# 08-Electric Shock

Text: Chapter 9.1

ECEGR 3500

Electrical Energy Systems

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# Overview

- Statistics
- Electric Shock
- Effect of Voltage
- Effect of Current
- Effect of Resistance
- Effect of Frequency

# Electrical Safety Statistics

- >30,000 non-fatal shock accidents each year
- >400 fatalities per year in the U.S.
- Deadliest consumer products
  - Small appliance
  - Power tool
  - Lighting equipment

Source: Electrical Safety Foundation International

# Safety Statistics: worker fatalities in the U.S.

- Falls: 294 (36.9%)
- Struck by object: 82 (10.3%)
- Electrocutions : 71 (8.9%)

"Electrocution" implies a fatality.

Source: https://www.osha.gov/oshstats/commonstats.html

# Electric Shock

- Current traveling through a body can cause pain and damage
  - Cells can overheat, causing internal burns
  - Nerves can be damaged
  - Organs can be damaged, primarily lungs, brain and heart (if within conduction path)
- Just how much current is needed to cause pain or death?

# Electric Shock

- Difficult to conduct experiments on the human responses to electric shock (would you volunteer?)
- Charles Dalziel conducted research in the 1970's which is the basis for our understanding today

*Source: Electric Energy: An Introduction, M. El-Sharkawi*

# Electric Shock

- Rules of Thumb
  - Women are more sensitive to shock than men
  - Uncomfortable sensation begins around 1.2 mA for women and 1.8 mA for men
  - Muscles can still be controlled if the current is less than 6mA for women and 9 mA for men
  - People tend to be more sensitive to ac rather than dc

# Electric Shock

| Reaction | Current (mA) | | | |
|---|---|---|---|---|
| | dc | | ac | |
| | Men | Women | Men | Women |
| No sensation on hand | 1.0 | 0.6 | 0.4 | 0.3 |
| Tingling (threshold of perception) | 5.2 | 3.5 | 1.1 | 0.7 |
| Shock: Uncomfortable, muscular control not lost | 9.0 | 6.0 | 1.8 | 1.2 |
| Painful shock, muscular control is not lost | 62.0 | 41.0 | 9.0 | 6.0 |

*Source:* IEEE Standard 524a, 1993.

This simple table overlooks several other factors, including the wide range of variability in humans.

# Exercise

Other than current magnitude and type (ac/dc), what other factors influence how severe a response to electric shock is?

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Answer. Many factors, especially voltage level, duration and conduction path, and even the frequency of the ac.

# Electric Shock

| | Current in mA | | | |
|---|---|---|---|---|
| | 0.5% of Population | | 50% of Population | |
| Threshold | Men | Women | Men | Women |
| Let-go: Worker cannot release wire | 9 | 6 | 16 | 10.5 |
| Respiratory tetanus | | | 23 | 15 |
| Ventricular fibrillation | 100 | 67 | | |

*Source:* IEEE Standard 1048, 1990.

# Effect of Voltage

- Most electric shocks are of lower voltage (100-400V), but still can be dangerous and fatal
- Current can cause muscles to contract, making release of the energized object difficult or impossible (also possibly tearing the muscle and breaking bones)—longer duration means more electrical energy dissipated in the person's body
- Shocks of >1000V can cause severe current to flow, and may cause the person to be thrown from the energized object (perhaps causing loss of limb or additional injury due to a fall)

An internet search for "electrical burn" images will test your stomach.

# Effect of Current

- Current, not voltage causes death (but voltage governs the current level)
- Concerned with current affecting the beating of the heart (fibrillation) and the energy dissipated into a person's tissue
  - As little as 10 microA can cause cardiac arrest

# Effect of Current

- Thermal energy dissipated by the current is:

$$E = i^2Rt$$

where

- E: energy (joules)
- i: current, RMS or dc (Amps)
- R: resistance (Ohms)
- t: time (s)

Recall that energy is power x time
(if power is constant)

The longer the time connected to the circuit,
the greater the chance of serious harm and death.

