

## 9. Electrical Services Part 2

### 9.2 Lightning protection and earthing systems



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# Contents 內容



- Electrical safety 電力安全
- Earthing & bonding 接地和接駁
- Lightning protection system 避雷系統
- Operation & maintenance 操作和維修

# Electrical safety



- Typical electrical safety devices:
  - 1. Fuse 熔斷器
    - A copper wiring with a set current fusion value, if exceeded, the fuse will blow & the current is cut-off
  - 2. Circuit breakers 斷路器
    - The current enables the coils of the circuit breaker to magnetise & disconnect the electric source, e.g. air circuit breaker (ACB), miniature circuit breaker (MCB)
  - 3. Earthing 接地
    - Provides a low resistance way of discharging electricity to the ground in case of current leakage

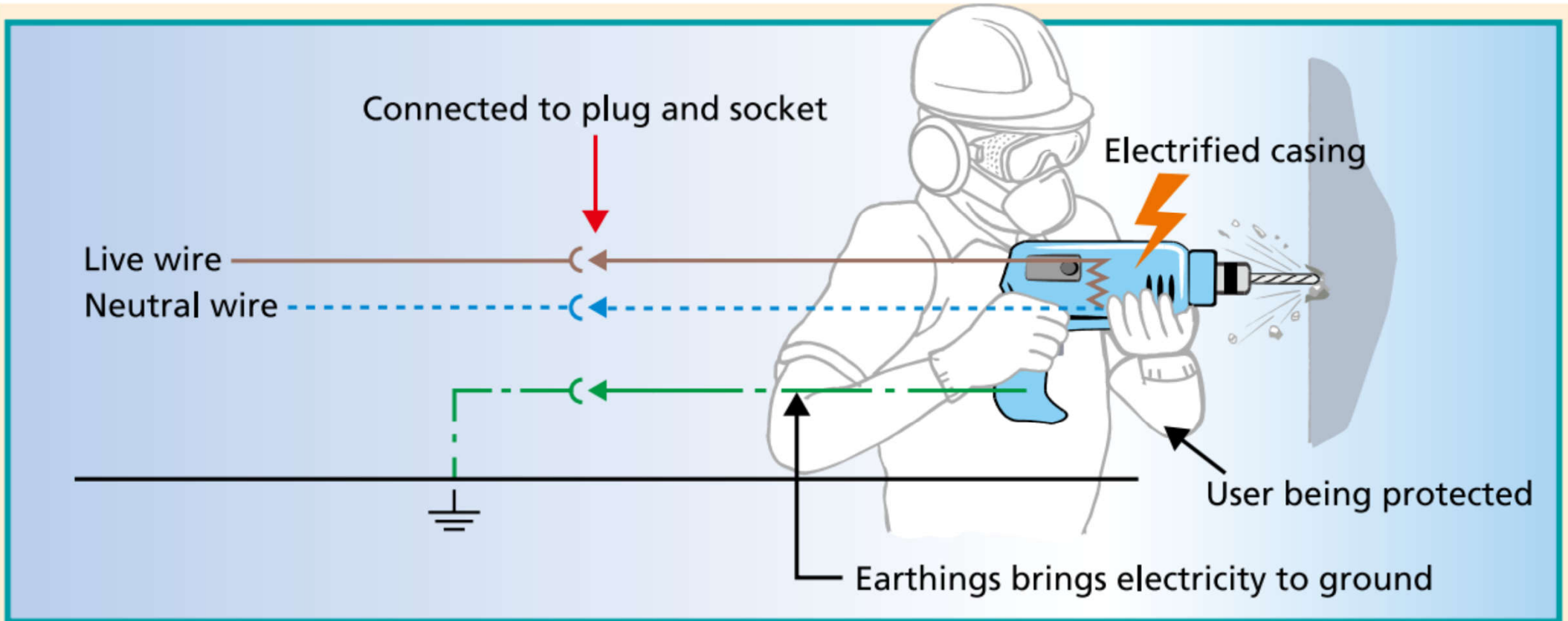
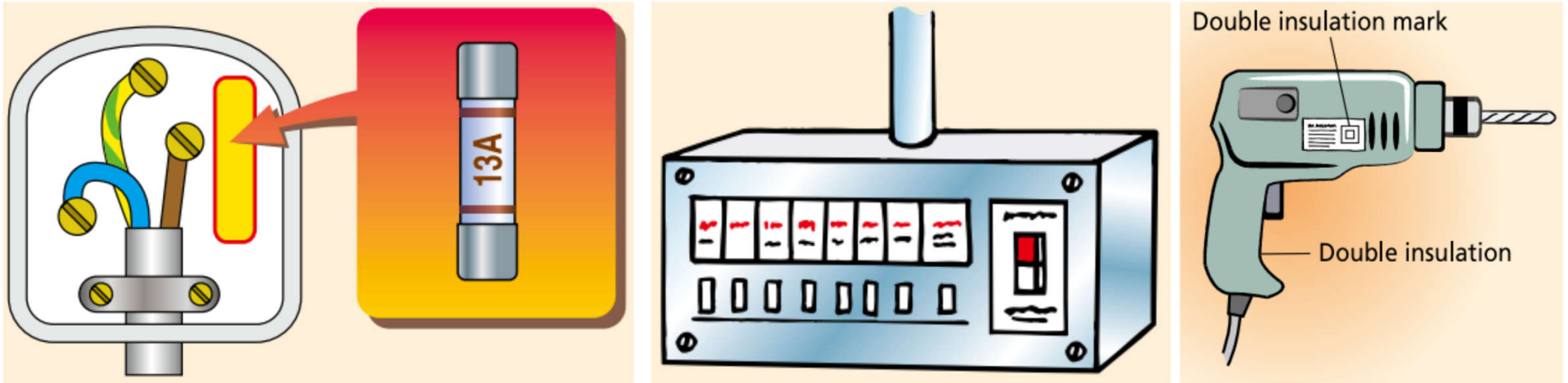
# Electrical safety



- Typical electrical safety devices: (cont'd)
  - 4. Earth leakage circuit breaker (ELCB or RCD)  
接地漏電斷路器 / 剩餘電流動作保護器
    - Monitor the operation of “neutral” or “live” wires & detect an imbalance to cut-off the electrical source
  - 5. Double insulation 雙重絕緣
    - An electrical appliance protected by a supplementary insulation layer in addition to basic insulation
  - 6. Extra-low voltage (ELV) 特低壓
    - Voltage of less than 50 V (AC) to minimise injury in case of electric shock

