

I n t e r n a t i o n a l T e l e c o m m u n i c a t i o n U n i o n

**ITU-T**

TELECOMMUNICATION  
STANDARDIZATION SECTOR  
OF ITU

**Series K**  
**Supplement 28**  
(07/2022)

SERIES K: PROTECTION AGAINST INTERFERENCE

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**Electric shock and related terms and definitions**

ITU-T K-series Recommendations – Supplement 28

ITU-T





# Supplement 28 to ITU-T K-series Recommendations

## Electric shock and related terms and definitions

### Summary

An electricity supply voltage classified as extra-low voltage (ELV) has a low probability of causing a hazardous electrical shock. It is important to realise that the actual ELV value is not absolute but depends on the electrical shock event circumstances. Supplement 28 to ITU-T K-series Recommendations covers established definitions, insulation types, equipment classes, electric shock physical reaction levels, electric shock event factors and circuit configuration examples.

### History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T K Suppl. 28	2022-07-01	5	<a href="http://handle.itu.int/11.1002/1000/15082">11.1002/1000/15082</a>

### Keywords

Application time, body current path, contact area, physical reaction, safety, skin condition, touch voltage.

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\* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

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# Supplement 28 to ITU-T K-series Recommendations

## Electric shock and related terms and definitions

### 1 Scope

Many networking configurations use the same wires for power and data communications. When non-shrouded wiring connectors are used there is a chance a user may touch the powering voltage. This Supplement reviews a contact event shock reaction and what levels of voltage, commonly called extra low voltage (ELV), should be considered safe. Reference materials are drawn from the following sources:

- [IEC Glossary]
- [IEC Electropedia]
- [IEC 60479]

### 2 References

- [IEC Glossary] International Electrotechnical Commission *Glossary*.  
<https://std.iec.ch/glossary>
- [IEC Electropedia] International Electrotechnical Commission *Terminology and Electropedia*.  
<https://www.iec.ch/electropedia>
- [IEC 60479] IEC 60479-X series, *Effects of current on human beings and livestock*.
- [IEC TR 60479-5] IEC TR 60479-5:2007, *Effects of current on human beings and livestock – Part 5: Touch voltage threshold values for physiological effects*.
- [IEC 60598-1] IEC 60598-1:2014, *Luminaires – Part 1: General requirements and tests*.
- [IEC 60669-2-5] IEC 60669-2-5:2013, *Switches for household and similar fixed electrical installations – Part 2-5: Particular requirements – Switches and related accessories for use in home and building electronic systems (HBES)*.
- [IEC 60950-1] IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*.
- [IEC 61140] IEC 61140 Ed. 3.0:2001, *Protection against electric shock – Common aspects for installation and equipment*.
- [IEC TR 61201] IEC TR 61201:1992, *Extra-low voltage (ELV) – Limit values*.
- [IEC 61558-1] IEC 61558-1:2017, *Safety of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests*.
- [IEC 61800-5-1] IEC 61800-5-1:2007, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*.
- [IEC 61850-3] IEC 61850-3:2013, *Communication networks and systems for power utility automation – Part 3: General requirements*.
- [IEC TR 62102] IEC TR 62102:2005, *Electrical safety – Classification of interfaces for equipment to be connected to information and communications technology networks*.
- [IEC 62103] IEC 62103:2003, *Electronic equipment for use in power installations*.
- [IEC TS 62257-7-3] IEC TS 62257-7-3:2018, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 7-3: Generator set – Selection of generator sets for rural electrification systems*.

[IEC 62282-5-1]	IEC 62282-5-1:2012, <i>Fuel cell technologies – Part 5-1: Portable fuel cell power systems – Safety</i> .
[IEC 62368-1]	IEC 62368-1:2018, <i>Audio/video, information and communication technology equipment – Part 1: Safety requirements</i> .
[IEC/TR 62513]	IEC/TR 62513 Ed. 1.0:2008, <i>Safety of machinery – Guidelines for the use of communication systems in safety-related applications</i> .
[IEC 62870]	IEC 62870:2015, <i>Electrical installations for lighting and beaconing of aerodromes – Safety secondary circuits in series circuits – General safety requirements</i> .

