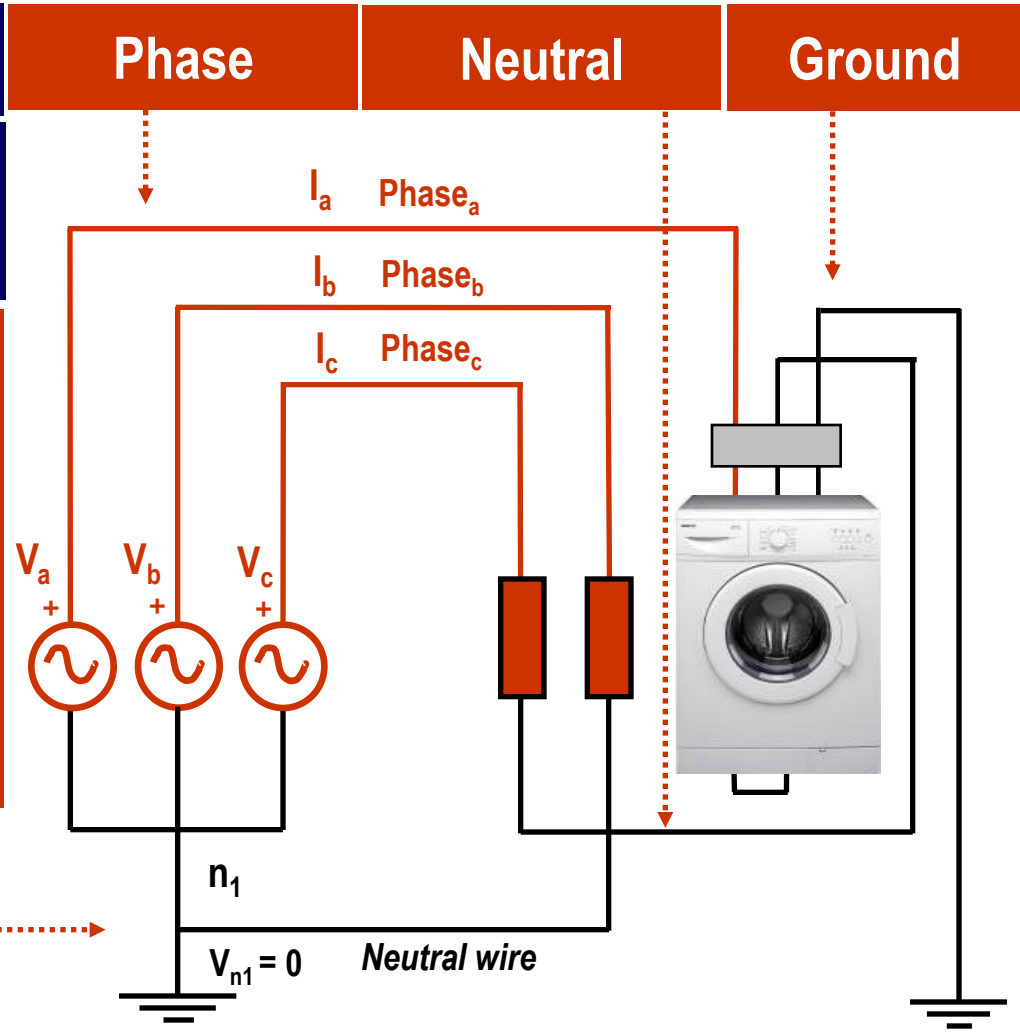
Grounded Neutral

Definition

Grounded neutral is the neutral point connected directly to ground

Grounded neutral

Neutral point of three-phase system should either be directly grounded as shown in the figure on the RHS or connected to the ground wire of the utility (TEDAS), otherwise the voltage on the ground point may rise to phase voltage level, which may result in harmful consequences on the consumer side.



Electrical Safety

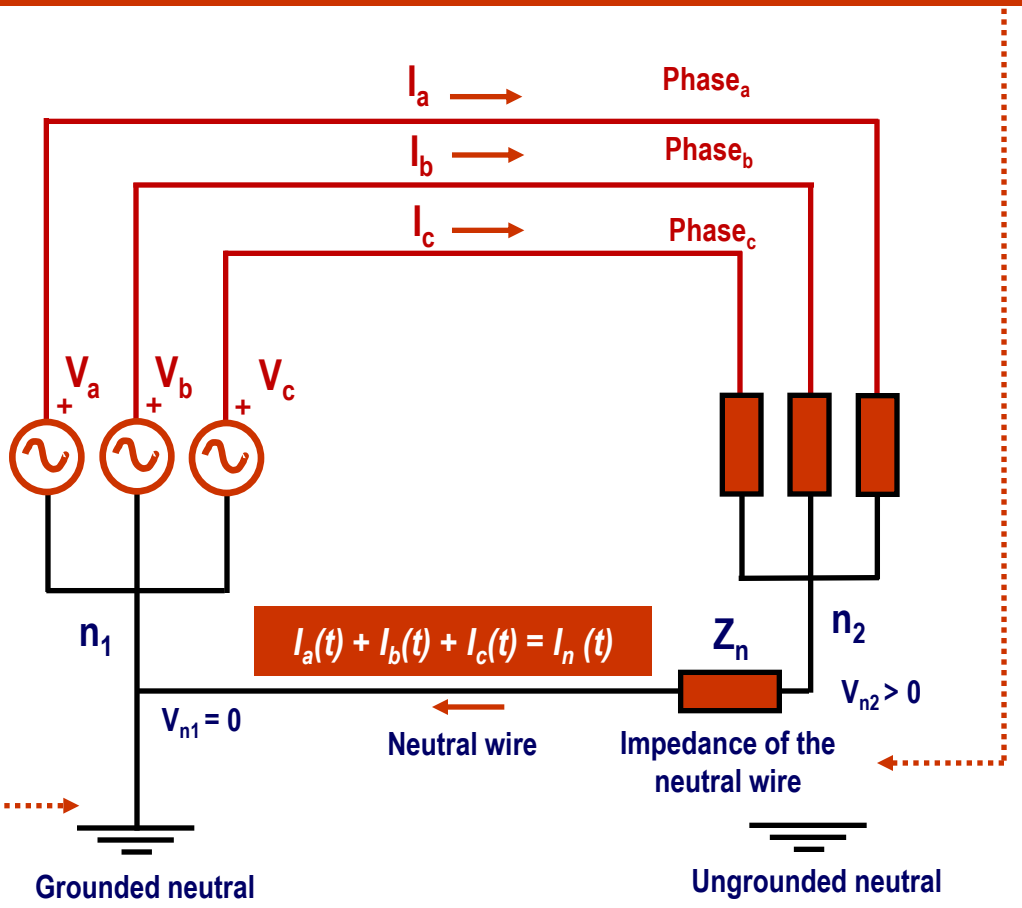
Ungrounded Neutral

Definition

Ungrounded neutral is the neutral point not connected to ground

- Neutral point n_1 at the source side (TEDAS) is always solidly grounded, hence voltage at that point is always zero,
- Neutral point n_2 at the consumer side may not always be grounded, hence voltage at that point may be nonzero due to unbalance in the loading

Ungrounded Neutral



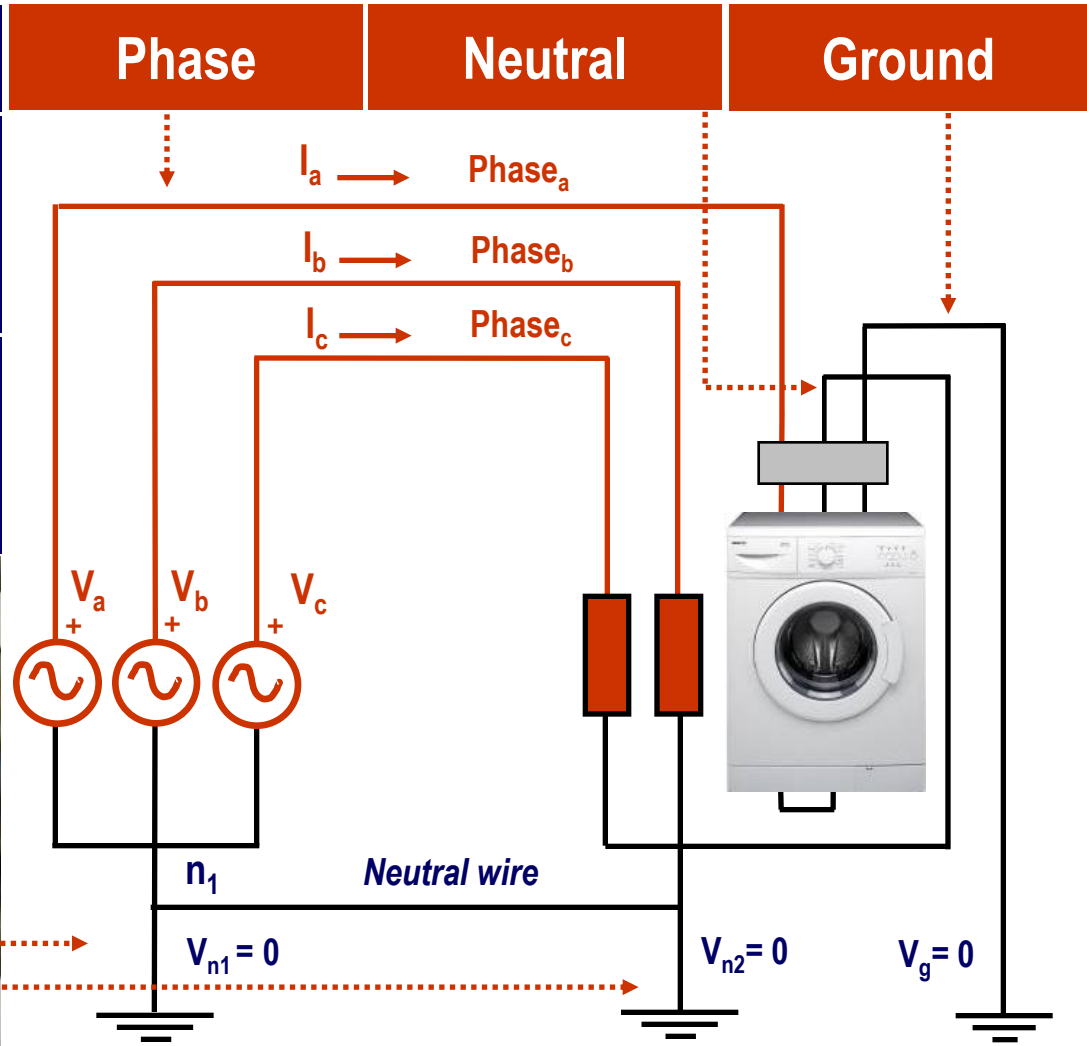
Electrical Safety

Grounding

Definition

Grounding the neutral points ***on BOTH sides*** of the neutral wire is best and preferable

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

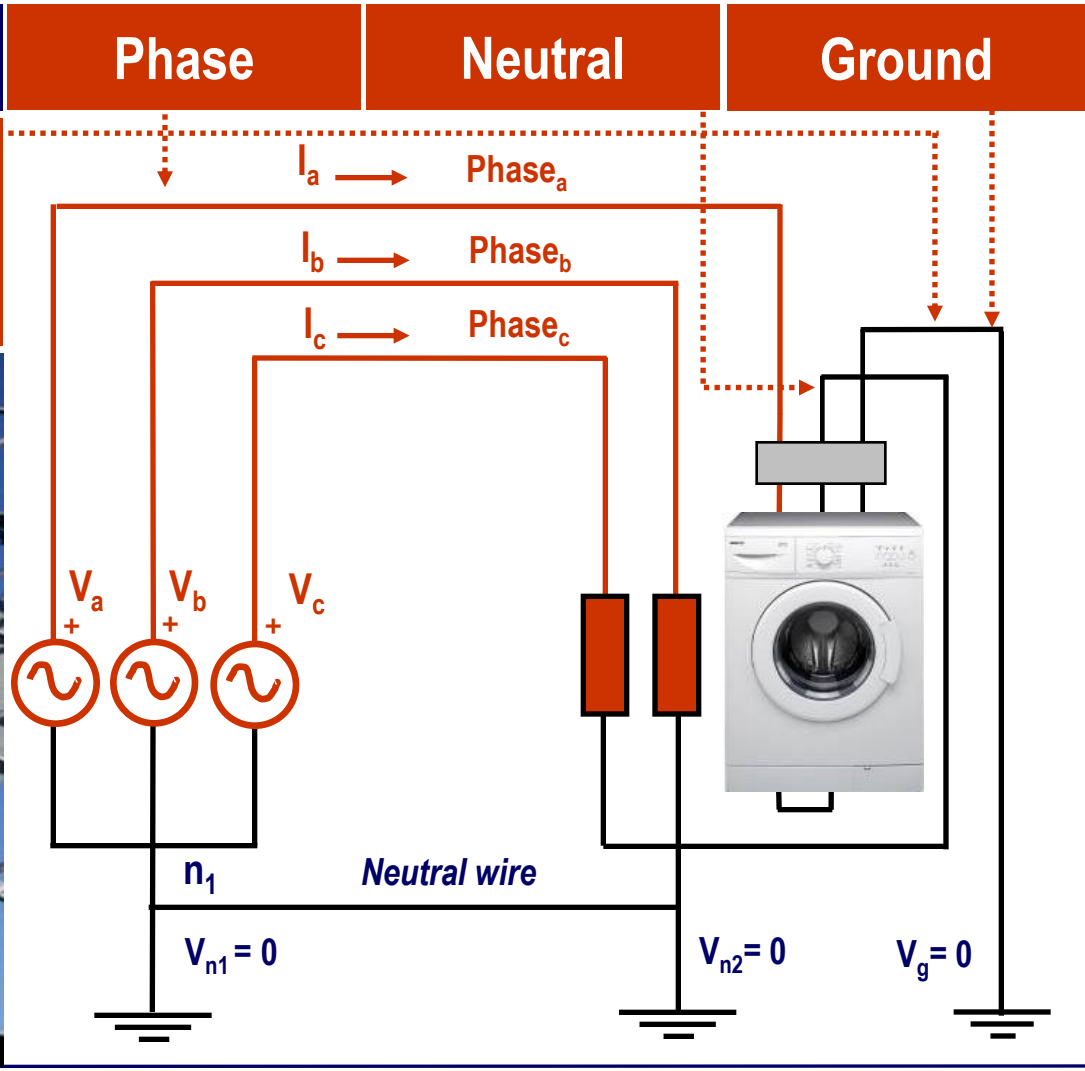


Electrical Safety

Grounding

Definition

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

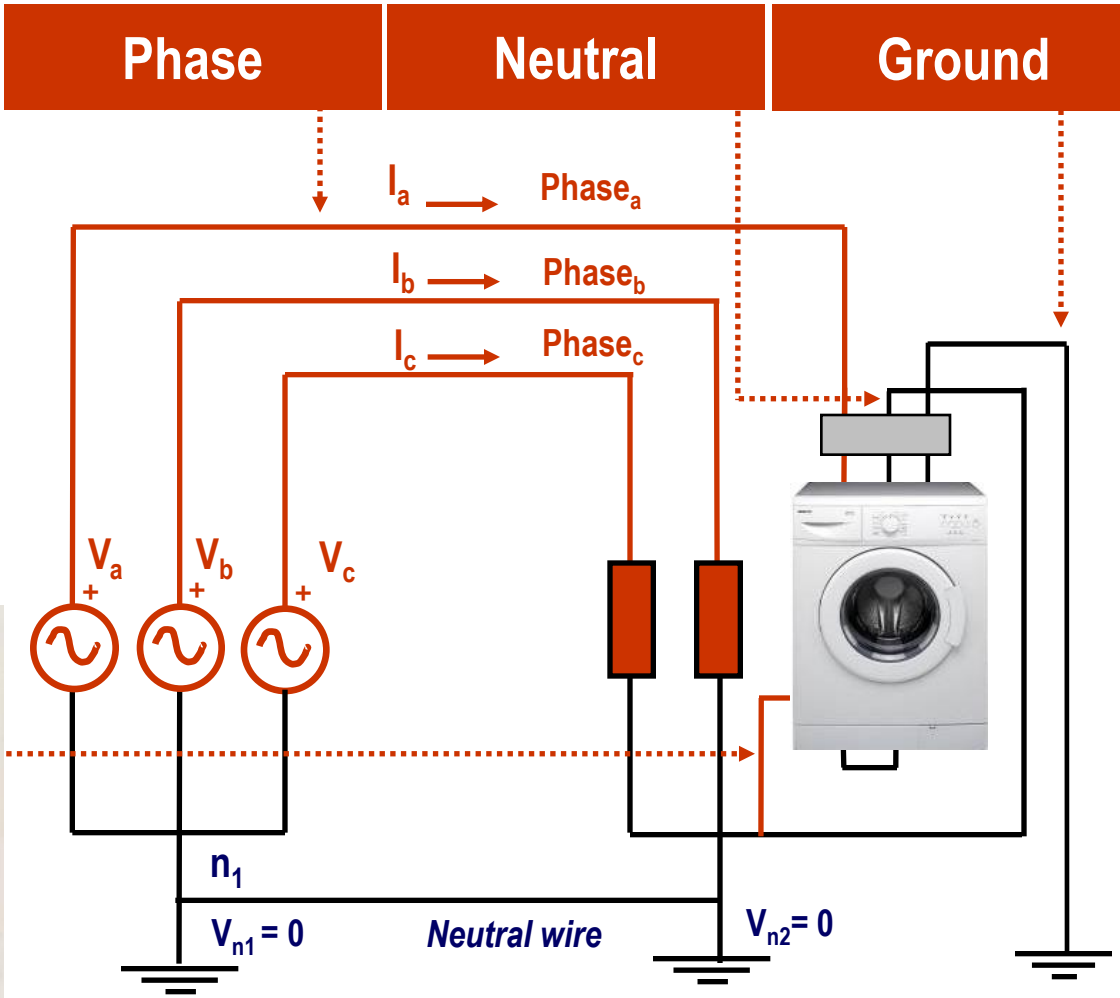


Electrical Safety

Grounding

Definition

Connecting the chassis of electrical equipments to the neutral point *so-called "zeroing"* is strictly ILLEGAL (FORBIDDEN) due to safety reasons that will be described in the following pages