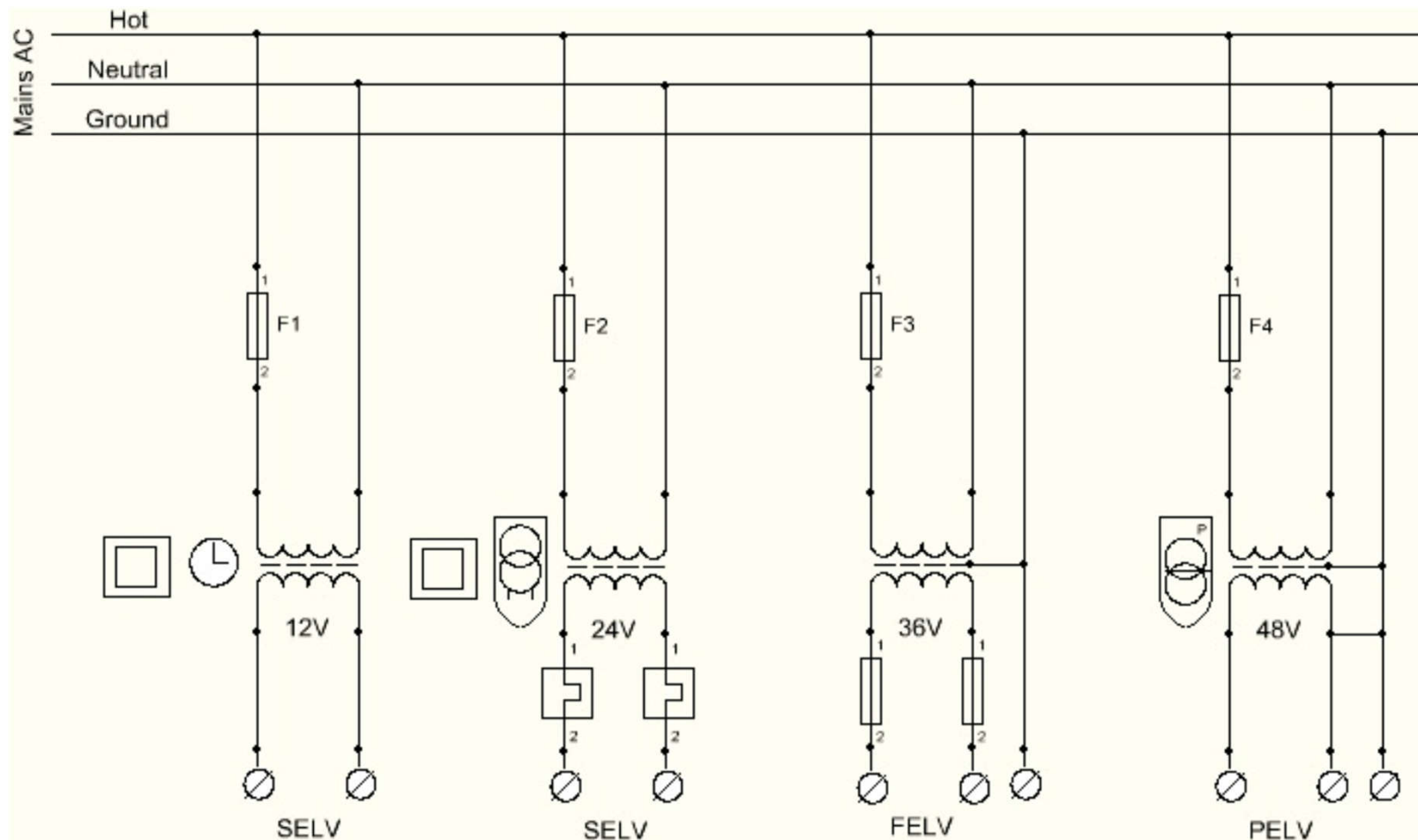


# Safety devices: fuse, circuit breakers (MCB), double insulation, earthing



# Electricity supply voltage & installations for extra low voltage

Voltage range	AC RMS voltage (V)	DC voltage (V)	Defining risk
High voltage	> 1000	> 1500	Electrical arcing
Low voltage	50 to 1000	120 to 1500	Electrical shock
Extra-low voltage	< 50	< 120	Low risk



FELV = Functional extra low voltage; PELV = Protective extra low voltage; SELV = Safety extra low voltage

(Source: Extra-low voltage - Wikipedia [https://en.wikipedia.org/wiki/Extra-low\\_voltage](https://en.wikipedia.org/wiki/Extra-low_voltage))

# Electrical safety



- Steps to handle fault & emergency repair:
  - 1. Assign qualified repair personnel
  - 2. Shut down & isolate the affected area/parts
  - 3. Properly isolate other live parts
  - 4. Inspect the fault part & identify main causes
  - 5. Confirm the part that needs repair/replacement & the required components/parts
  - 6. Arrange the necessary tools, materials for repair
  - 7. Perform final testing & resume power supply

# 3 steps to electrical work safety

## 3 STEPS TO ELECTRICAL WORK SAFETY: SWITCH OFF • LOCK UP • POST NOTICE



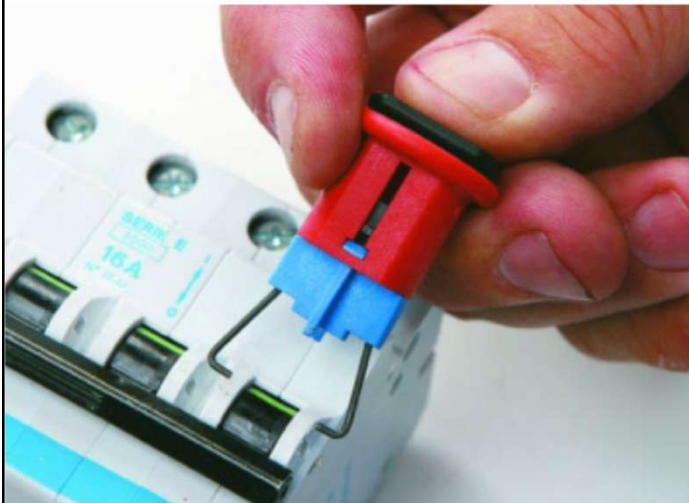


# Electrical safety



- Precautions for inspection on fixed electrical installations
  - 1. Use of lockable switches (to prevent accidental switch-on of circuit breakers)
  - 2. Permit-to-work shall be issued for carrying out electrical work on de-energised equipment
  - 3. Electrical safety assessment shall be carried out for live work
  - 4. Working on 3-phase 4-wire AC system shall disconnect its neutral conductor

# Locking Device 鎖類設備



# Risk assessment report on electrical live work 帶電工作風險評估報告

## Risk Assessment Report on Live Work 帶電工作風險評估報告

Report No.  
報告編號: G-01-130102

Location  
地點: 一般電力裝置

Assessed by  
評估者: 陳安全(W000001)

Date  
日期: 2013年1月2日

Details of work to be done  
要進行的工程詳情: 一般電力裝置接地故障環阻測試

Endorsed by  
審批者: 李守規(W000002)

Hazard 危害	People Affected 受影響人士	Existing Control Measures 現有控制措施	Risk Assessment (Note) 風險評估 (註)			Recommended Action 建議行動	Remark 備註
			Likelihood 可能性	Consequence 後果	Risk Level 風險程度		
Electric shock 觸電	測試人員	<p><b>a.</b> 測試人員必須配用公司的絕緣手套</p> <p><b>b.</b> 有需要時，必須使用公司配備的非金屬梯</p> <p><b>c.</b> 測試時，必須由不少於兩人一組合作進行</p>	<b>Un</b>	<b>Mi</b>	<b>L</b>	<p><b>1.</b> 嚴格執行非經公司指定人員不得進行本項測試工作</p> <p><b>2.</b> 公司指定人員必須在進行本項測試工作前切實檢查使用的工具、儀器、<b>a</b>和<b>b</b>項設施，符合安全使用要求</p>	<p>陳安全 李守規</p> <p>為公司可進行本項測試的指定人員</p>

Note 註: 1. Likelihood 可能性:

Ac – Almost certain 幾乎肯定  
Li – Likely 有機會發生  
Po – Possible 有可能發生  
Un – Unlikely 不大可能發生  
Ra – Rare 罕見

2. Consequence 後果:

Ca – Catastrophic 致命或極嚴重後果  
Ma – Major 嚴重後果  
Mo – Moderate 一般後果  
Mi – Minor 輕微後果  
In – Insignificant 極輕微後果