### 3 Definitions

This Supplement uses the following terms defined elsewhere:

#### 3.1 ELV terms defined in [IEC Glossary]

Glossary terms ceased being updated in 2015. Some terms of this list may be now modified or removed:

NOTE – Terms that have specified voltage values have been omitted.

**3.1.1 FELV-system (functional extra-low voltage)** [IEC 62103]: Electrical system in which:

- the voltage cannot exceed ELV, and
- the safety requirements for SELV or PELV systems are not satisfied.

**3.1.2 FELV (functional ELV) circuit** [IEC 61800-5-1]: Electrical circuit in which the voltage does not exceed ELV, and which does not comply with the safety requirements for SELV or PELV circuits.

**3.1.3 FELV (functional extra-low voltage circuit)** [IEC 60669-2-5]: Electrical circuit in which the voltage cannot exceed ELV used for functional purposes and having simple separation from LV.

NOTE 1 to entry – Functional extra low voltage (FELV) does not fulfil the requirements for safety extra-low voltage (SELV or PELV).

NOTE 2 to entry – A functional extra low voltage (FELV) circuit is not safe to touch and may be connected to protective earth.

**3.1.4 FELV** [IEC 60598-1]: ELV in a circuit having ELV voltage for functional reason and not fulfilling the requirements for SELV (or PELV).

**3.1.5 safety extra low voltage (SELV)** [IEC/TR 62513]: Unearthed circuits which are insulated from hazardous voltage by double insulation or any better insulation, and in which the voltage cannot exceed ELV specified in [IEC TR 61201] under normal conditions and single fault conditions.

**3.1.6 SELV circuit** [IEC 61850-3]: Non-primary circuits complying with ELV voltage limits and the following conditions separated from HLV by reinforced/double insulation, and there shall be no provision for an earth connection.

EXAMPLE 1: Analogue/digital inputs and outputs which may be connected direct to unearthed communication networks or circuits.

EXAMPLE 2: SELV ports which are suitable for connection to SELV ports of other products.

NOTE 1 to entry – See IEC 60255-27:2013, Figure A.1.

NOTE 2 to entry – SELV circuits may be accessible and are safe to touch under both normal operational and single fault conditions.



NOTE 3 to entry – Connection of an earth to a SELV circuit is not permitted; for example, connection to an earthed cable screen or earthed communication circuit is not permitted. Where this is required, the circuit definition should change in accordance with IEC 60255-27:2013, Figure A.2 (PELV).

**3.1.7 extra low voltage (ELV)** [IEC 61140]: Any voltage not exceeding the relevant voltage limit specified in [IEC TR 61201].

**3.1.8 PELV system** [IEC 61140]: An electrical system in which the voltage cannot exceed ELV:

- under normal conditions, and
- under single fault conditions, except earth faults in other circuits.

**3.1.9 SELV system** [IEC 61140]: An electrical system in which the voltage cannot exceed ELV:

- under normal conditions; and
- under single fault conditions, including earth faults in other circuits.

**3.1.10 safety extra-low voltage, SELV** [IEC TS 62257-7-3]: Extra-low voltage system which is electrically separated from earth and from other systems in such a way that a single fault cannot give rise to the risk of electric shock.

**3.1.11 FELV circuit (functional extra low voltage)** [IEC 61558-1]: ELV circuit having the ELV voltage for functional reasons and not fulfilling the requirements for SELV or PELV.

**3.1.12 SELV system** [IEC Electropedia] (IEV ref 826-12-31): Electrical system in which the voltage cannot exceed the value of extra-low voltage:

- under normal conditions, and
- under single fault conditions, including earth faults in other electric circuits.

NOTE 1 to entry – SELV is the abbreviation for safety extra low voltage.

**3.1.3 SELV/PELV power supply** [IEC 62870]: Single physical unit or an assembly of physical units performing as the power supply according to SELV/PELV definitions.

**3.1.14 safety extra-low voltage, SELV** [IEC 62870]: Voltage values of which does not exceed values in 4.7.2, between conductors, or between any conductor and reference earth, in an electric circuit which has galvanic separation from the supplying electric power system by such means as a separate-winding transformer.

**3.1.15 SELV circuit** [IEC 61558-1]: ELV circuit with protective separation from other circuits, and which has neither provisions for earthing of the circuit nor of the exposed conductive parts.

NOTE 1 to entry – SELV circuit does not include the housing of the light fixture.