Electrical Safety

Grounded and Ungrounded Neutral Points

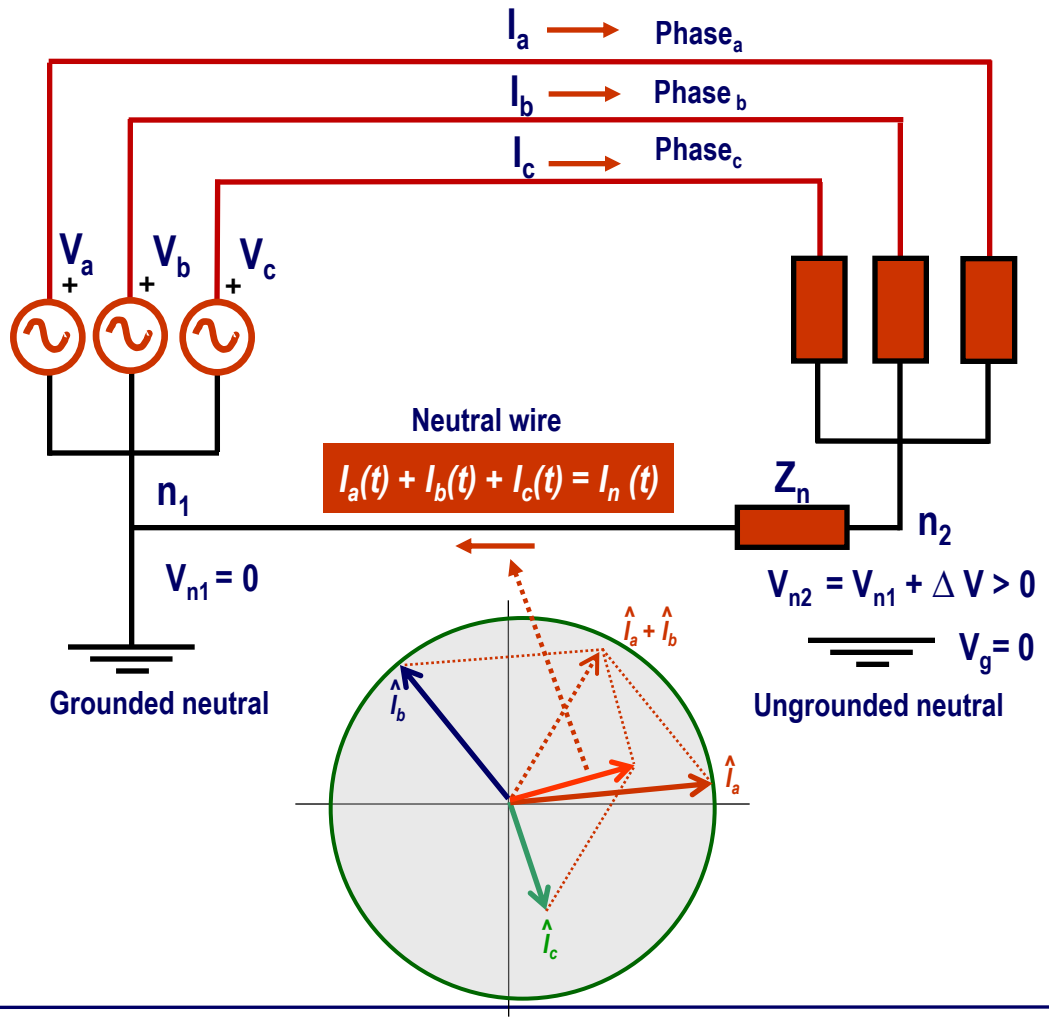
Voltage Rise on an Ungrounded Neutral Point

In case that the phases are unbalanced, i.e. the phase loads; $Phase_a$, $Phase_b$, $Phase_c$ 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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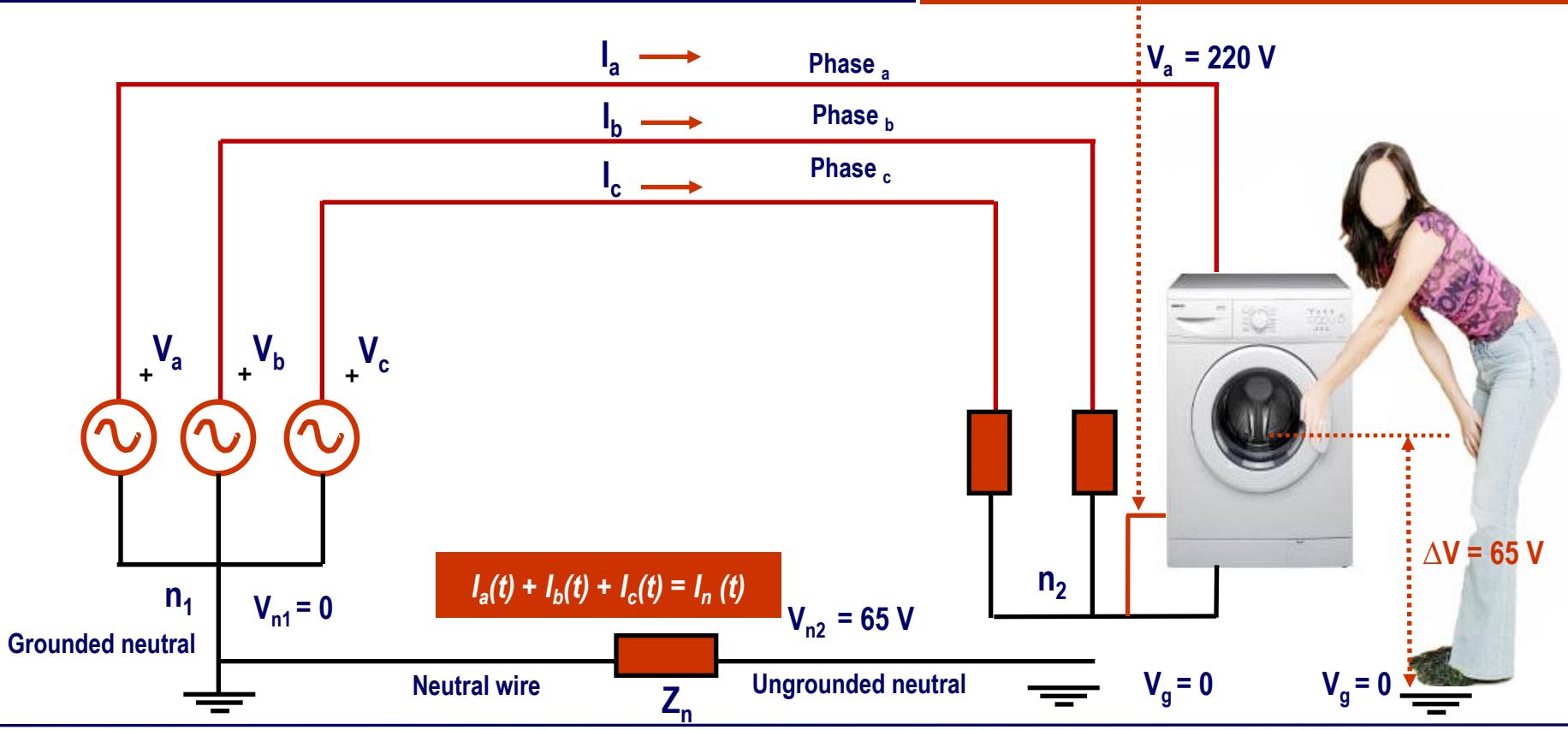
Why "Zeroing" is Illegal ?

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

Metal cover of the washer is connected to neutral point the equipment : i.e. "Zeroed"

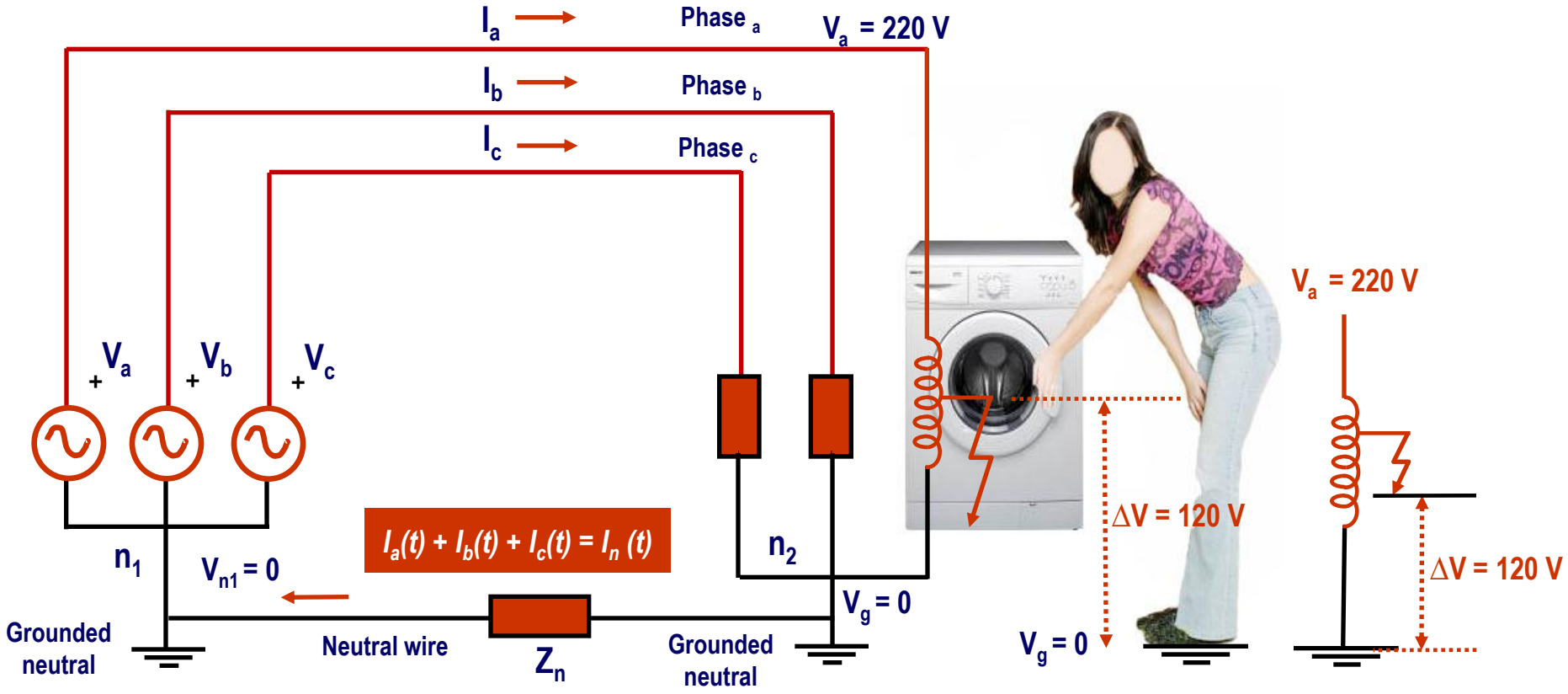


Electrical Safety

Electrical Hazards due to Insulation failure in the Equipment

Voltage on the ungrounded metal cover of an equipment may reach to dangerous levels when the insulation of the equipment fails

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

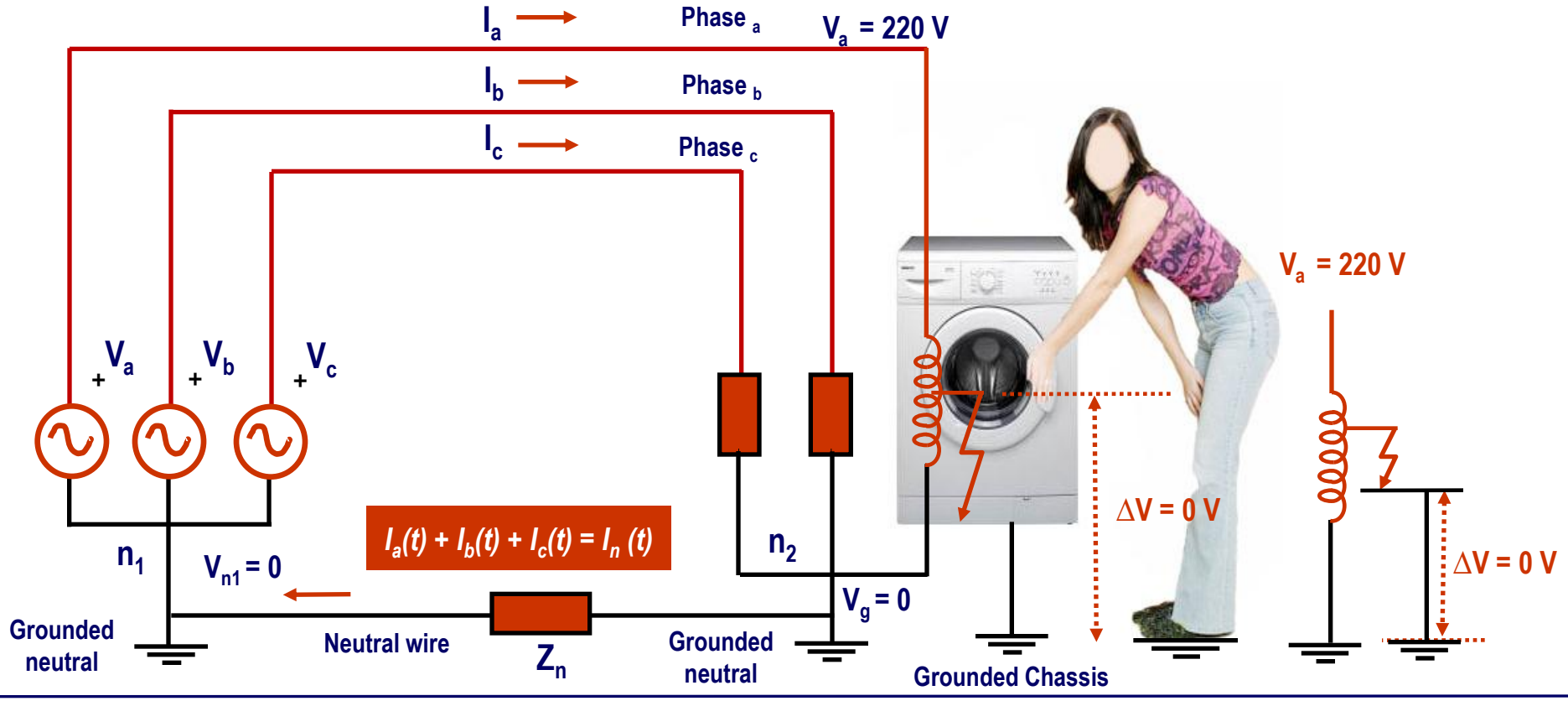


Electrical Safety

Eliminating Electrical Hazards due to Insulation failure in the Equipment

Grounding the metal cover of an equipment eliminates hazards due to insulation failure of the equipment