3. Risk Level 風險程度:

E – Extreme 極高風險  
H – High 高度風險  
M – Moderate 中度風險  
L – Low 較低風險

Likelihood 可能性	Consequence 後果				
	Ca	Ma	Mo	Mi	In
Ac	E	E	E	H	H
Li	E	E	H	H	M
Po	E	E	H	M	L
Un	E	H	M	L	L
Ra	H	H	M	L	L

# An example of electrical risk management for portable tools

- **藍黃綠橙**
- 以顏色代碼每三個月監管工具狀況



檢查後打隆作紀錄



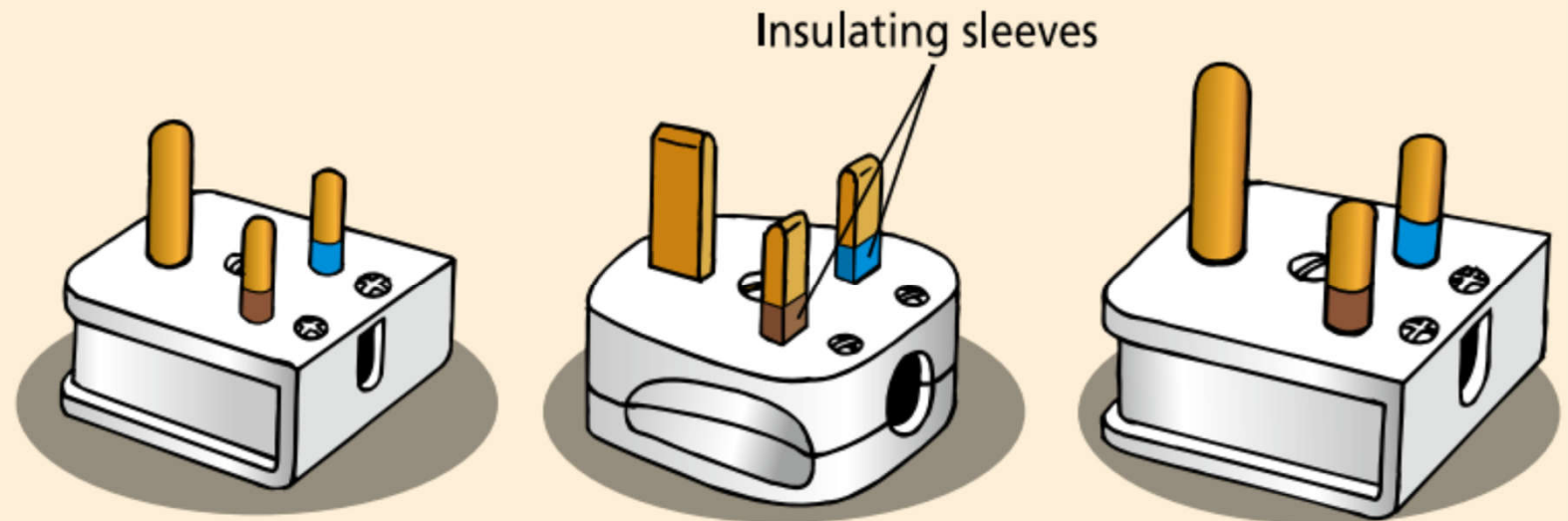
工具曾於一月至三月和四月至六月作出檢查

一月至三月 Jan - Mar	藍 BLUE	
四月至六月 Apr - Jun	黃 YELLOW	
七月至九月 Jul - Sep	綠 GREEN	
十月至十二月 Oct - Dec	橙 ORANGE	
不能再使用 待遷離工地 To be removed from the site	紅 RED	
工具待驗 Equipment under quarantine	白 WHITE	

January - March 一月至三月	Blue 藍	
April-June 四月至六月	Yellow 黃	
July-September 七月至九月	Green 綠	
October-December 十月至十二月	Orange 橙	

便攜式電動工具顏色代碼

# Specification of electric plugs in Hong Kong



Rating	5-Ampere plug	13-Ampere plug	15-Ampere plug
Standard	BS 546	BS 1363	BS 546

- Plugs for electrical equipment shall match the power/current rating (calculated by voltage 220V).

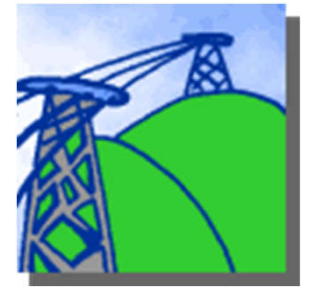
Maximum power  
Watt (W)

1100

2860

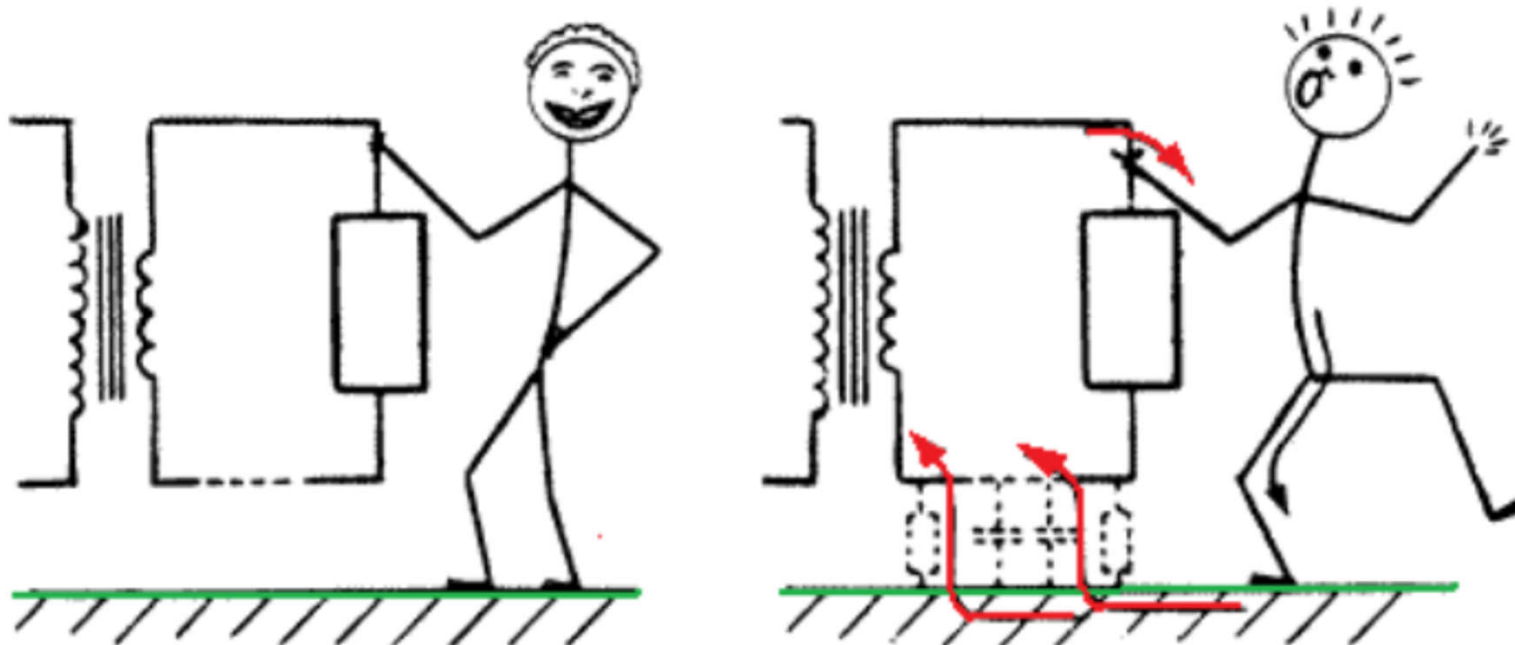
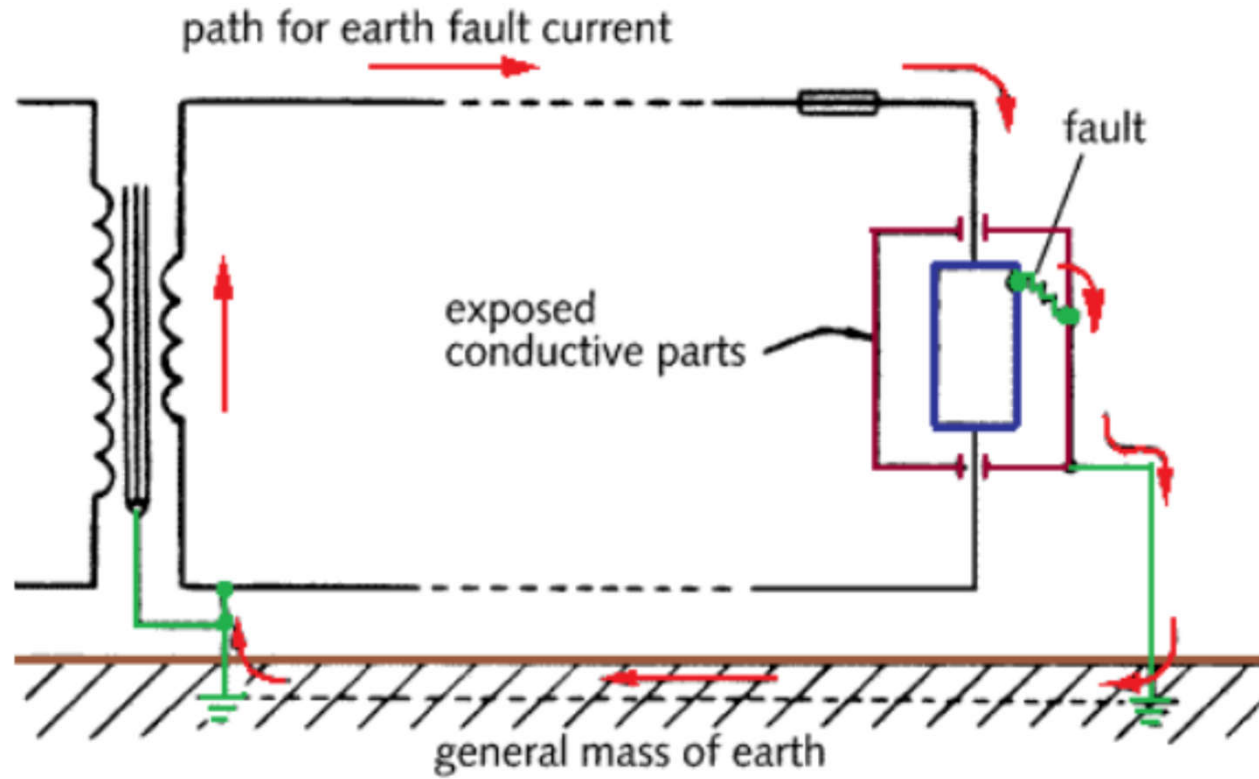
3300