**3.1.16 PELV-circuit** [IEC 61558-1]: ELV circuit with protective separation from other circuits and which, for functional reasons, may be earthed and/or the exposed conductive parts of which may be earthed.

NOTE 1 to entry – PELV-circuits are used where the circuits are earthed and SELV is not required.

**3.1.17 SELV circuit** [IEC 62282-5-1]: Secondary circuit that is so designed and protected that under normal operating conditions and single fault conditions, its voltages do not exceed a safe value.

NOTE 1 to entry – For commercial, industrial and telecommunication applications, the SELV voltage limits provided in [IEC 60950-1] are applicable. For household applications, the SELV voltage limits in IEC 60335-1:2010 shall be used.

NOTE 2 to entry – The limit values of voltages under normal operating conditions and single fault conditions (see 1.4.14 of [IEC 60950-1] are specified in 2.2 of [IEC 60950-1]. See Table 1A of [IEC 60950-1].

NOTE 3 to entry – This definition of a SELV circuit differs from the term "SELV system" as used in [IEC 61140].

**3.1.18 SELV circuit (separated/safety extra low voltage circuit) (SELV circuit)** [IEC 60950-1]: Secondary circuit that is so designed and protected that under normal operating conditions and single fault conditions, its voltages do not exceed a safe value.

NOTE 1 – The limit values of voltages under normal operating conditions and single fault conditions (see 1.4.14) are specified in 2.2. See also Table 1A.

NOTE 2 – This definition of an SELV circuit differs from the term "SELV system" as used in [IEC 61140].

From [IEC 60950-1] table SELV circuits are not subject to overvoltages, but TNV-1 is.

**3.1.19 SELV circuit** [IEC TR 62102]: Secondary circuit which is so designed and protected that under normal operating conditions and single fault conditions, its voltages do not exceed a safe value.

## **3.2 ELV, insulation and equipment terms defined in IEC Electropedia**

Insulation types are generally classified as solid, creepage distance and clearance.

NOTE – Terms listed and defined in this clause include their IEC reference numbers from [IEC Electropedia].

**3.2.1 extra-low voltage (ELV)** [IEC Electropedia] (ref 195-05-24): Voltage not exceeding the maximum value of the prospective touch voltage that is acceptable to be maintained indefinitely under specified conditions of external influences.

**3.2.2 extra-low voltage ELV (abbreviation)** [IEC Electropedia] (ref 826-12-30): Voltage not exceeding the relevant voltage limit of band I specified in IEC 60449.

**3.2.3 SELV system** [IEC Electropedia] (ref 195-06-28): Electric system in which the voltage cannot exceed the value of extra-low voltage:

- under normal conditions and
- under single fault conditions, including earth faults in other electric circuits.

NOTE 1 to entry – SELV is the abbreviation for safety extra-low voltage.

**3.2.4 SELV system** [IEC Electropedia] (ref 826-12-31): Electric system in which the voltage cannot exceed the value of extra-low voltage:

- under normal conditions and
- under single fault conditions, including earth faults in other electric circuits.

NOTE – SELV is the abbreviation for safety extra-low voltage.

Term FELV has no entry.

**3.2.5 solid insulating material** [IEC Electropedia] (ref 212-11-02): Insulating material consisting entirely of a solid.

**3.2.6 creepage distance** [IEC Electropedia] (ref 151-15-50): Shortest distance along the surface of a solid insulating material between two conductive parts.

**3.2.7 clearance** [IEC Electropedia] (581-27-76): Shortest distance in air between two conductive parts.

**3.2.8 basic insulation** [IEC Electropedia] (ref 195-06-06): Insulation that provides basic protection.

NOTE 1 to entry – This concept does not apply to insulation used exclusively for functional purposes.

**3.2.9 basic protection** [IEC Electropedia] (ref 195-06-01): Protection against electric shock under normal conditions.

**3.2.10 double insulation** [IEC Electropedia] (ref 195-06-08): Insulation comprising both basic insulation and supplementary insulation.

**3.2.11 functional insulation** [IEC Electropedia] (ref 195-02-41): Insulation between conductive parts, necessary for the proper functioning of the equipment.

**3.2.12 prospective touch voltage** [IEC Electropedia] (ref 195-05-09): Voltage between simultaneously accessible conductive parts when those conductive parts are not being touched by a human being or livestock.