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



Electrical Safety

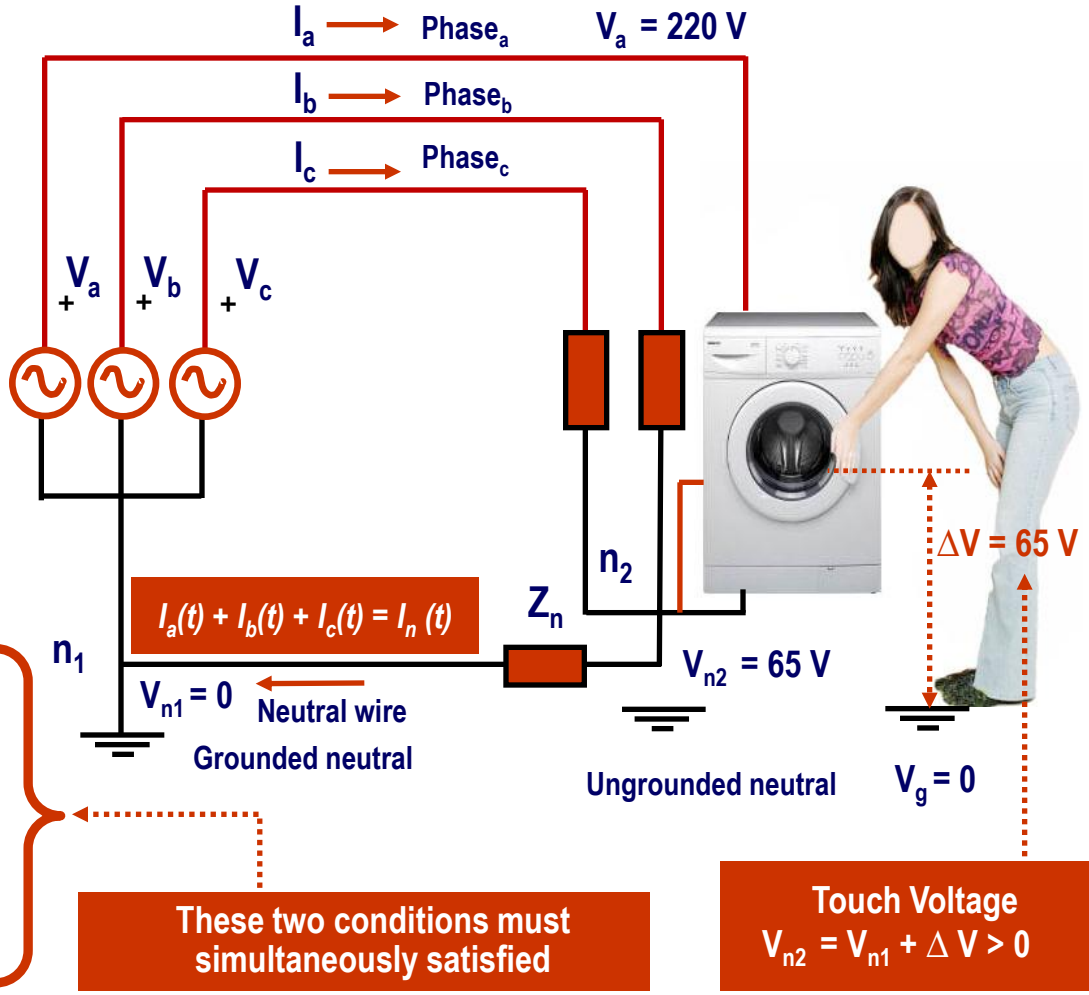
Touch Voltage

Definition

"Touch Voltage" is the voltage on the metal cover of an electrical equipment

"Touch Voltage" will appear on the metal cover of the electrical equipment when;

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



Electrical Safety

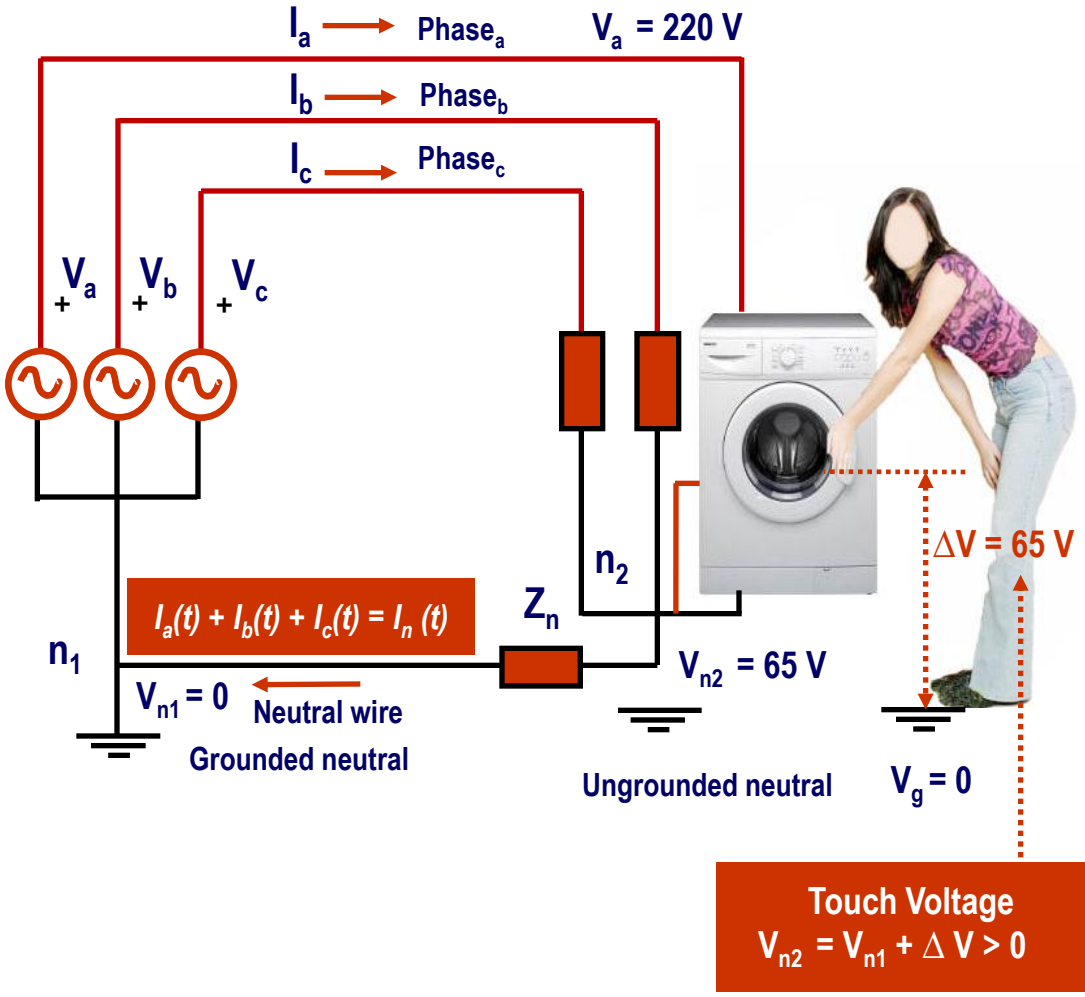
Touch Voltage

Definition

Touch Voltage may rise to fatal levels, such as few hundred volts, when the chassis of the equipment is ungrounded

Touch Voltage at node n_2 will be;

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



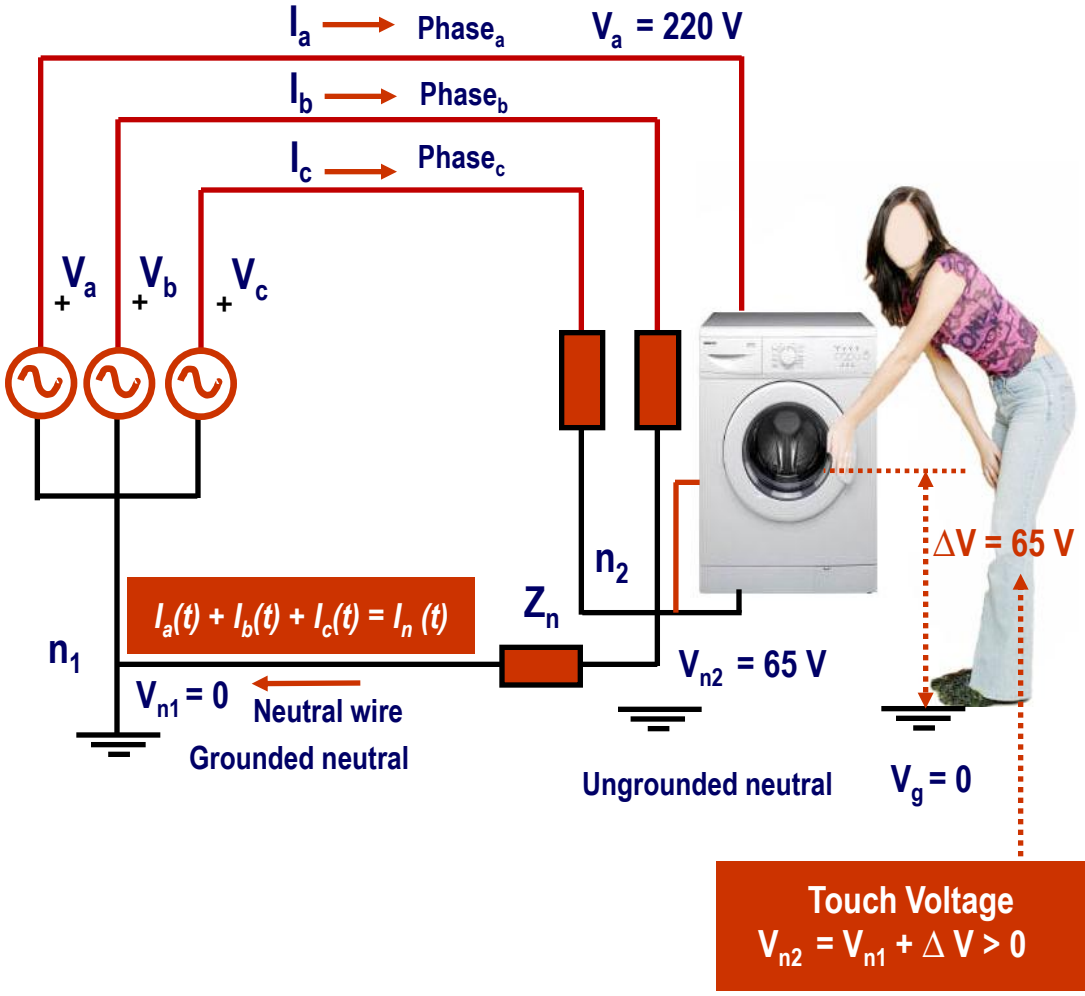
Electrical Safety

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 fatal level, such as few hundred volts

Touch voltages above 65 Volts (AC) are regarded to be fatal



Electrical Safety

Earth Leakage Current Relay (Single Phase)

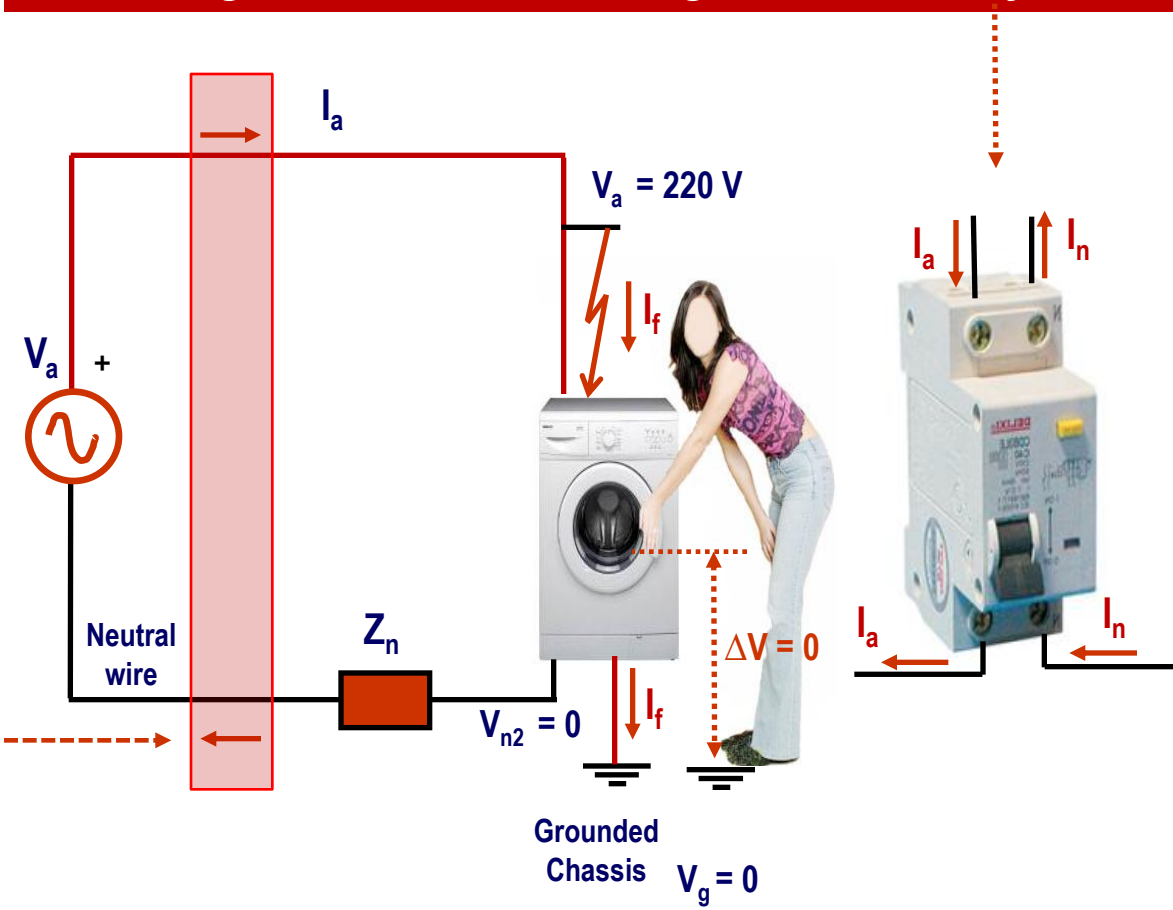
Description

Earth Leakage Current Relay is a device checks whether the sum of phase and neutral currents is zero, i.e.

$I_a(t) - I_n \stackrel{?}{=} 0$

If not, it triggers the circuit breaker

Single Phase Earth Leakage Current Relay



$I_a(t) - I_n(t) = I_f(t) \neq 0$

Electrical Safety

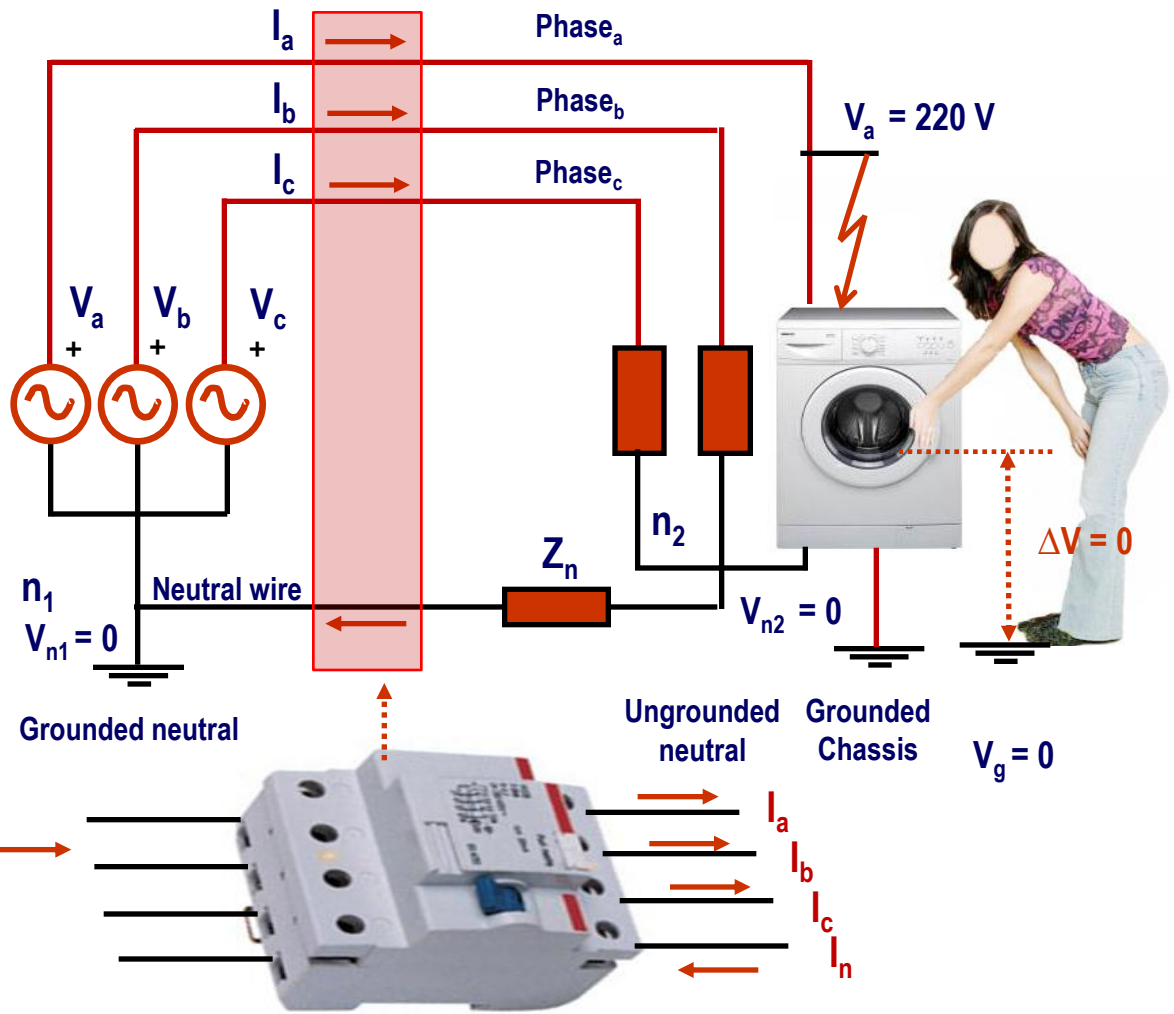
Earth Leakage Current Relay (Three-Phase)

Description

Three phase Earth Leakage Current Relay is a device checks whether the sum of phase currents minus neutral current is zero, i.e.

$$I_a(t) + I_b(t) + I_c(t) - I_n \stackrel{?}{=} 0$$

If not, it triggers the circuit breaker



Three phase Earth Leakage Current Relay

$$I_a(t) + I_b(t) + I_c(t) - I_n(t) = I_f(t) \neq 0$$

Electrical Safety

Earth Leakage Current Relay (Single Phase)

Description

Earth Leakage Current Relay is a device checks whether the sum of phase and neutral currents is zero, i.e.