# Earthing & bonding



- Earthing system (or grounding system)
  - It connects parts of the electric circuit with the ground, thus defining the electric potential of the conductors relative to the Earth's conductive surface
  - Purposes:
    - To protect a structure from lightning strike (direct the lightning into the earthing rod in the ground)
    - Form part of the safety system of mains electricity
    - Common ground plane for radio antenna

# Basic concepts of earthing and bonding



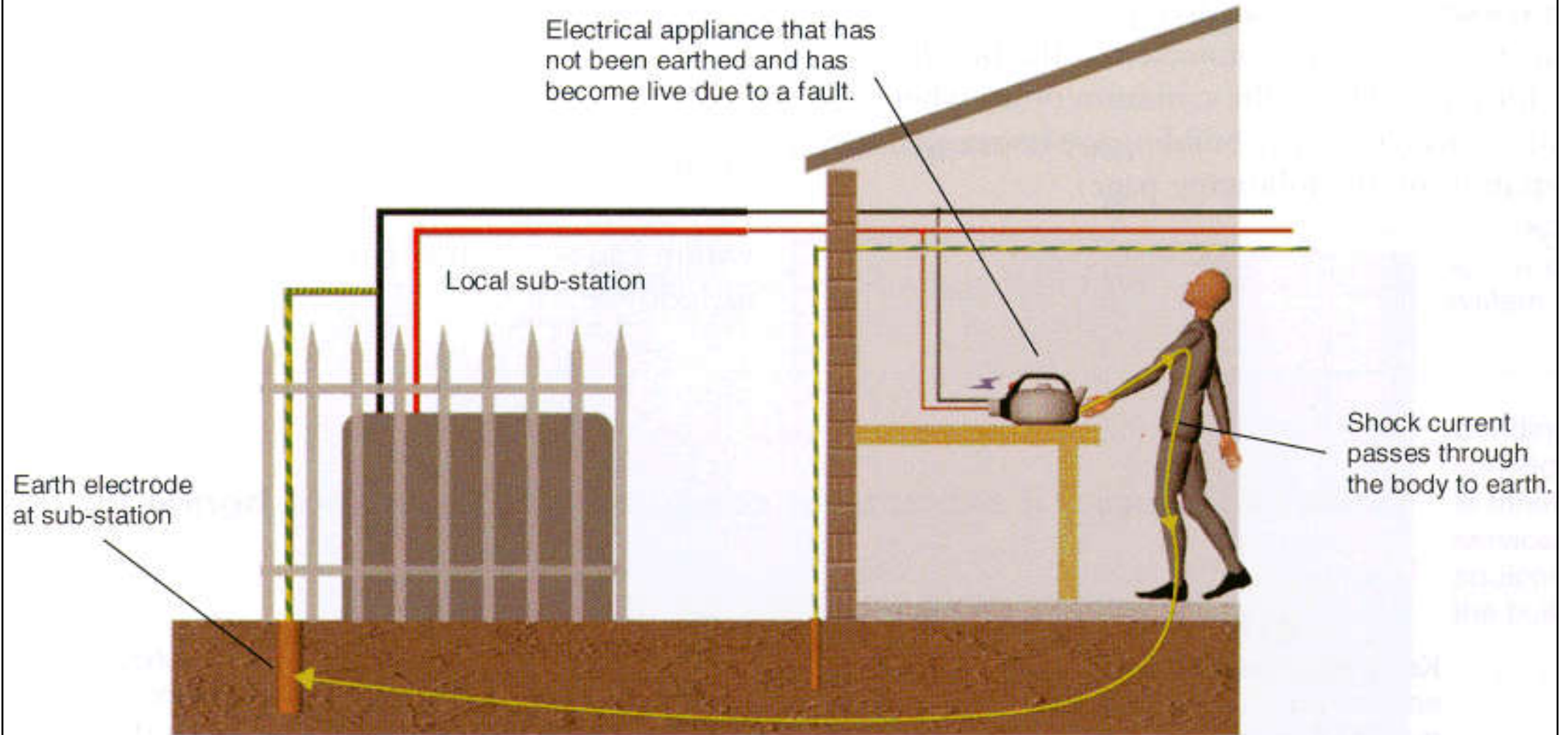


# Earthing & bonding

- Earthed equipotential bonding and automatic disconnection 接地等電位接駁和自動斷電
  - To bond all the exposed and extraneous conductive parts to earth in order to create a zone at earthed potential so that the potential difference (touch voltage) between those parts are minimized in the event of an earth fault inside the zone (touch voltage would be reduced by bonding), and then to cut the supply within the maximum safe time duration