**3.2.13 reinforced insulation** [IEC Electropedia] (ref 195-06-09): Insulation that provides a degree of protection against electric shock equivalent to double insulation.

NOTE 1 to entry – Reinforced insulation can comprise several layers that cannot be tested singly as basic insulation or supplementary insulation.

**3.2.14 supplementary insulation** [IEC Electropedia] (ref 195-06-07): Independent insulation applied in addition to basic insulation, that provides fault protection.

**3.2.15 touch voltage, <effective>** [IEC Electropedia] (ref 195-05-11): Voltage between conductive parts when touched simultaneously by a human being or livestock.

NOTE 1 to entry – The value of the touch voltage is influenced by the impedance of the human being or the livestock in electric contact with these conductive parts.

**3.2.16 class I equipment** [IEC Electropedia] (ref 195-06-35): Equipment with at least one provision for basic protection and with means for protective-equipotential-bonding for fault protection.

**3.2.17 class II equipment** [IEC Electropedia] (ref 195-06-36): Electrical equipment where basic protection and fault protection are provided by double insulation or reinforced insulation.

**3.2.18 class III equipment** [IEC Electropedia] (ref 195-06-37): Electrical equipment in which voltages are limited to extra-low voltage values as the provision for basic protection, and with no provision for fault protection.

### **3.3 IEC 60479 touch voltage threshold terms**

**3.3.1 voltage threshold for startle reaction:** Minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary muscular contraction to the person through which it is flowing.

**3.3.2 voltage threshold for strong muscular reaction:** Minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, such as inability to let-go from an electrode (a.c.), but not including startle reaction.

**3.3.3 voltage threshold for ventricular fibrillation:** Minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause ventricular fibrillation.

## **4 Abbreviations and acronyms**

This Supplement uses the following abbreviations and acronyms:

ELV Extra-Low Voltage

FELV Functional Extra-Low Voltage

HLV Hazardous Live Voltage

PELV Protective Extra-Low Voltage

SELV Separated/Safety Extra-Low Voltage

## 5 Conventions

None.

## 6 Electric shock event factors

The IEC 60479 effects of current on human beings and livestock standards series cover AC, DC and pulsed electric shock events. The ELV value is set by the touch voltage that causes a particular reaction; startle, strong muscular or ventricular fibrillation. In turn these touch voltages depend on the event factors such as the body current path, skin condition (dry, water wet or salt water wet), contact area, the voltage source; impedance, type (such as AC or DC) and application time. With all these variables it is impossible to specify a universal safe touch voltage value.

### 6.1 Shock reactions

The IEC 60749 series considers three levels of shock reaction:

- **startle reaction:** minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary muscular contraction to the person through which it is flowing;
- **strong muscular reaction:** minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, such as inability to let-go from an electrode (a.c.), but not including startle reaction;
- **ventricular fibrillation:** minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause ventricular fibrillation.

This Supplement does not consider the hazardous ventricular fibrillation condition.

### 6.2 Body current path

The IEC 60749 series considers three body current paths, see Figure 1.

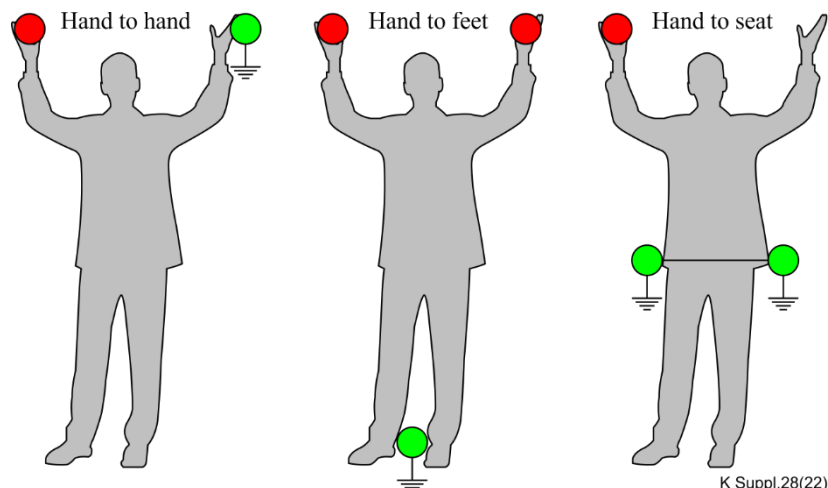


Figure 1 – Three basic IEC 60479 body current paths

### 6.3 Skin condition and contact area

The contact resistance reduces contact area increase, [IEC 60479] standardizes on contact areas of 1 cm<sup>2</sup>, 12.5 cm<sup>2</sup> or 82.5 cm<sup>2</sup>, with skin wetness values of dry, water wet or saltwater wet.