$I_a(t) - I_n \stackrel{?}{=} 0$

If not, it triggers the circuit breaker

Single and Three-Phase Earth Leakage Current Relays

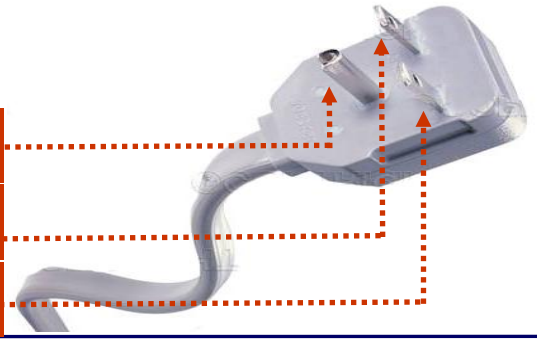
Electrical Safety

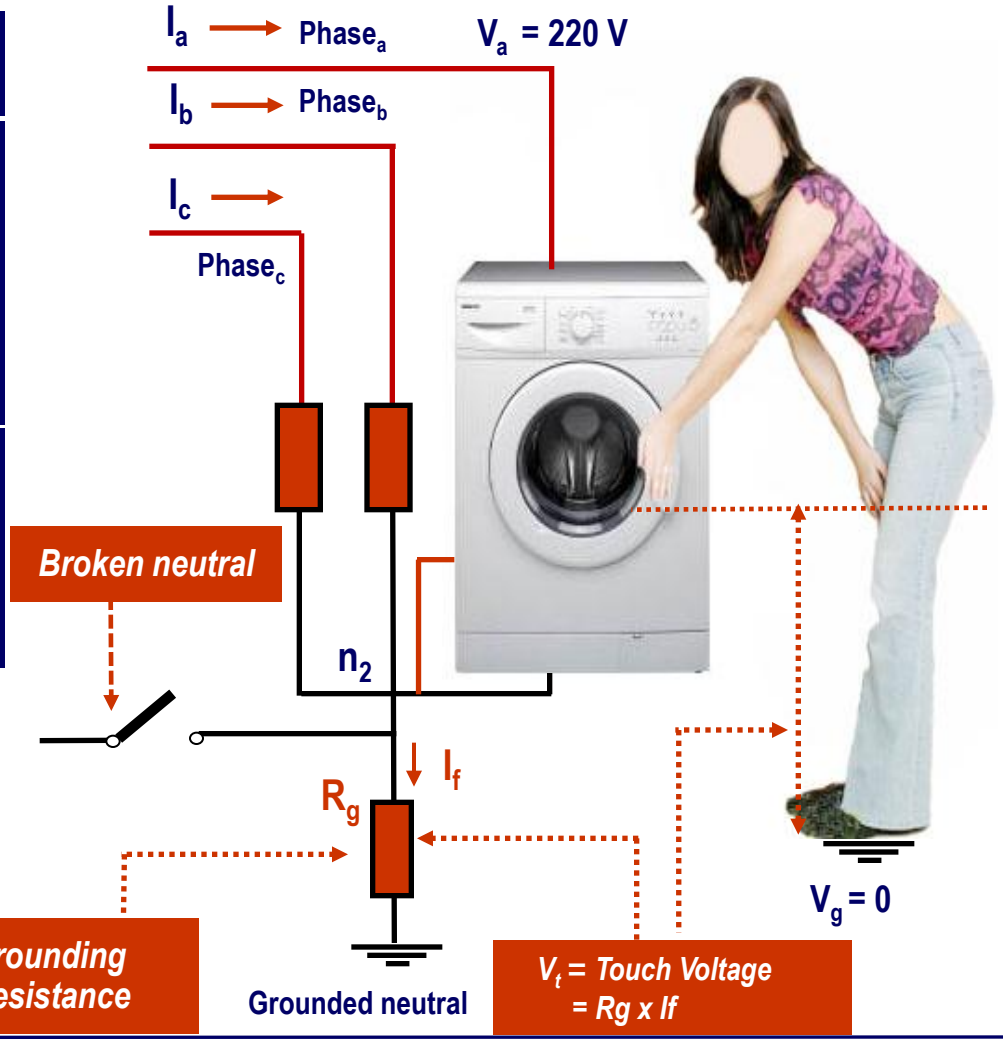
Grounding Resistance

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***





Electrical Safety

Touch Voltage

Definition

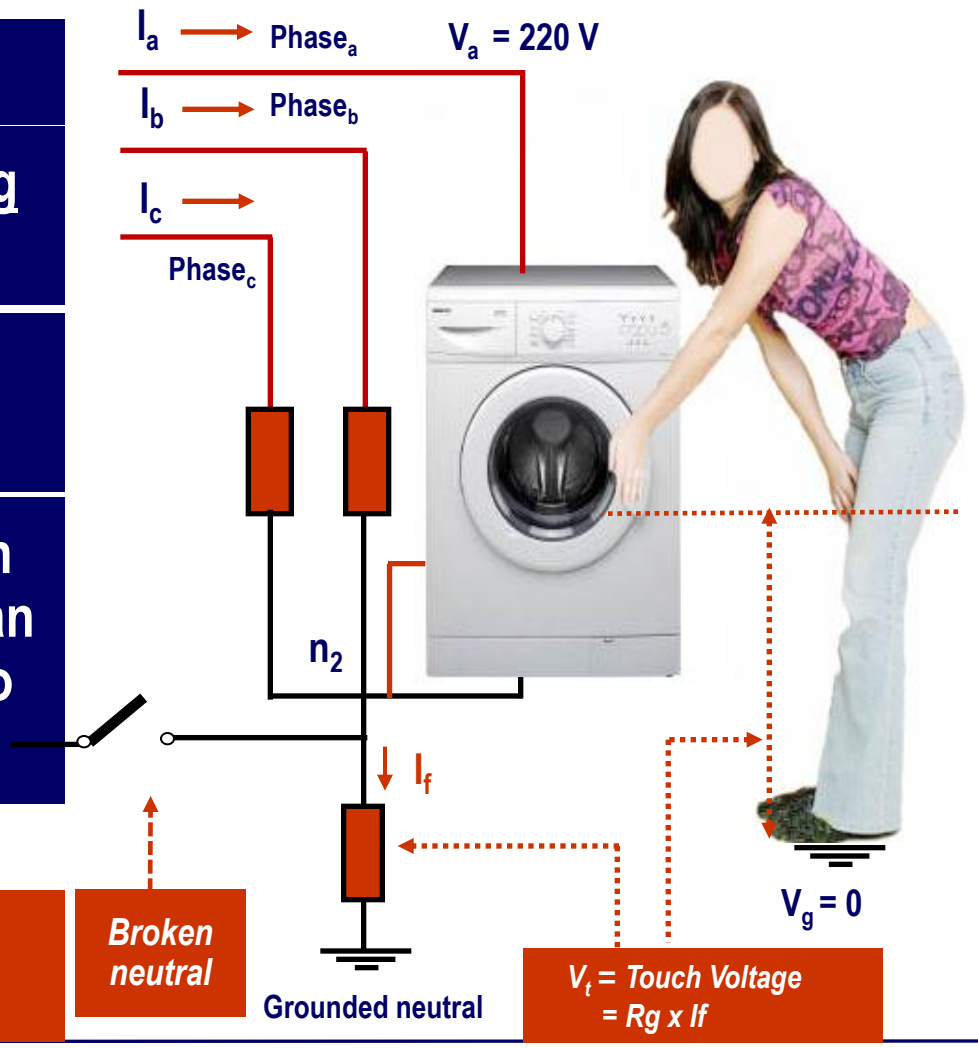
Touch Voltage is the voltage appearing on the metal cover of an equipment

Basic Rule for Safety: Touch Voltage must always be zero

Touch Voltage becomes nonzero when a line-to-ground type fault occurs in an equipment with metal cover shorted to neutral wire (Called "zeroing")

Illegal !

Tolerable limit for human safety for AC Touch Voltage is 65 V (rms)



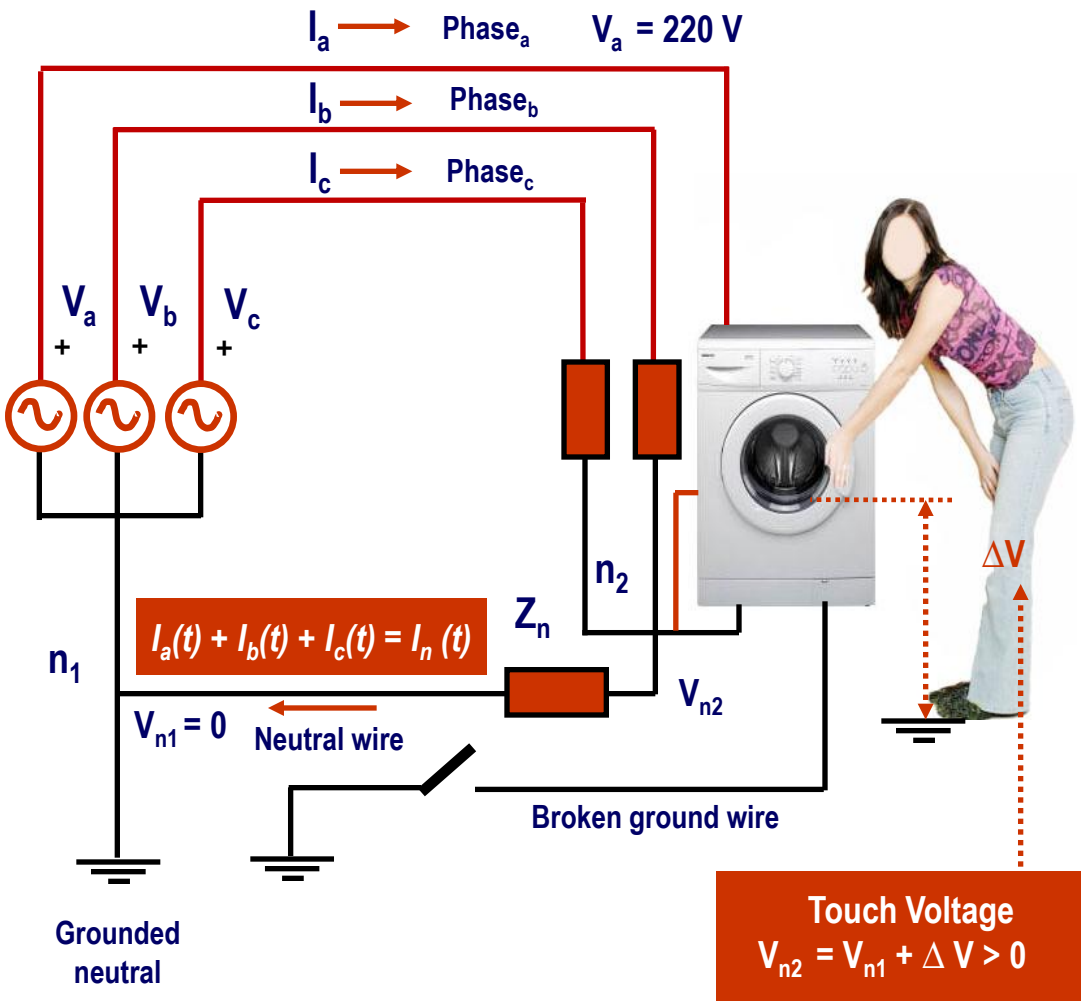
Electrical Safety

Touch Voltage due to Broken Ground Wire

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



Electrical Safety

Calculation of the Touch Voltage

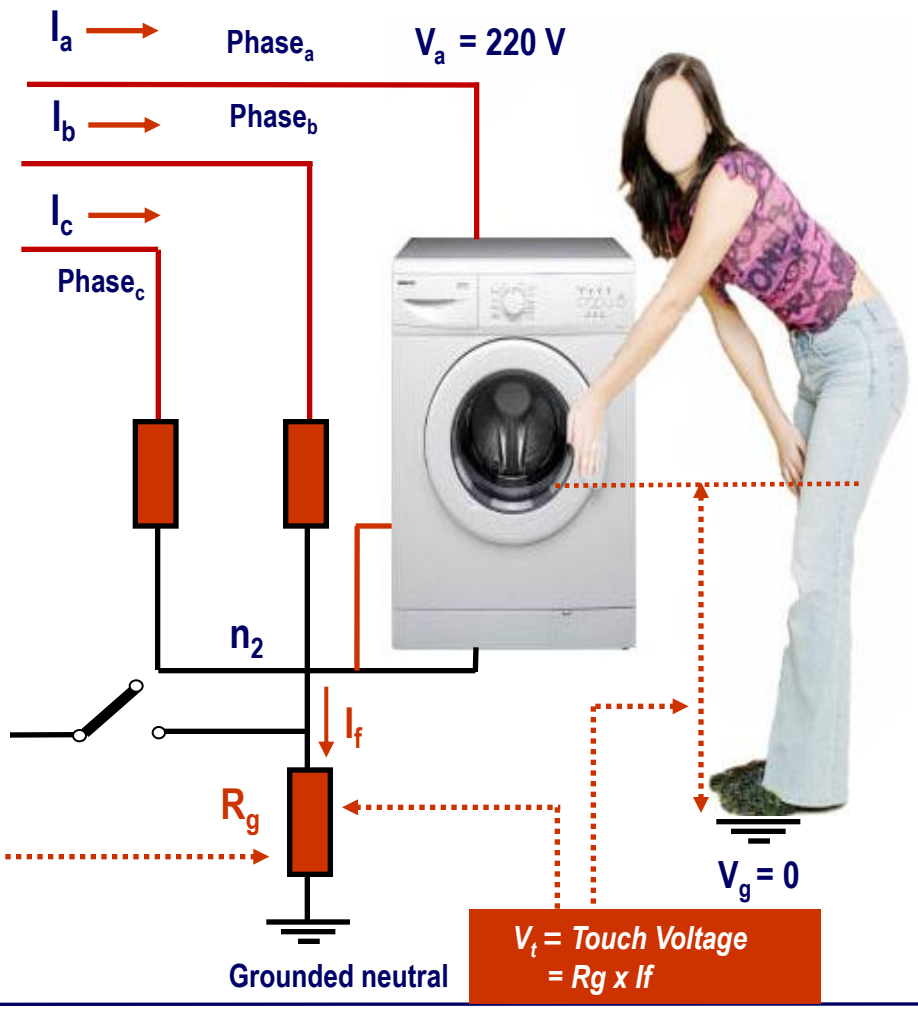
Calculation of the Touch Voltage

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 human safety for AC Touch Voltage is 65 V (rms)

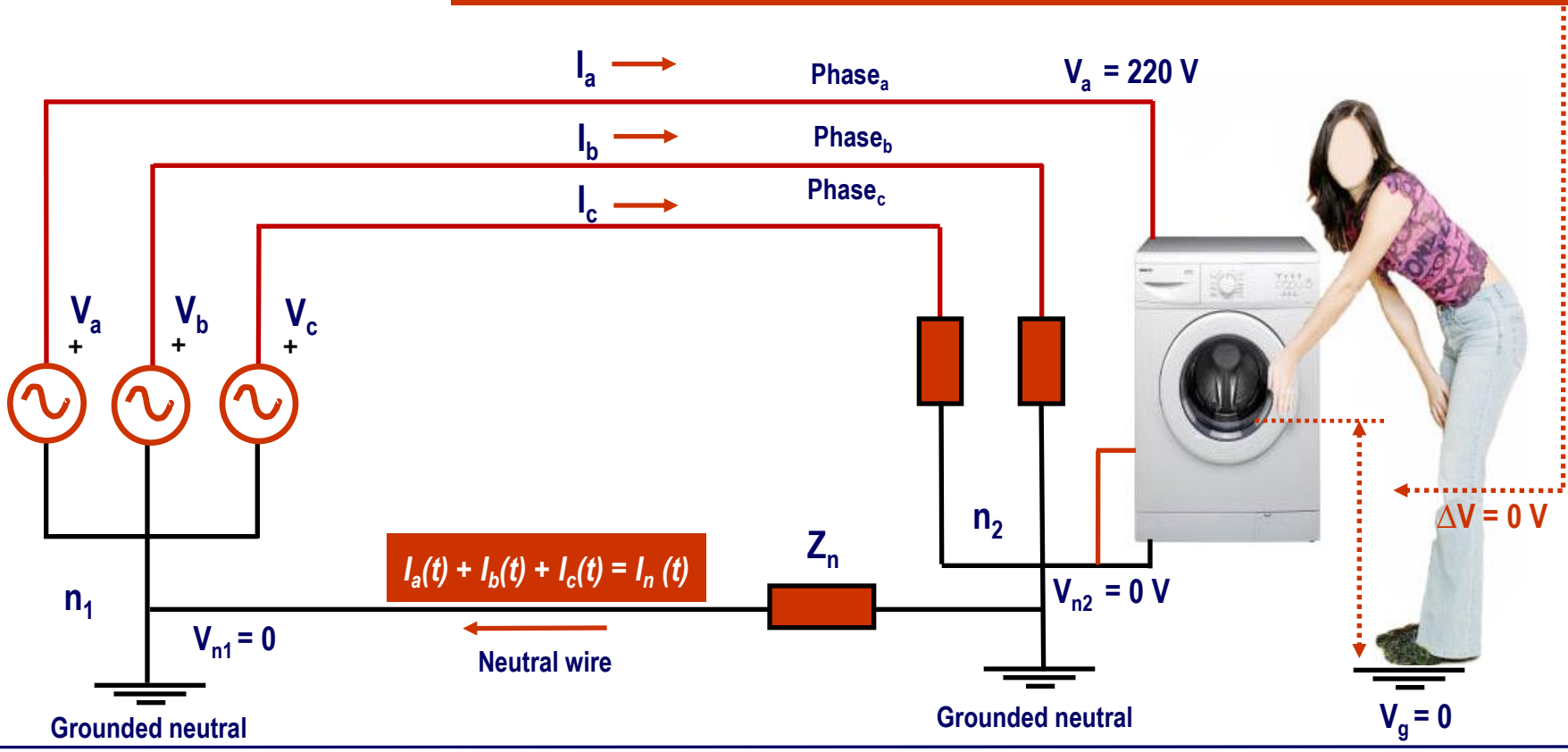


Electrical Safety

Ways of Reducing Touch Voltage in Household equipments

Ground the neutral wire at the load terminals

Please note that grounding neutral wire now prevents electrical hazards that may be arised due to improper connection between ground and netral, i.e. zeroing"