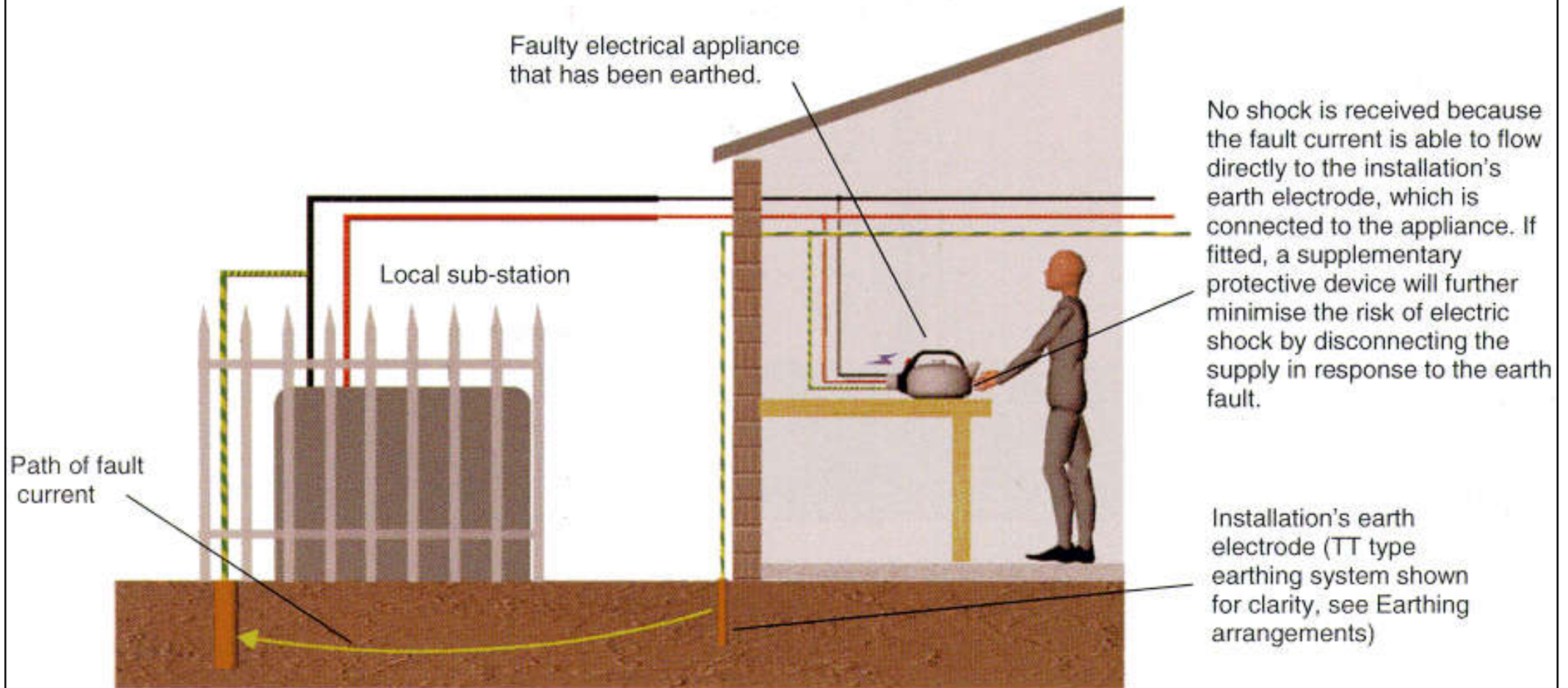


## What can happen if electrical appliances are not earthed

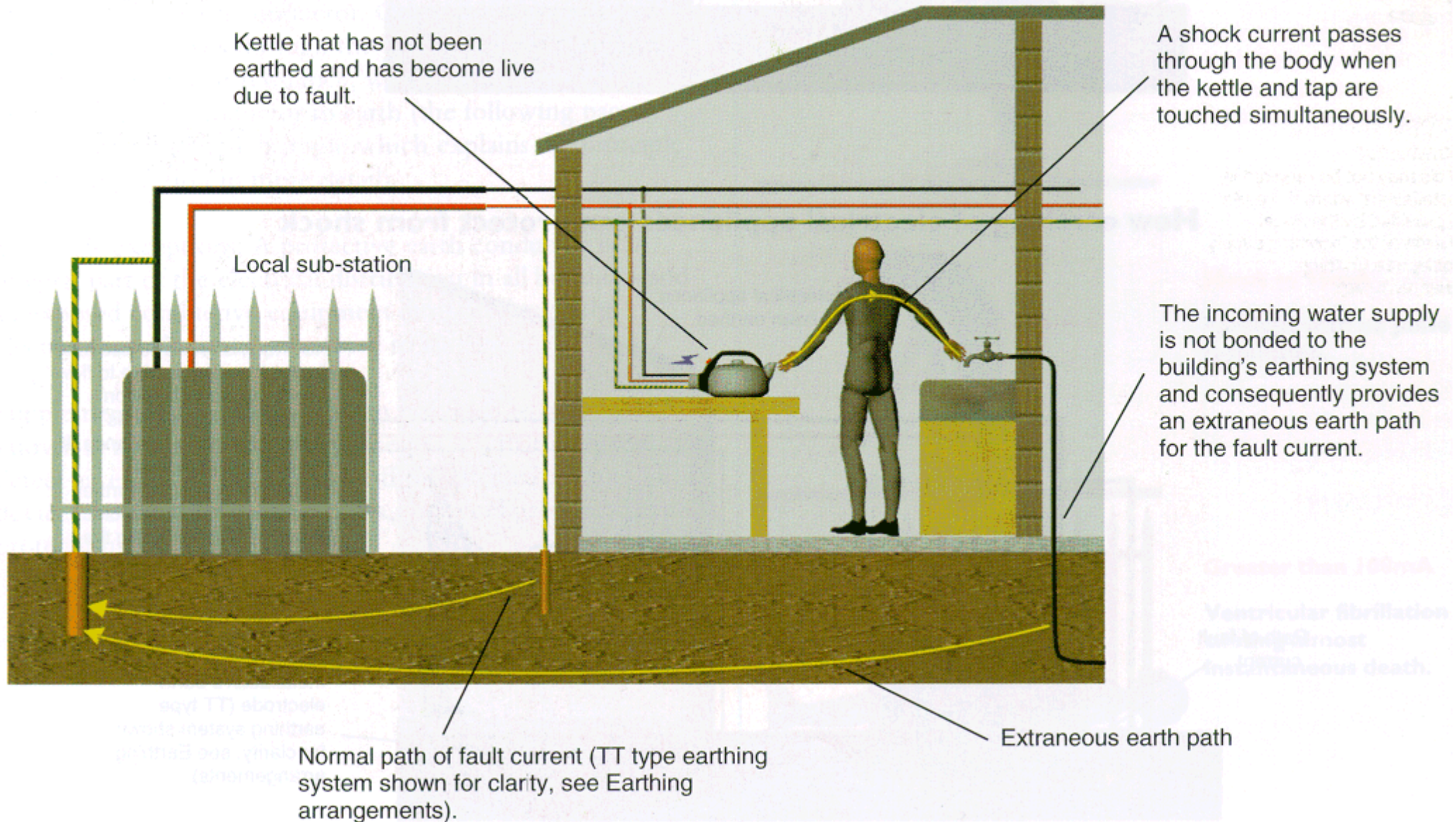


[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

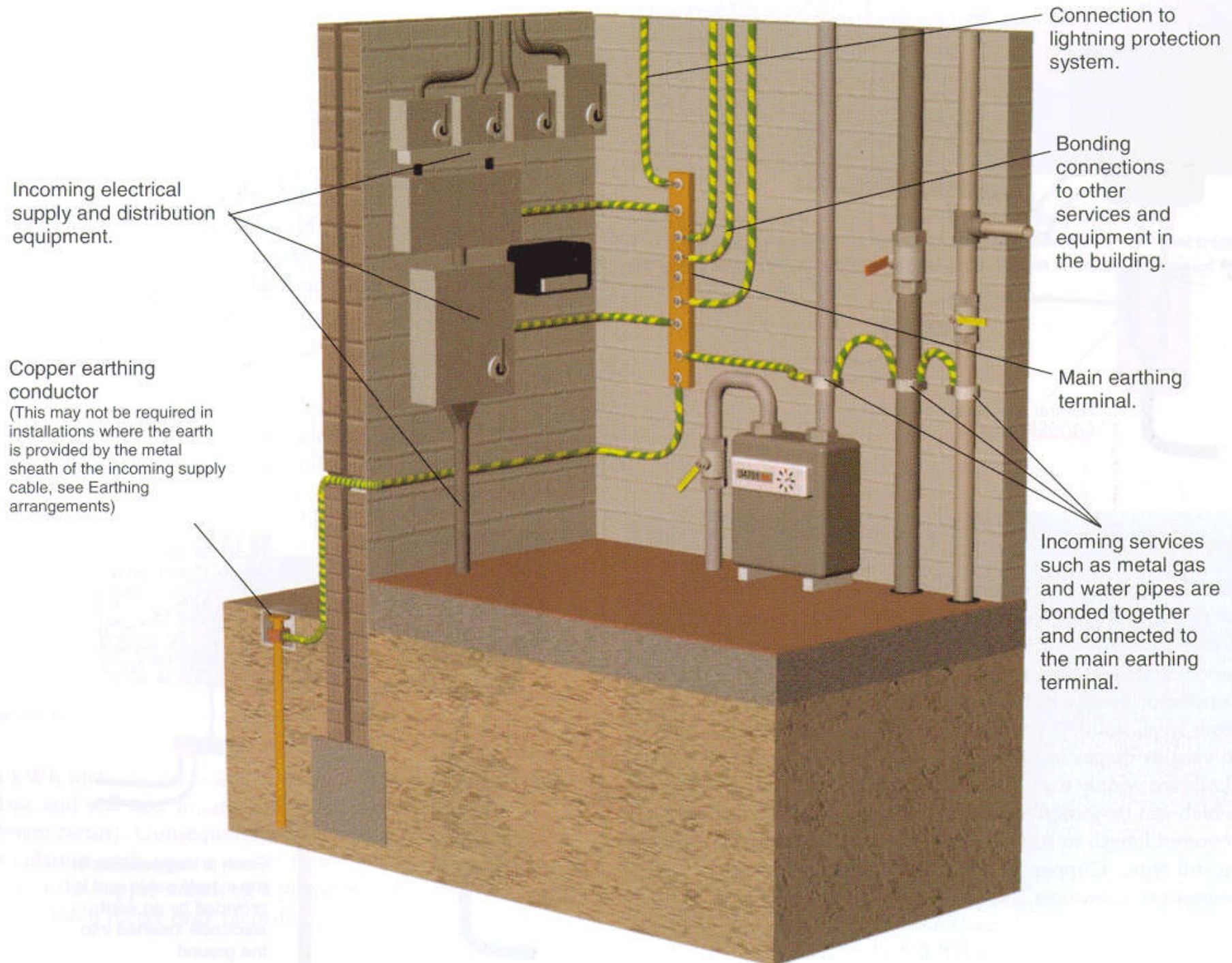
## How earthing of electrical appliances can protect from shock



## What can happen if extraneous conductive parts are not bonded



## Main bonding of incoming services



[Source: De Saulles, T., 2001. *The Illustrated Guide to Electrical Building Services*]