### 6.4 Summary of [IEC TR 60479-5] DC touch voltage thresholds

Table 1 collects the various touch voltage thresholds and their conditions from [IEC TR 60479-5].

**Table 1 – ELV values of [IEC TR 60479-5] DC touch voltage thresholds**

Reaction	Body Current path	Contact area cm <sup>2</sup>	Continuous DC touch voltage thresholds – V		
			Saltwater-wet	Water wet	Dry
Startle	Hand-to-hand	1	12	56	78
		12.5	4	12	23
		82.5	2	3	7
	Both-hands-to-feet	1	6	35	59
		12.5	2	7	15
		82.5	1	2	4
	Hand-to-seat	1	6	28	39
		12.5	2	6	12
		82.5	1	1	3
Strong muscular	Hand-to-hand	1	112	156	156
		12.5	44	81	89
		82.5	24	29	43
	Both-hands-to-feet	1	63	133	133
		12.5	23	51	67
		82.5	13	16	26
	Hand-to-seat	1	56	78	78
		12.5	22	41	45
		82.5	12	15	21

An inference from Table 1 is that the commonly used 60 V powering voltage only applies for a restricted set of conditions; hand-to-hand or both-hands-to-feet current path, dry skin and a contact area of less than 1 cm<sup>2</sup>. Had the current path been hand-to-seat the voltage would be lower at about 40 V. The contact area when touching connector contacts is likely to be small, for example 0.1 cm<sup>2</sup>. It is a pity IEC TR 60749 does not give touch voltage values for smaller contact areas.

Although specifying values in a definition is frowned upon, ELV definitions often quote values which do not correlate with IEC 60749 values. Table 2 gives a selection of found values and demonstrates why specific event factors need to be given to justify the defined values.

NOTE – The [IEC 62368-1] 60 V ES1 level is not directly equivalent to an ELV touch voltage value of 60 V.

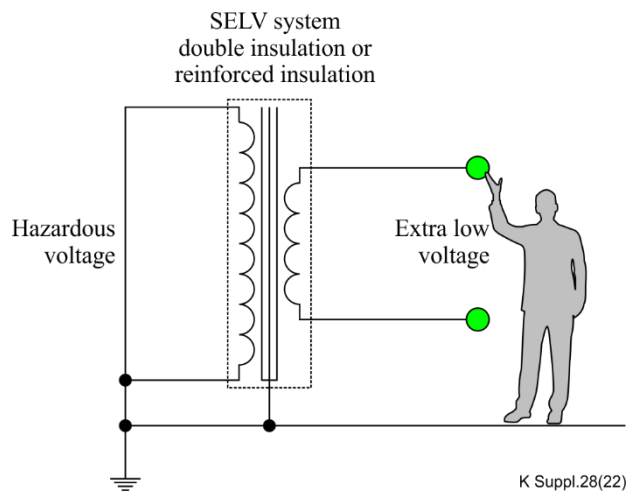
**Table 2 – ELV values in IEC documents**

Standard	DC V
[IEC 60669-2-5]	50
[IEC 60598-1]	120
[IEC 61850-3]	70
[IEC 60950-1]	60
[IEC Electropedia] SELV	120
[IEC 62368-1]	60 (ES1 body text value quoted)
[IEC 61140]	40 (Muscular reaction, dry conditions, contact area 35 cm <sup>2</sup> )