Electrical Safety

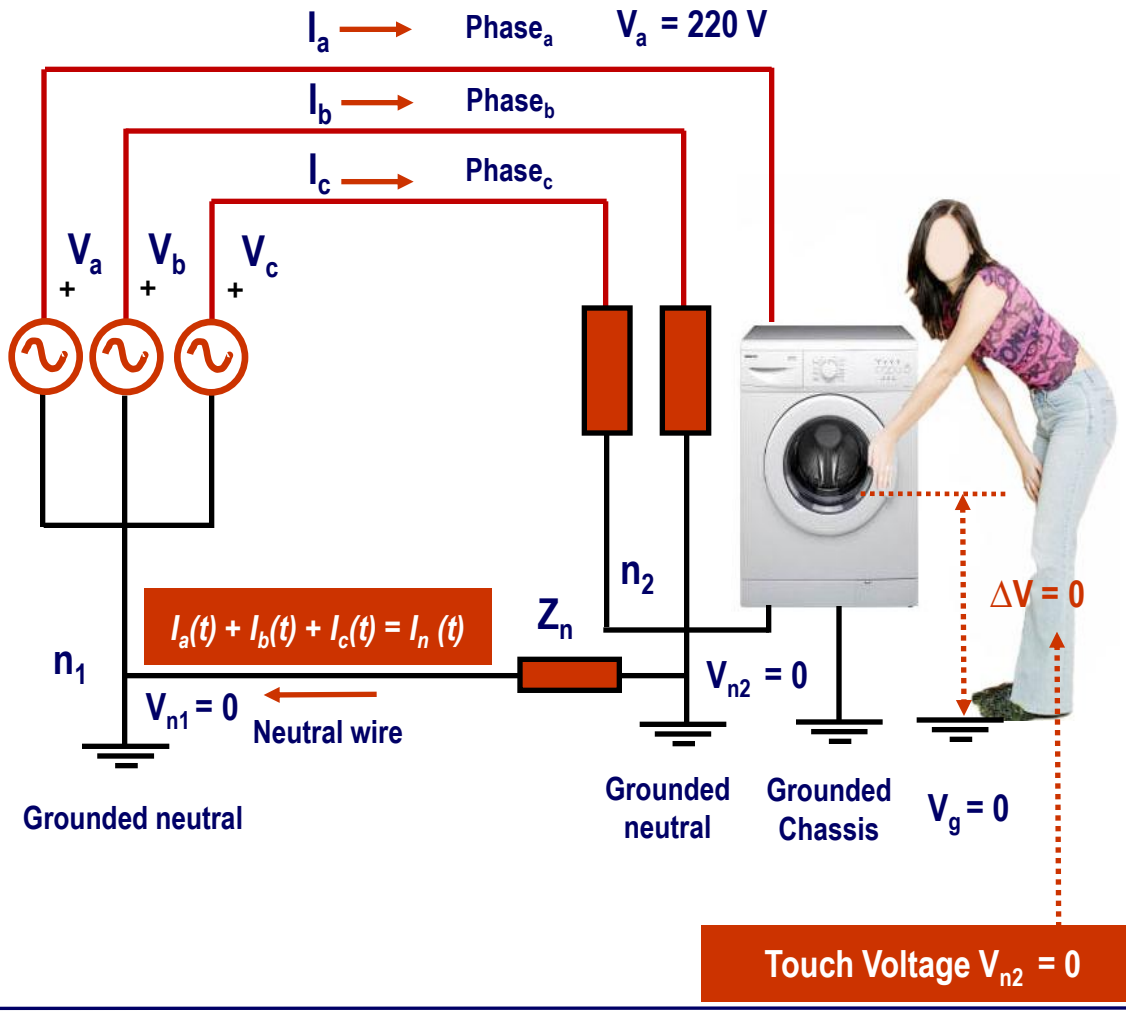
Ways of Eliminating Touch Voltage

Ways

Do either or both of the followings;

- Ground the chassis of the electrical equipment solidly,
- Ground the neutral wire solidly at both ends

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

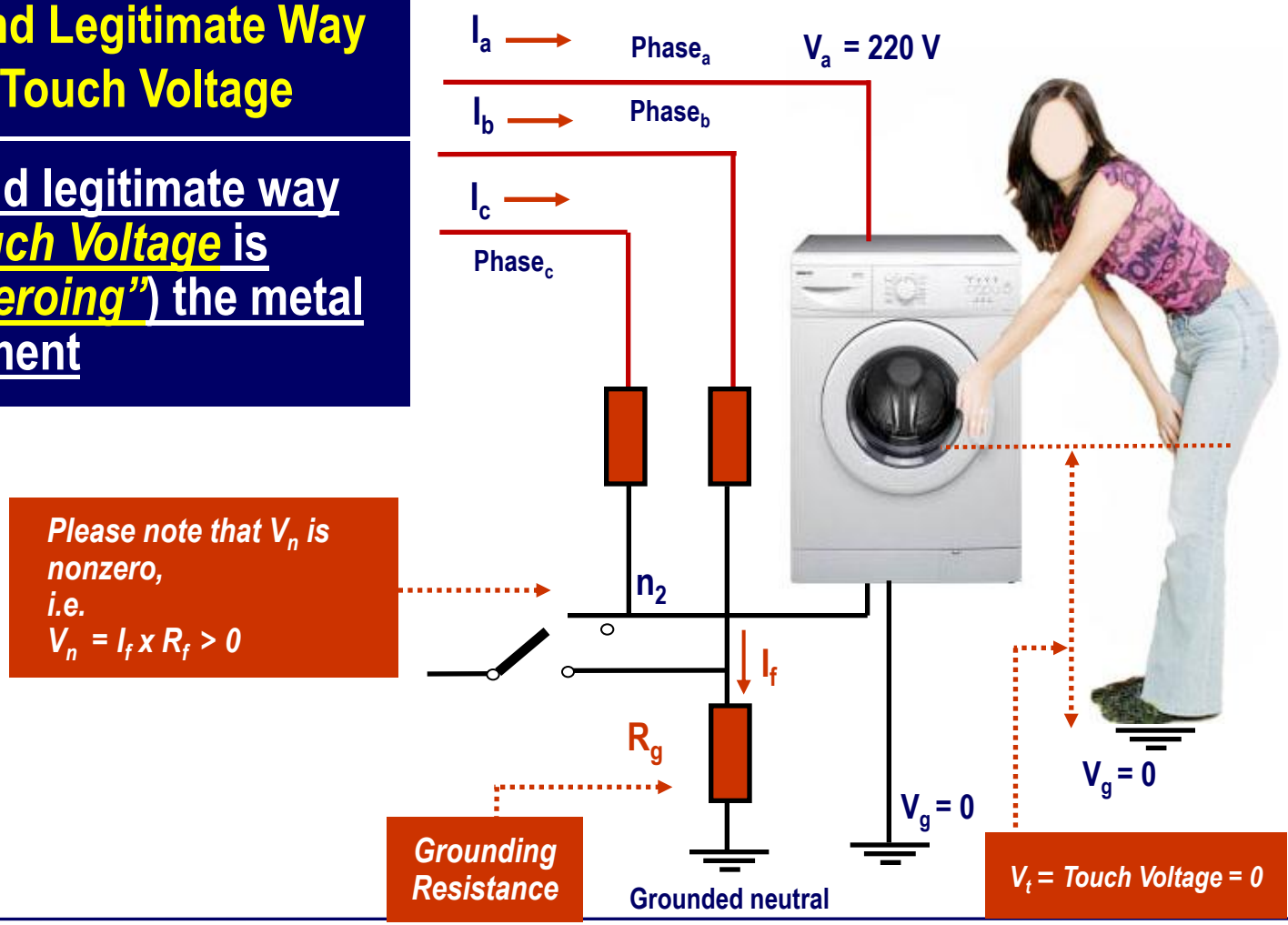


Electrical Safety

Ways of Reducing the Touch Voltage

The Most Formal and Legitimate Way of Reducing the Touch Voltage

The most formal and legitimate way of reducing the *Touch Voltage* is *"earthing"* (NOT *"zeroing"*) the metal cover of the equipment



Electrical Safety

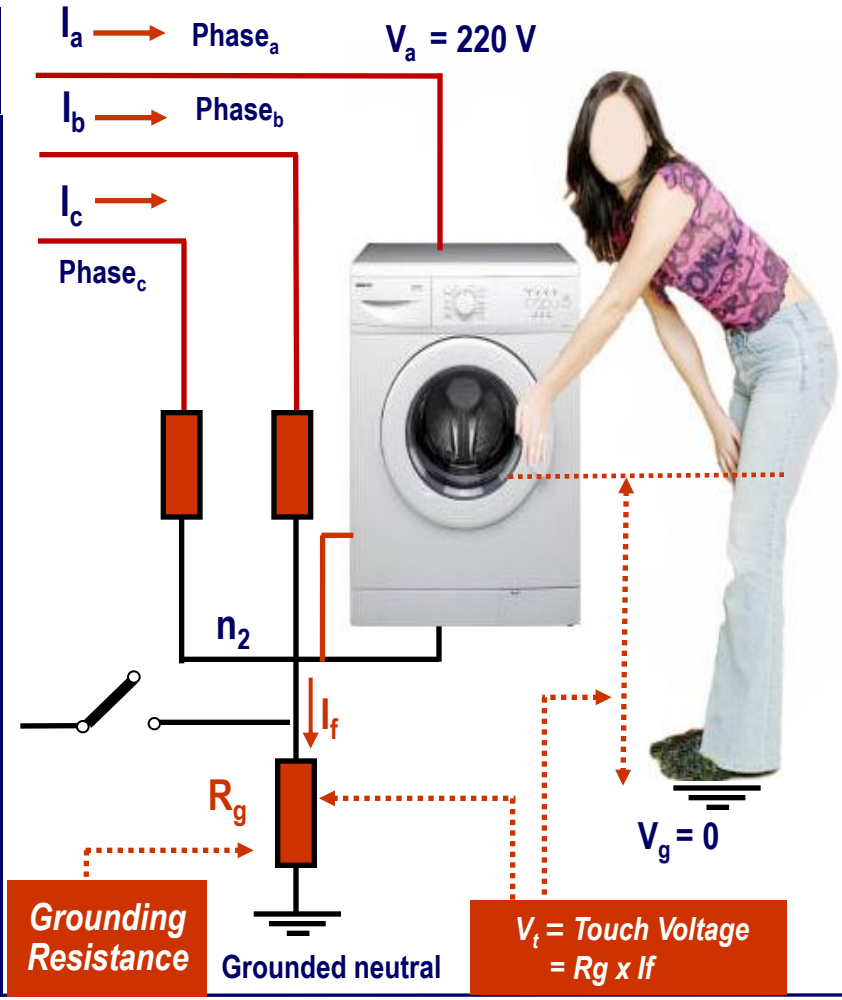
Ways of Reducing the Touch Voltage

Other Ways of Reducing the Touch Voltage

(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 copper material with proper cross-section 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

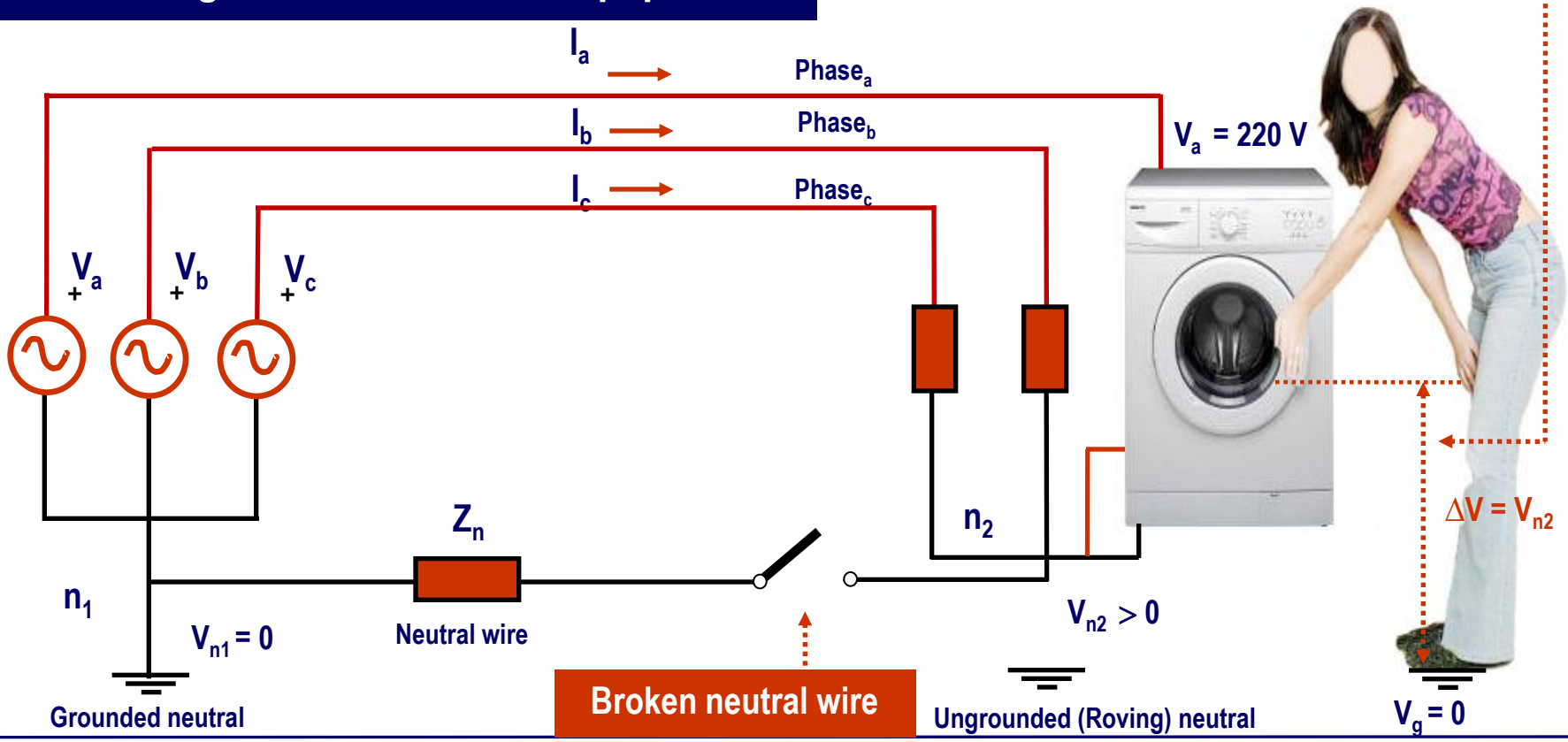


Electrical Safety

Broken Neutral Wire – Roving Neutral

Sometimes neutral wire may be broken for any reason, resulting in a case, called ***"Roving Neutral"*** yielding a touch voltage on the metal cover of the ungrounded electrical equipment