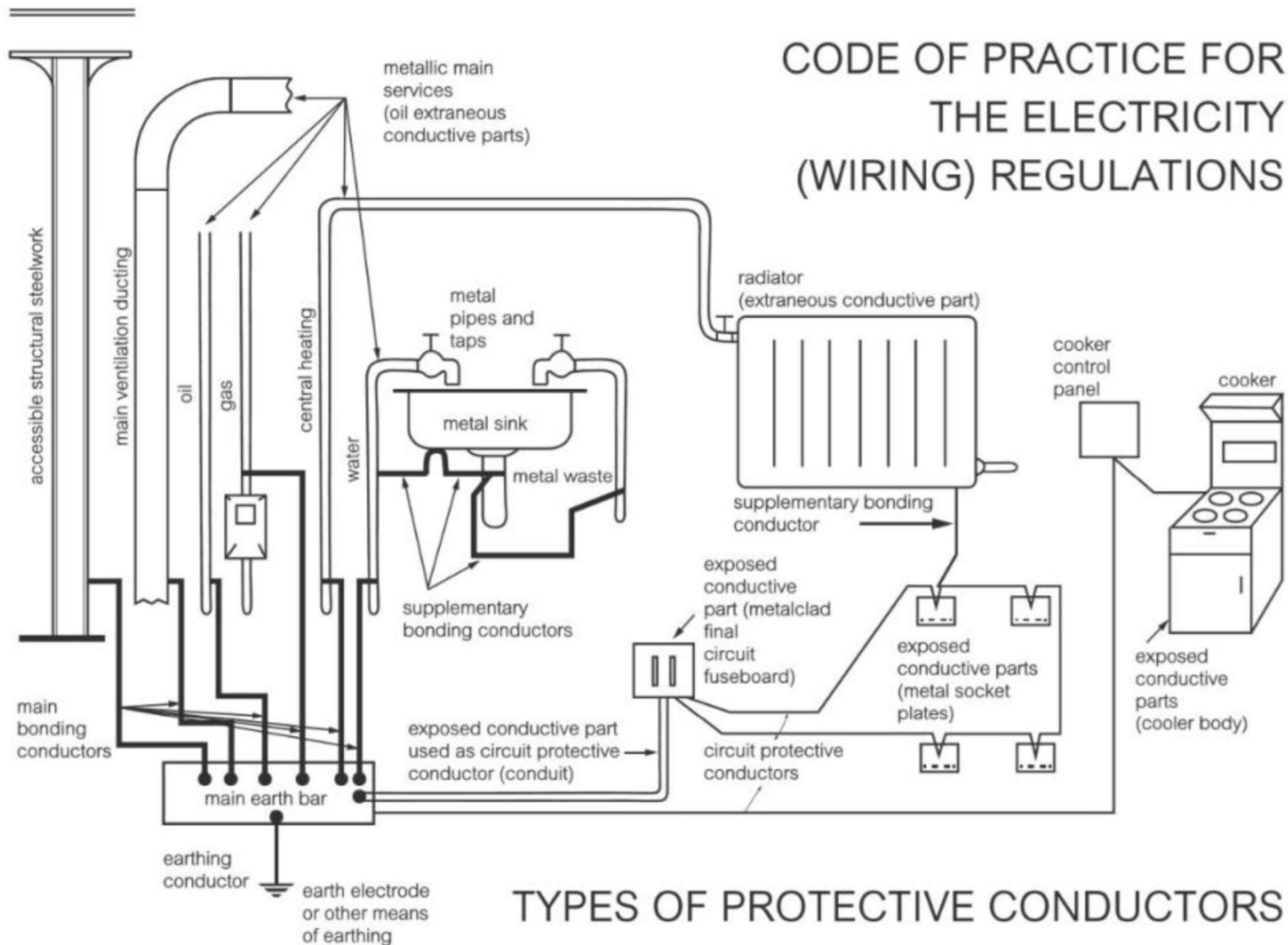
# Earthing & bonding



- Four types of protective conductors:
  - 1. Circuit protective conductors (CPC)
  - 2. Main equipotential bonding conductors
  - 3. Supplementary bonding conductors
  - 4. Earthing conductors
- Local supplementary bonding to metal parts to maintain the equipotential zone (to prevent a hazardous potential difference)
  - (a) Extraneous conductive parts
  - (b) Simultaneously accessible with exposed conductive parts or other extraneous conductive parts