# Effect of Resistance

- Current through the body must obey Ohm's Law, like any other circuit
- Therefore, the current through the body depends on the resistance of the body, and the circuit connected to the body

# Body Resistance

- Your body has resistance (impedance in general)
- Body resistance depends on the where it is measured, body composition and the conditions of the skin
  - sweat/water reduces resistance
  - fat, bone, tendon have higher resistances than muscle, nerves and arteries
- Wide range of variability
- Always use the lower value of the resistance range when designing for safety

# Body Resistance

TABLE 9.3 Body Resistance in Ohms

| | Hand-to-Hand | | Hand-to-Feet |
|---|---|---|---|
| **Resistance** | **Dry Condition** | **Wet Condition** | **Wet Condition** |
| Maximum | 13,500 | 1,260 | 1,950 |
| Minimum | 1,500 | 610 | 820 |
| Average | 4,838 | 865 | 1221 |
| *Source*: IEEE Standard 1048, 1990. | | | |

| Body Part | Resistance (Ω) |
|---|---|
| Each hand plus arm | 500 |
| Each leg | 500 |
| Torso | 100 |

# Exercise

Is it safe to grab the terminals of a 12V battery with your bare hands?

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Is it safe to grab the terminals of a 12V battery with your bare hands?

Answer. Assuming the resistance of both arms and hands is 1000 Ohms, then the current is 12mA. This should be perceptible, but in general your resistance is much greater than 1000 Ohms. However, always be careful when working around voltage sources.

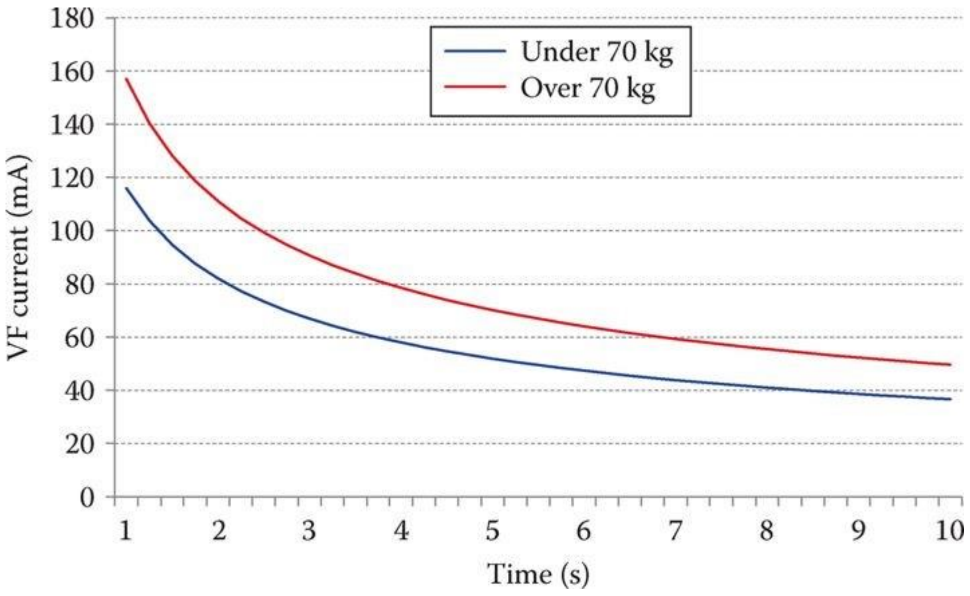
# Shock Duration

- The longer the duration of the shock, the more likely death will occur
- An empirical formula developed by Dalziel

$$i = \frac{K}{\sqrt{t}}$$

where

- i: current (in mA)
- K: constant dependent on the weight of the victim (K = 116 for weight less than 70 kg, K = 157 for weight greater than 70 kg)



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An adult male weighing 95kg is shocked by 100mA. How long until ventricular fibrillation is induced according to Dalziel's formula?

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Answer. $i = \frac{K}{\sqrt{t}}$

$$t = \frac{K^2}{i^2} = \frac{157^2}{100^2} = 2.46s$$

# Effect of Frequency

- ac is more dangerous than dc
- 50/60 Hz is more likely to cause ventricular defibrillation than dc
- Ability to let go of the energized circuit is also frequency dependent