Neutral voltage is now nonzero

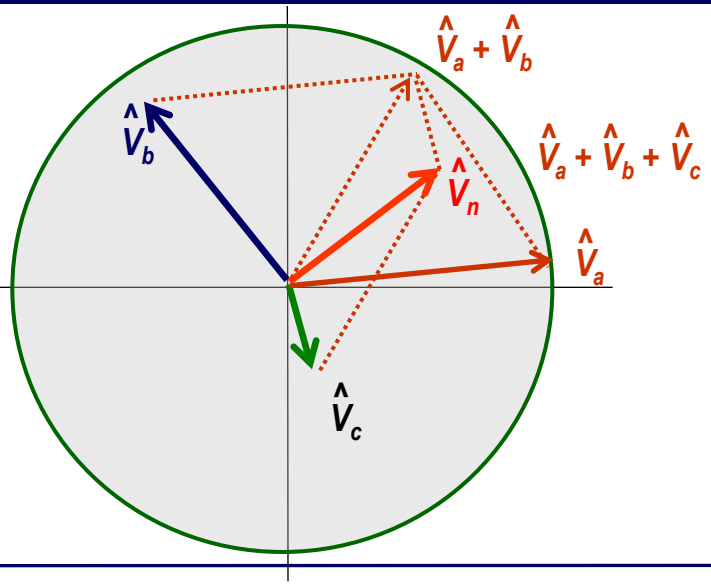


Electrical Safety

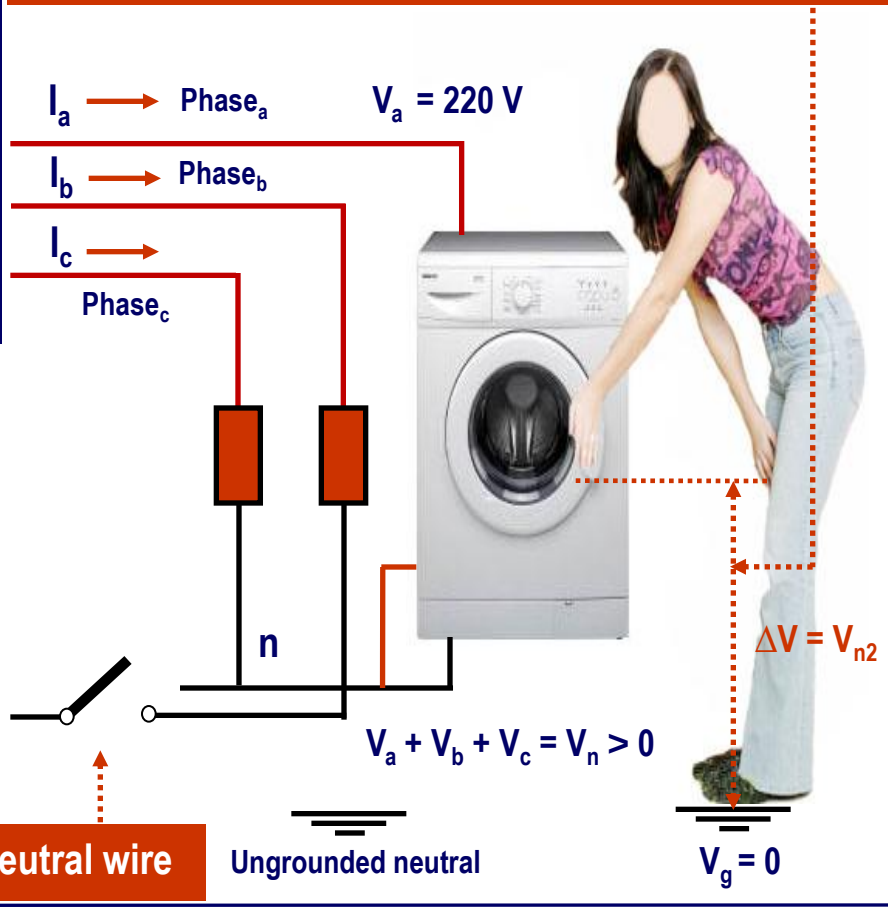
Overvoltages due to Roving Neutral

Sum of the phase voltages at a neutral point with broken neutral wire is never zero, since the phase voltages are unbalanced

The resulting voltage V_n appearing on the broken neutral wire passes to the metal cover of the electrical equipment connected to this neutral



Touch (neutral) voltage is now nonzero

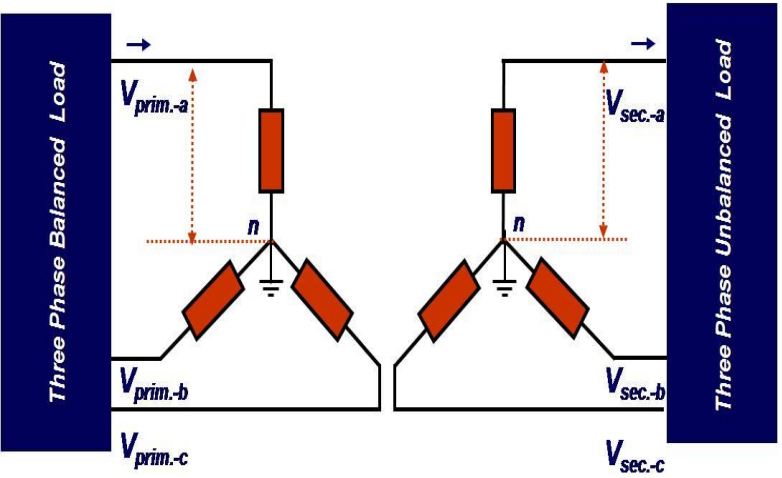


Electrical Safety

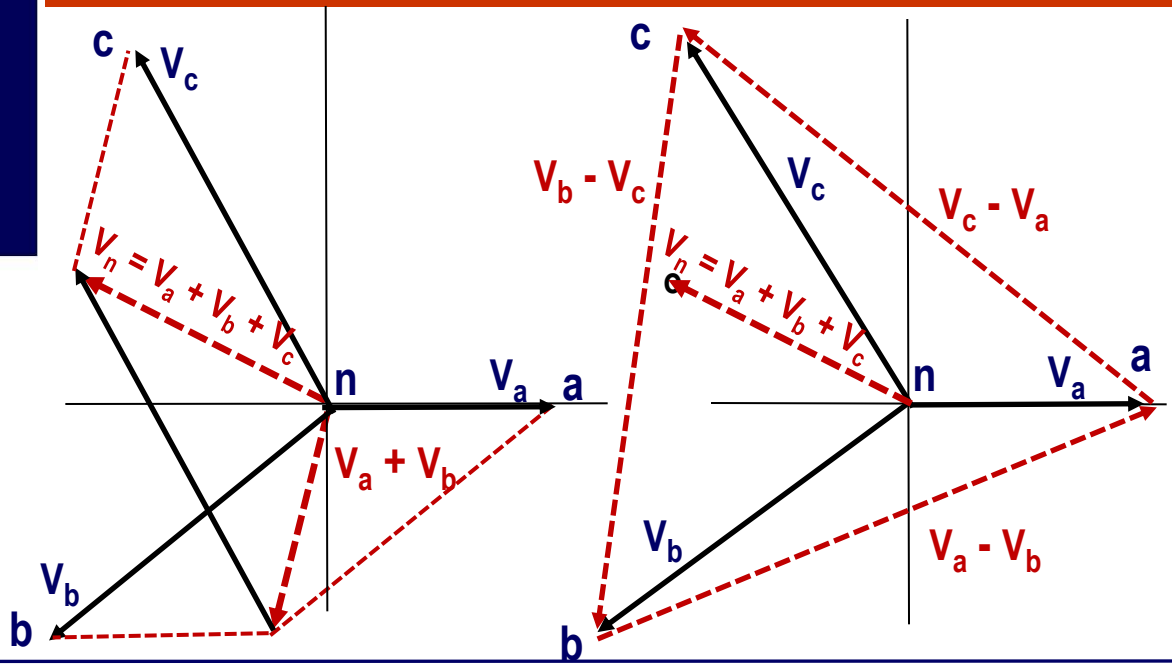
Overvoltages due to Roving Neutral

Three-phase Y - Y transformer with the neutral wire broken on the secondary side

The line voltages V_{ca}, V_{ab}, V_{bc} on the primary side are kept constant and balanced by the control mechanisms in the MV system



Please note that , a reduction in V_a causes overvoltage in phase-c and/or phase-b, which may cause significant harms in the customer equipment connected to these phases



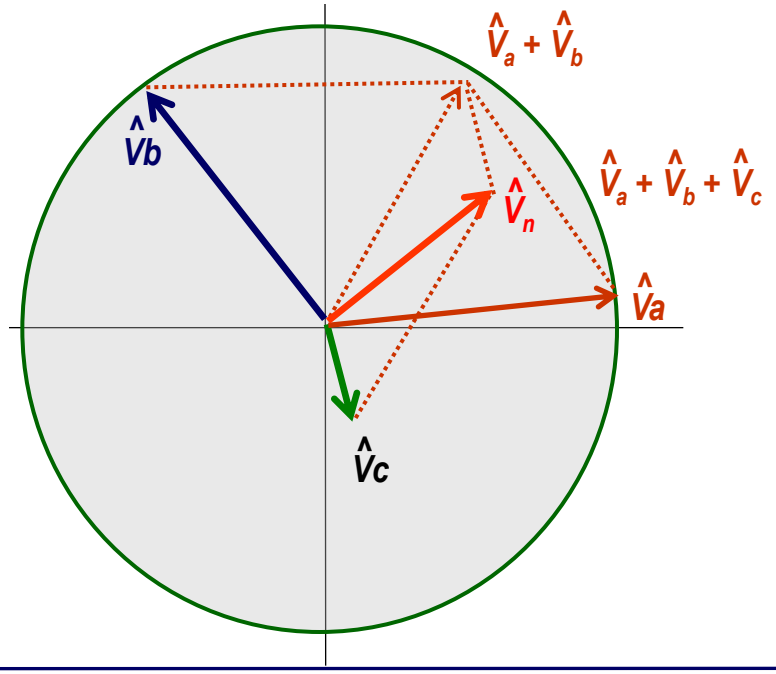
Electrical Safety

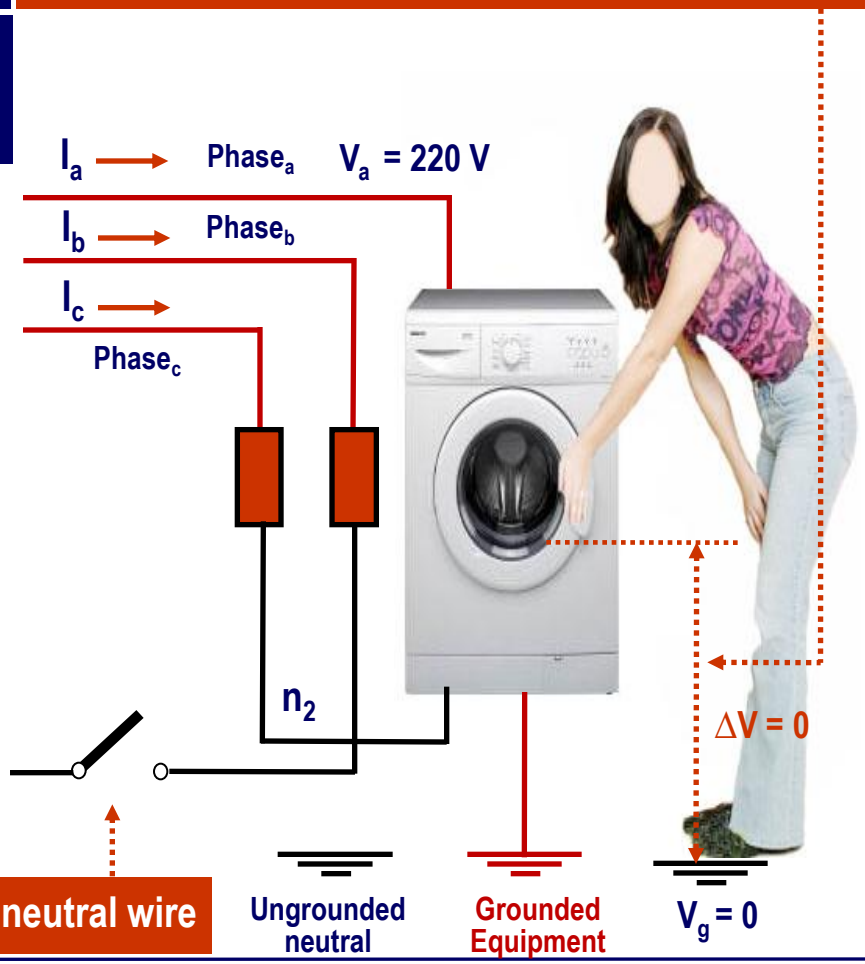
Ways of Reducing Touch Voltage in this case

The Most Proper (Legitimate) Solution

Solidly earth the metal cover of the equipment

Touch voltage is now zero





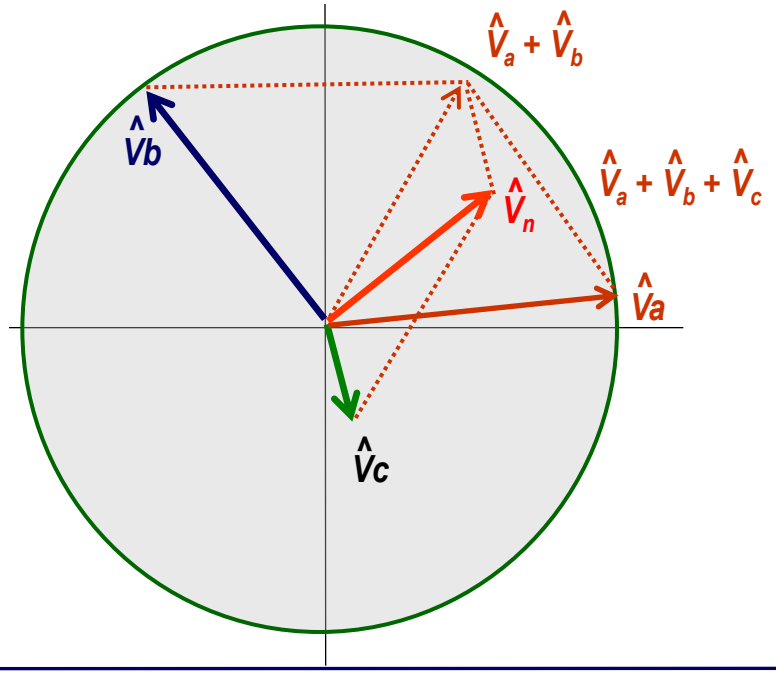
Electrical Safety

Ways of Reducing Touch Voltage in this case

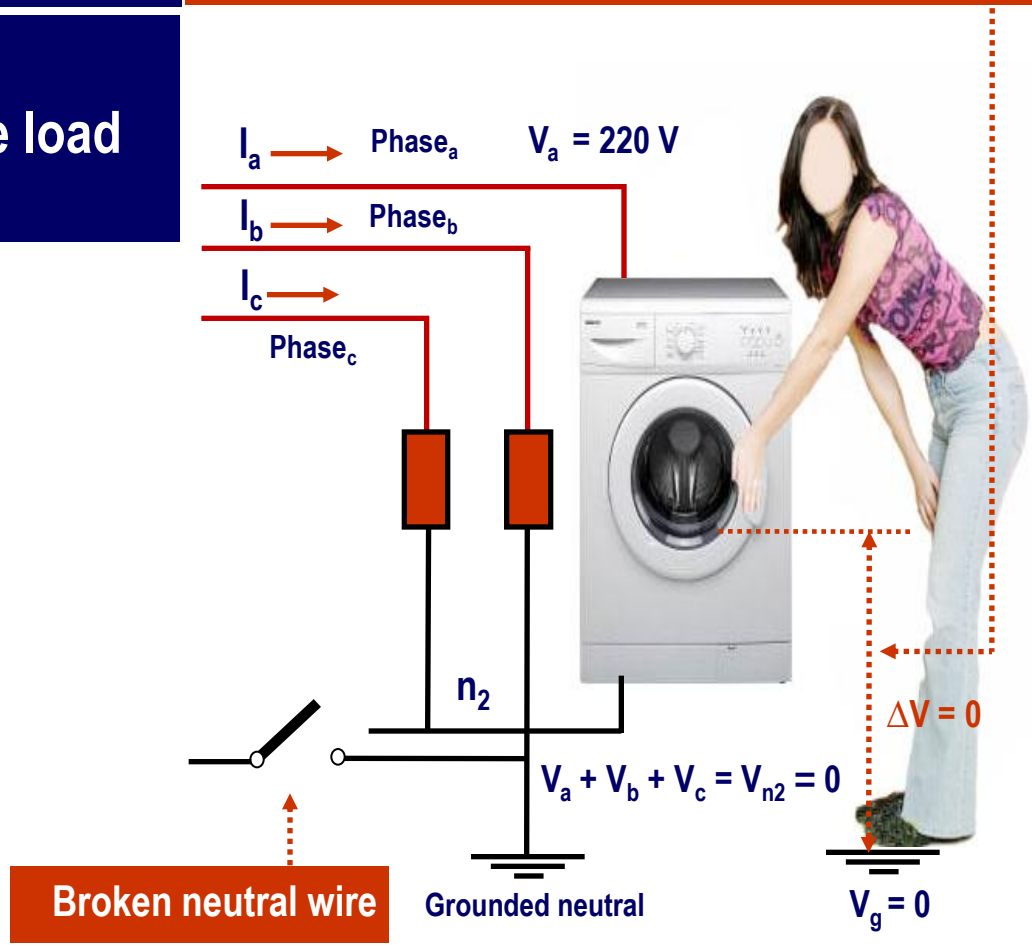
Acceptable (undesirable) Solution

In case, where this is not possible;

Solidly earth the neutral wire at the load terminals



Touch voltage is now zero



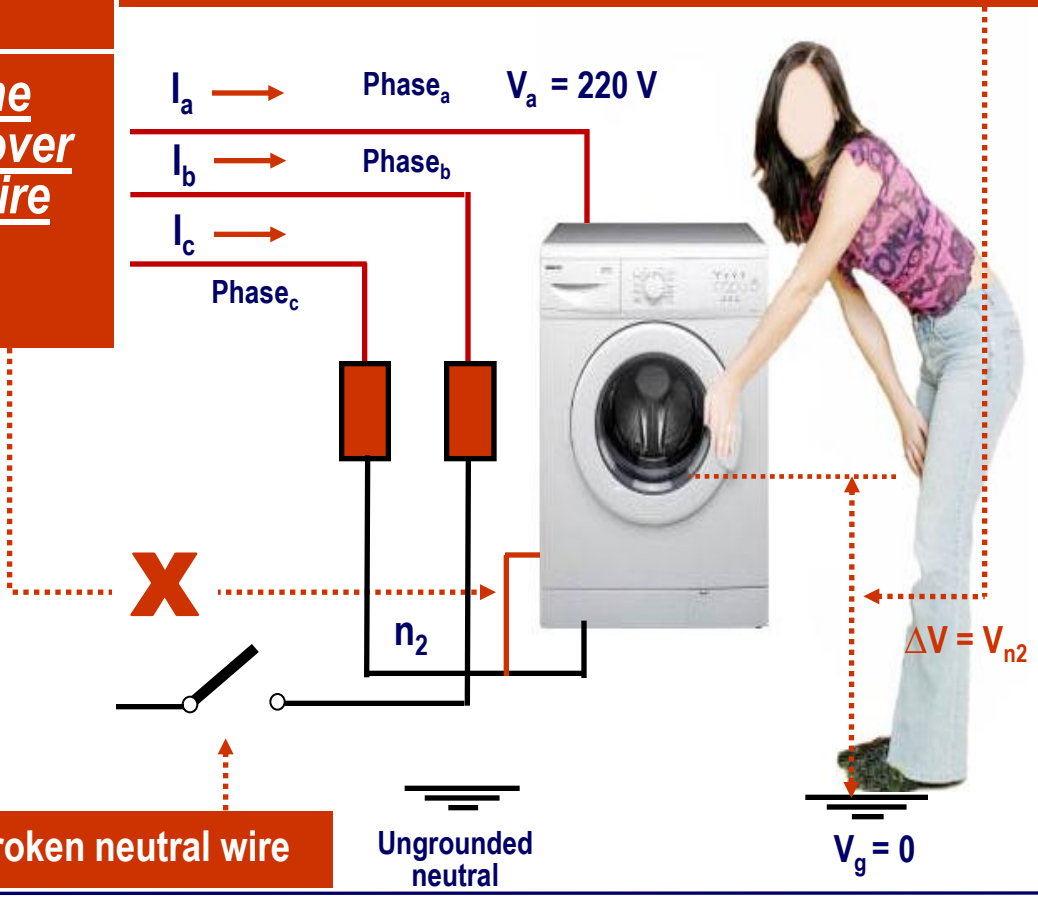
Electrical Safety

Important Caution

In any case, NEVER connect the metal cover of the equipment to the neutral point (Illegal, called "zeroing") !!!