# Earthing and supplementary bonding protective conductors



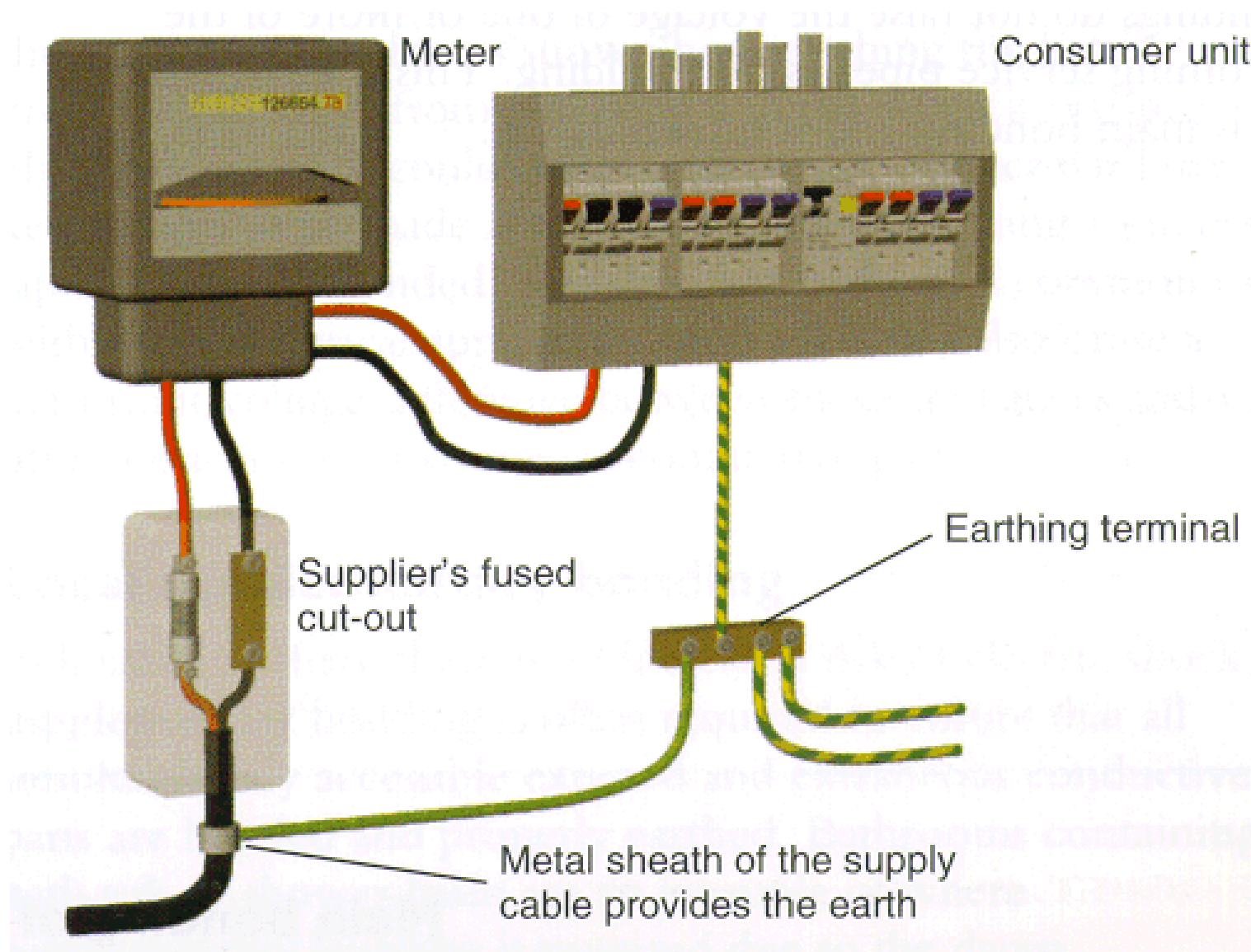


# Earthing & bonding

- Earthing arrangements: letter coding
  - First letter – type of earthing (at the source of energy)
    - T: at least one point of the supply is directly earthed (Terra)
    - I: the supply is not directly earthed, but connected to earth through a current limiting impedance
  - Second letter – installation earthing arrangement
    - T: all exposed conductive metalwork is directly earthed
    - N: all exposed conductive metalwork is connected to an earth provided by the supply company
  - Third and fourth letters – earth conductor arrangement
    - S: earth and neutral conductors separate
    - C: earth and neutral conductors combined
    - C-S: earth and neutral conductors combined in part of system only
- Three common types of earthing systems
  - TN-S system, TN-C-S system, TT system

# TN-S system

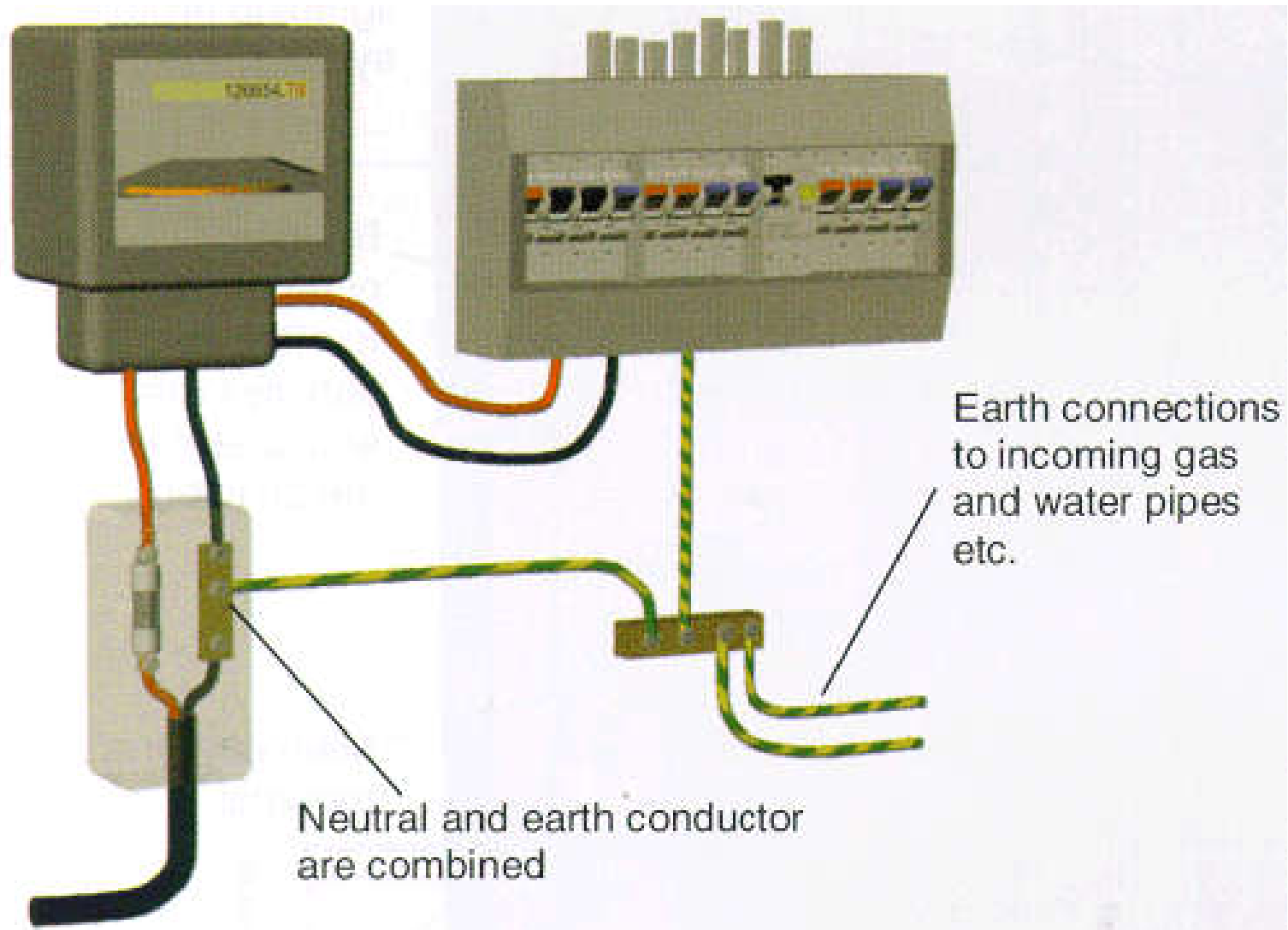
Separate neutral conductor and protective earth conductor within the supply to the building.