## 7 Examples of SELV, PELV and FELV systems

### 7.1 Safety extra-low voltage (SELV) system

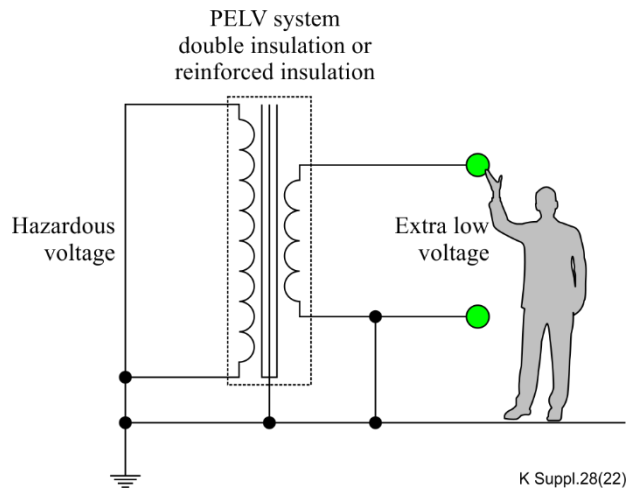
SELV is also called 'separated' extra-low voltage to emphasise that potentially hazardous voltages are isolated from the ELV voltage. The winding insulation of the isolation transformer used for SELV must be reinforced or double insulated, see Figure 2.



**Figure 2 – SELV system with output voltage floating**

### 7.2 Protective extra-low voltage (PELV) system

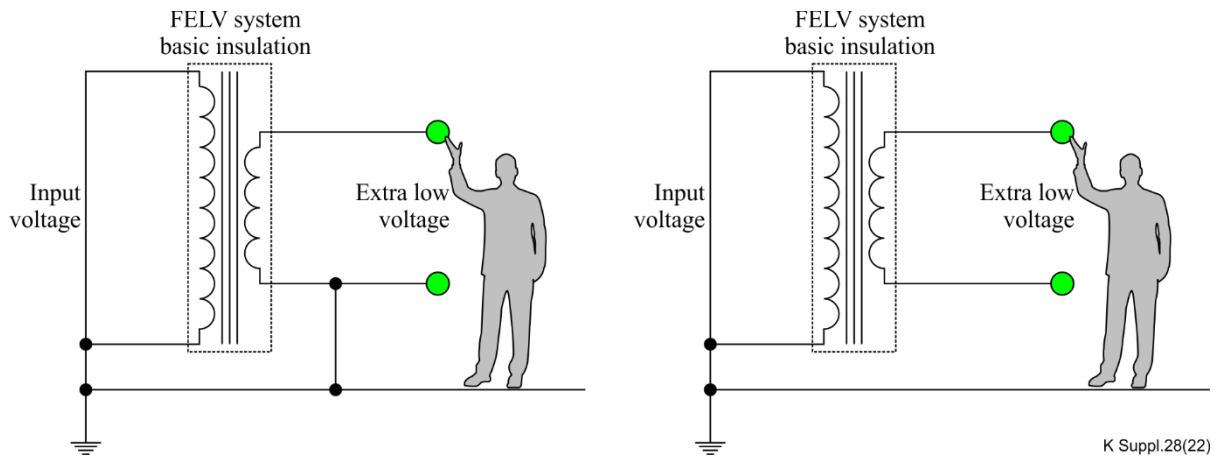
A PELV system is an SELV system with a protective earth connection, see Figure 3.



**Figure 3 – PELV system with output earth reference**

### 7.3 Functional extra low voltage (FELV) system

Figure 4 shows a FELV system which does not meet safety requirements for SELV or PELV.



**Figure 4 – FELV system which does not meet safety requirements for SELV or PELV**

## 8 Summary of [IEC TR 60479-5] AC touch voltage thresholds

Table 3 collects the various AC touch voltage thresholds and their conditions from [IEC TR 60479-5].

**Table 3 – ELV values of [IEC TR 60479-5] AC touch voltage thresholds**

Reaction	Current path	Contact cm <sup>2</sup>	Continuous AC touch voltage thresholds – V		
			Saltwater-wet	Water-wet	Dry
Startle	Hand-to-hand	1	3	21	40
		12.5	1	4	9
		82.5	1	1	2
	Both-hands-to-feet	1	2	13	23
		12.5	1	3	5
		82.5	0.3	0.4	1
	Hand-to-seat	1	2	11	20
		12.5	0.5	2	4
		82.5	0.3	0.4	1
Strong muscular	Hand-to-hand	1	27	93	104
		12.5	9	25	40
		82.5	5	7	11
	Both-hands-to-feet	1	27	93	104
		12.5	9	25	40
		82.5	5	7	11
	Hand-to-seat	1	13	46	52
		12.5	5	13	20
		82.5	3	3	6





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