This type of connection may cause the phase voltage appear on the metal cover of the equipment, when the neutral wire is broken, resulting in fatal consequences

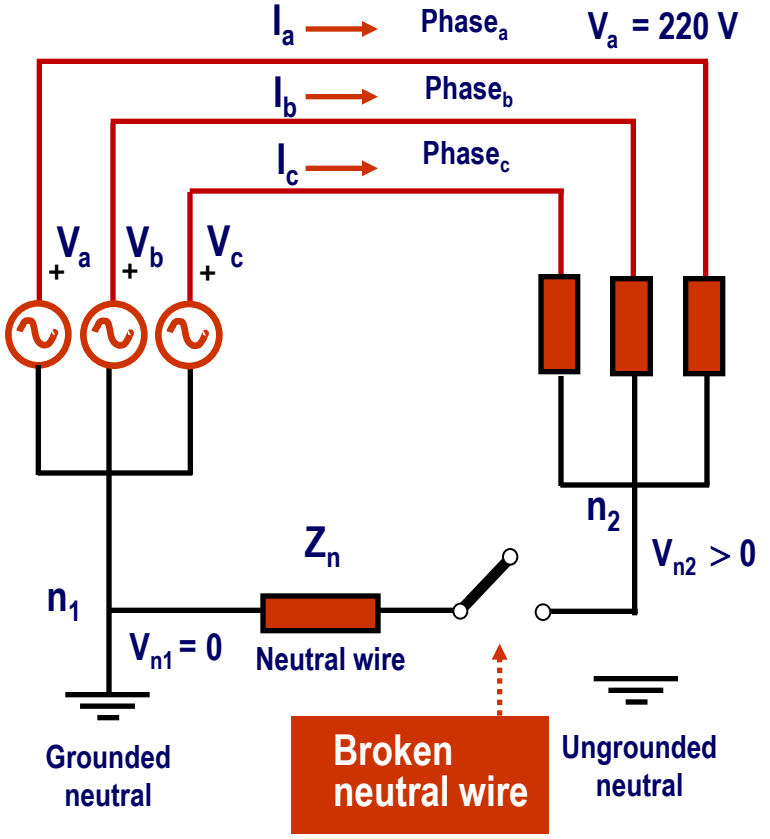
Touch voltage is now phase voltage, which is extremely harmful



Electrical Safety

Why does Neutral Line break ?

Neutral line may break due to severel reasons, such as severe weather conditions, external interventions / collisions



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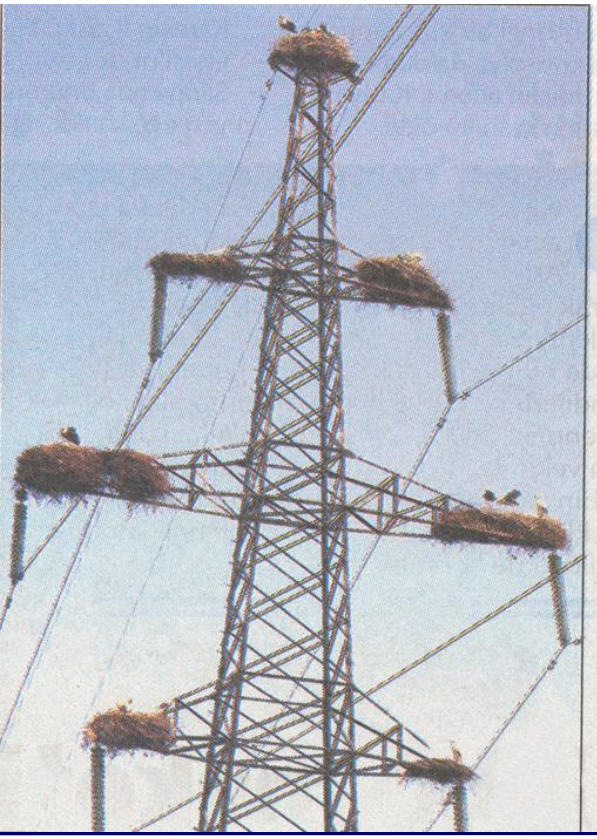


'Hacı'lar apartmanı

AZERBAYCAN'a bağlı Nahcivan Özerk Cumhuriyeti'nin Şerur İlçesi'nde 'kutsal' kabul edilen ve göç yolları üzerinde Kutsal Topraklar da olduğu için "Hacı" diye anılan leyleklerin yüksek gerilim hatları üzerine yaptıkları yuvalara, saygıdan dolayı kimse dokunmuyor. Şerur İlçesi'ne 7 kilometre uzaklıktaki 5 bin nüfuslu Yukarı Daşarık Köyü'nden geçen yaklaşık 20 metre yükseklikteki enerji nakil hatları, leyleklerin yaptığı yuvalarla dikkat çekiyor. Anadolu'nun birçok yerinde de "Hacı" diye anılan ve her bir direğe yuva yapan leylekler, yüksek gerilim hatlarını apartmana çeviriyorlar. Şerur ve çevresinde kutsal sayılan leyleklerin kendilerine 'uğur' getirdiğine inanan yöre halkı onların daha uzun süreli kalması için gerilim hattı yakınlarına yem bile bırakıyor.

Possible contact point

Electrical Safety

Why does Neutral Line break ?

Due to severe weather conditions

Electrical Safety

Why does Neutral Line break ?

Due to severe weather conditions

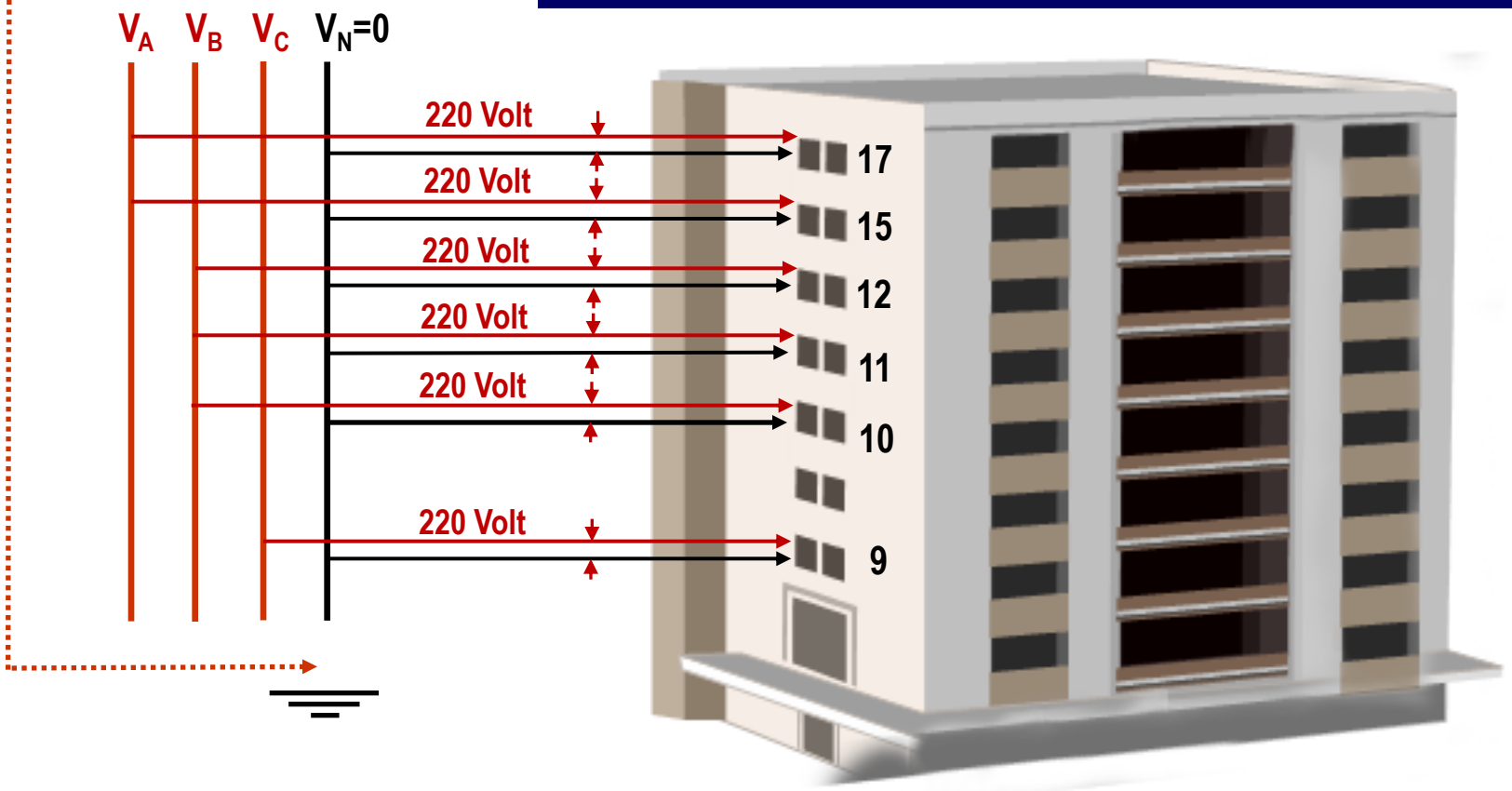
Electrical Safety

Overvoltages due to line to Ground Fault

Ungrounded Neutral

Normal (Ungrounded, Unfaulted Configuration)

When there is no fault, all voltages are normal, i.e. 220 Volt



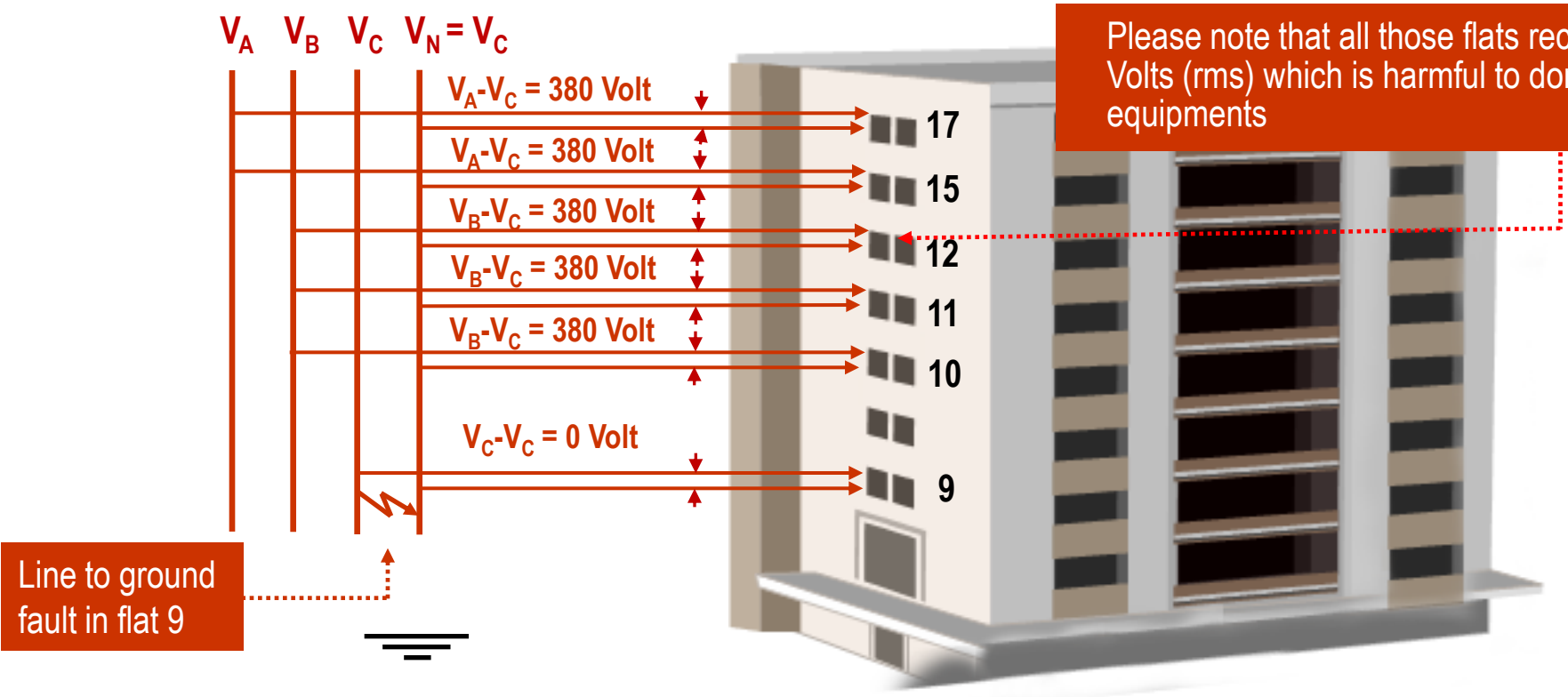
Electrical Safety

Overvoltages due to line to Ground Fault

Ungrounded Neutral

Abnormal (Ungrounded, Faulted Configuration)

When there is a fault, all voltages in the flats other than the flat with fault rise to 380 Volts (rms)



Please note that all those flats receive 380 Volts (rms) which is harmful to domestic equipments

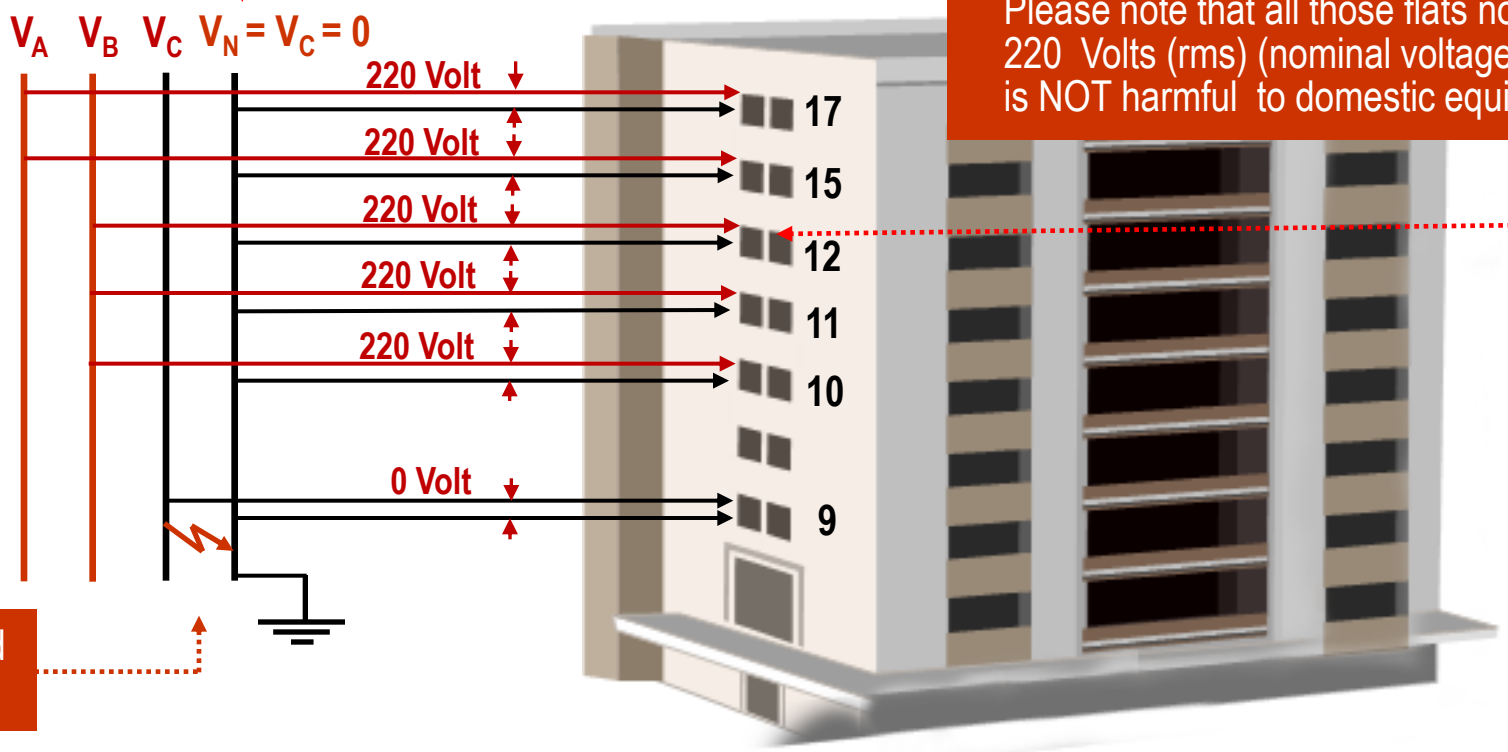
Electrical Safety

Overvoltages due to line to Ground Fault

Grounded Neutral

Abnormal (Grounded, Faulted Configuration)

When there is a fault, all voltages in the flats other than the flat with fault remain at 220 Volt (rms) level if the neutral wire is grounded



Please note that all those flats now receive 220 Volts (rms) (nominal voltage) which is NOT harmful to domestic equipments

Line to ground fault in flat 9

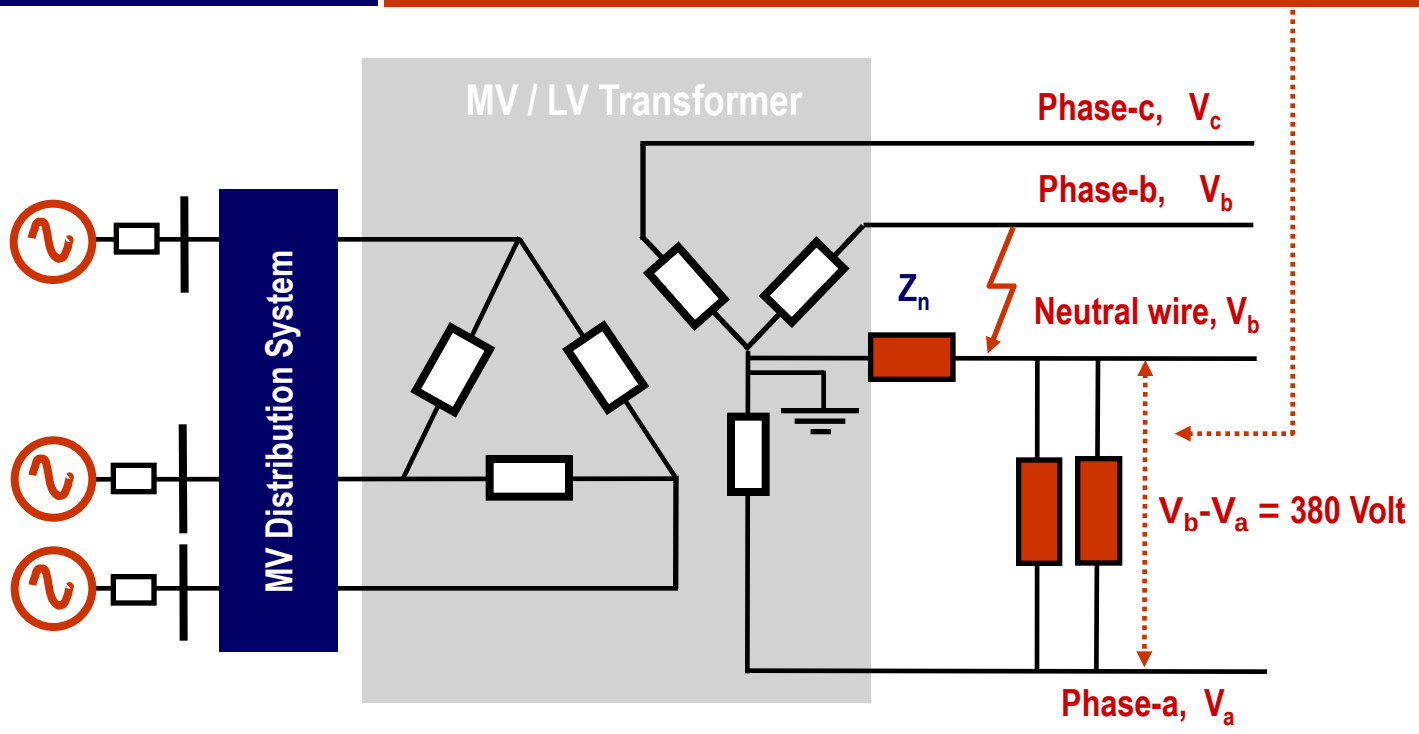
Electrical Safety

Overvoltages due to line to Ground Fault

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 customer side, hence, the voltage across the phases becomes;

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

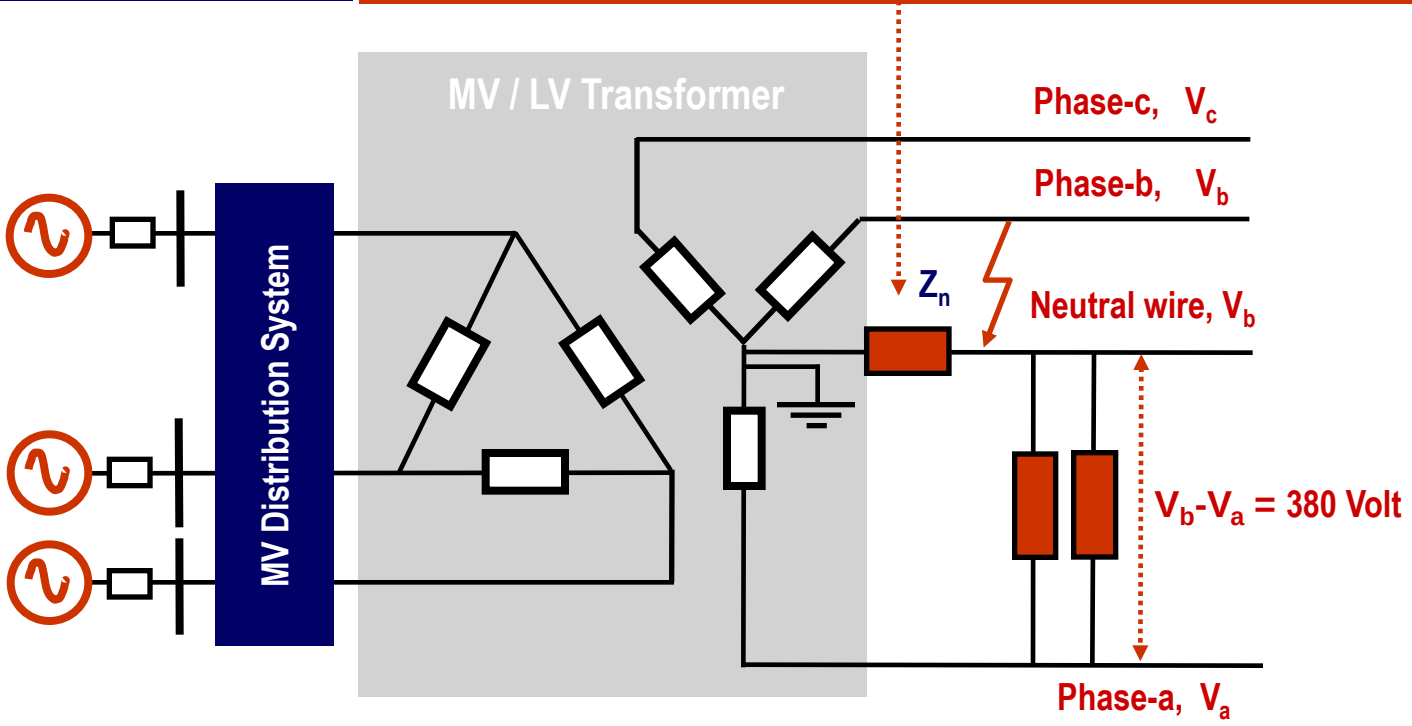


Electrical Safety

Overvoltages due to line to Ground Fault

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

Please note that grounding the neutral point of the Y connected windings on the secondary side *does not help* to solve the problem, as the voltage drop on the impedance of the neutral wire is nonzero



Electrical Safety

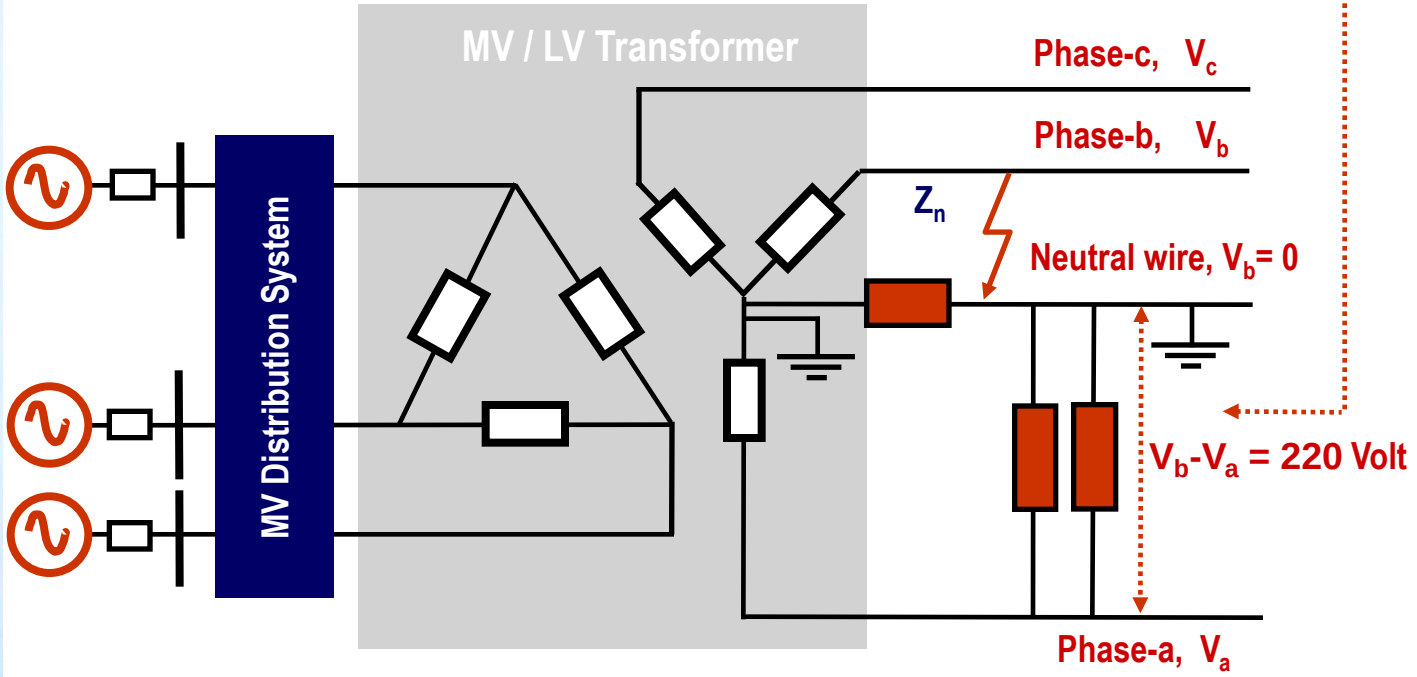
Solution for Reducing Overvoltages due to line to ground fault

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

Voltage at the customer terminals now becomes;

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

which is now proper.



Electrical Safety

Damages due to Overvoltages

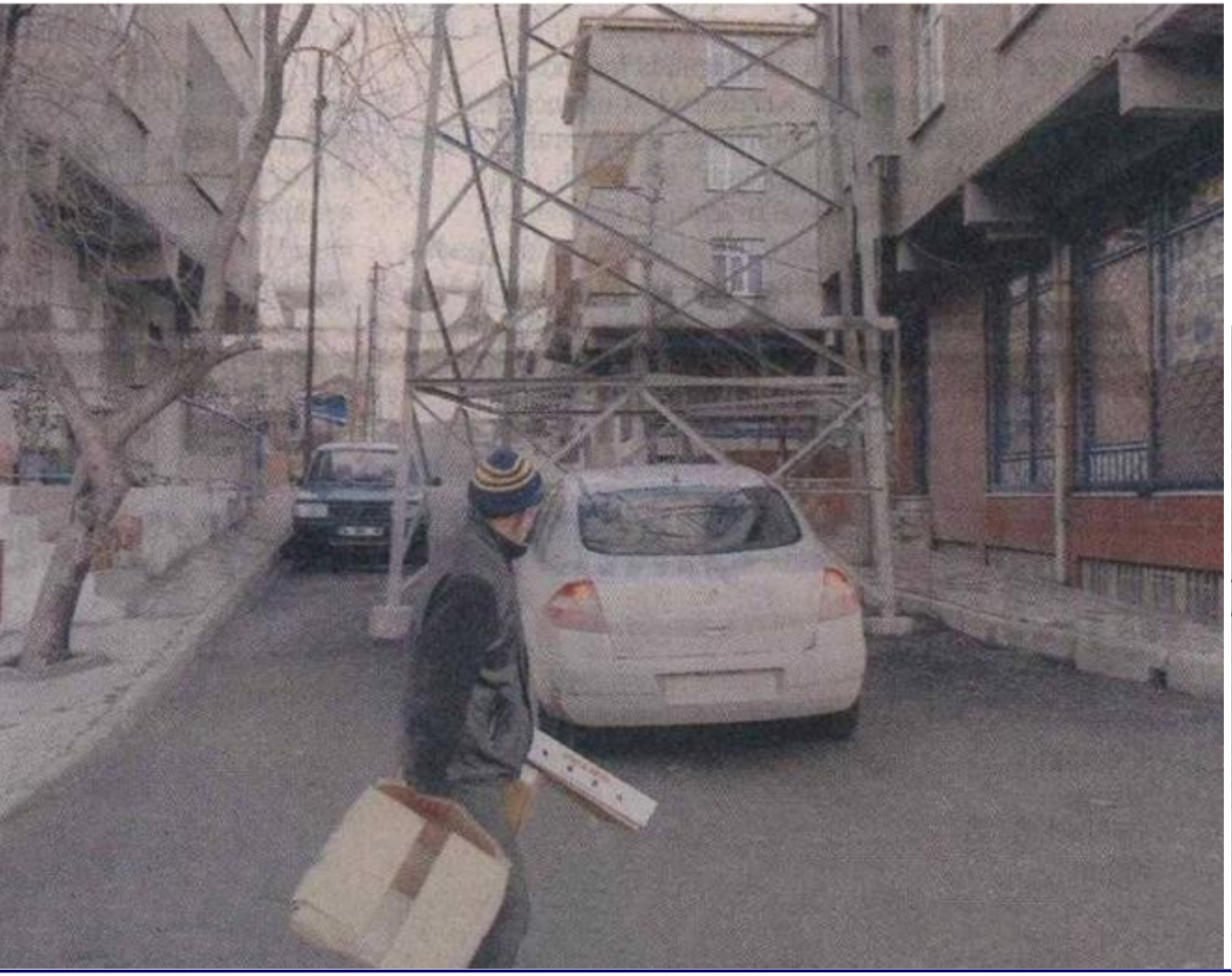
Overvoltage at the load terminals may yield;

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

Overvoltage in Adana Çimsa 154/34 kV Substation due to reclosure of 154 kV circuit breaker on staff

Electrical Safety

Example to Illegal Cases – High Voltage Street



AVCILAR Tahtakale Mahallesi'ndeki İstanbul Caddesi'ne açılan Yaprak Sokak, tam ortasından yükselen, elektrik direği nedeniyle geçit vermiyor. Küçükçekmece Gölü kıyısındaki mahallede yerleşim yıllar önce başladı. Binalar yapılmadan önce dikilen yüksek gerilim hatlarının yanına evler yapılınca yıllar sonra ortaya ilginç bir görüntü çıktı. Yaprak Sokak girişinde kalan 20 metre yüksekliğindeki 861 numaralı yüksek gerilim direği yeni yapılanan sokağı araç girişine kapattı. 13 yıl önce kurulan mahallenin muhtarı Ramazan Sezanoğlu, "Tüm yıldırımları çekiyor. Elektrikli aletlere zarar verdi. 6 ay içinde kaldıracağız dediler. Araçlar geçemiyor ama yolu asfaltlayıp, kaldırımını yaptılar" dedi. Avcılar Belediyesi İmar Müdürlüğü yetkilileri, mahallenin kadastrosu olduğunu ancak imar planının bulunmadığını söyledi.

Electrical Safety

Example to Illegal Cases – High Voltage Tower on the Street

Electrical Safety

Example to Illegal Cases – High Voltage Tower on the Street

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