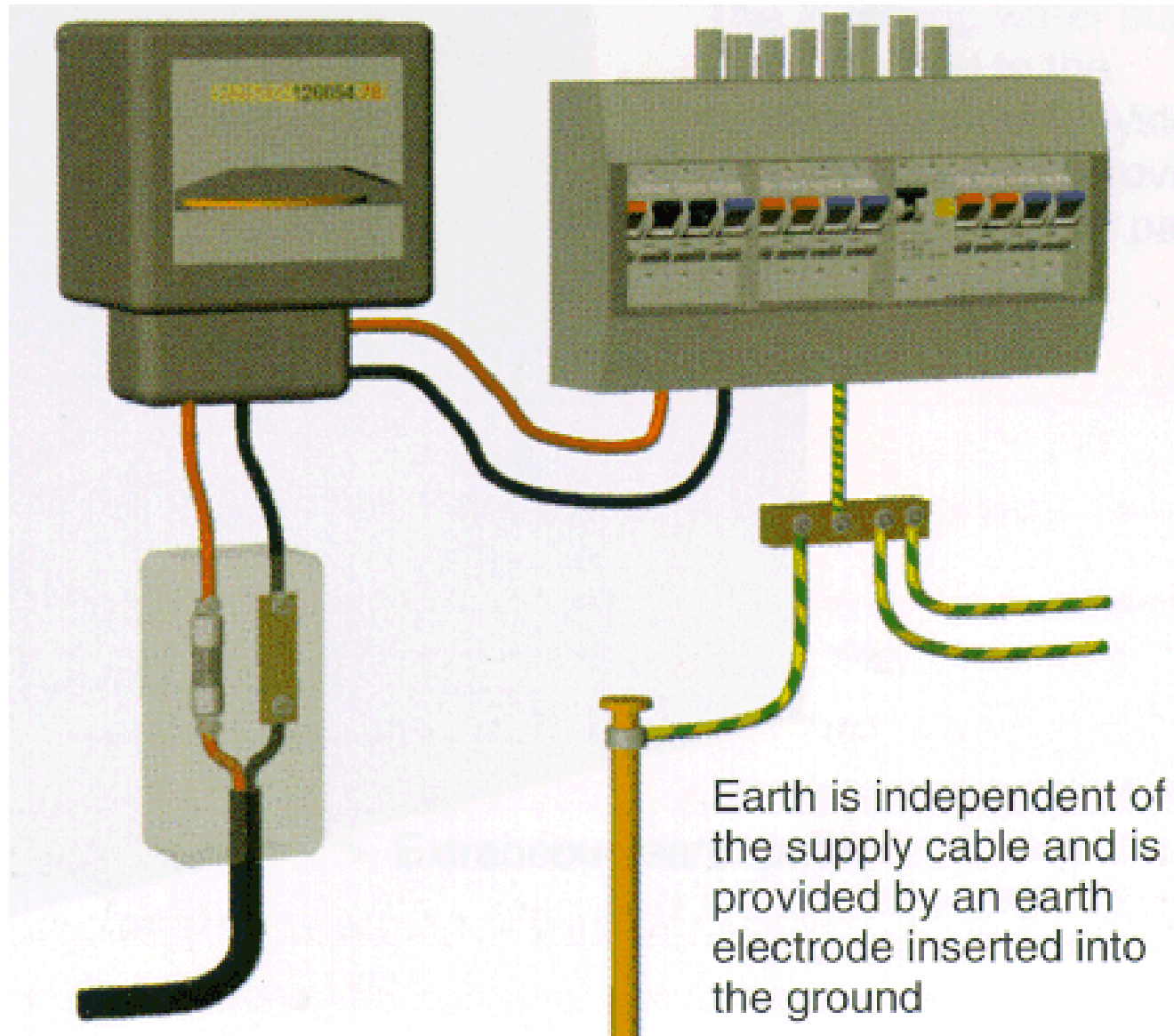
## TN-C-S system

Metal sheath of incoming supply acts as both the neutral and the earthing conductor (PEN conductor). Also known as protective multiple earthing (PME)



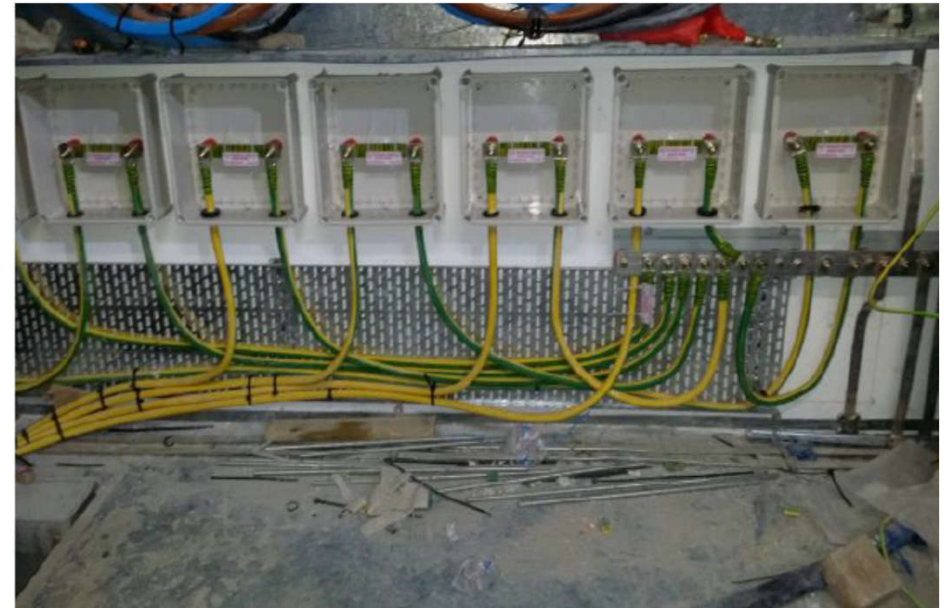
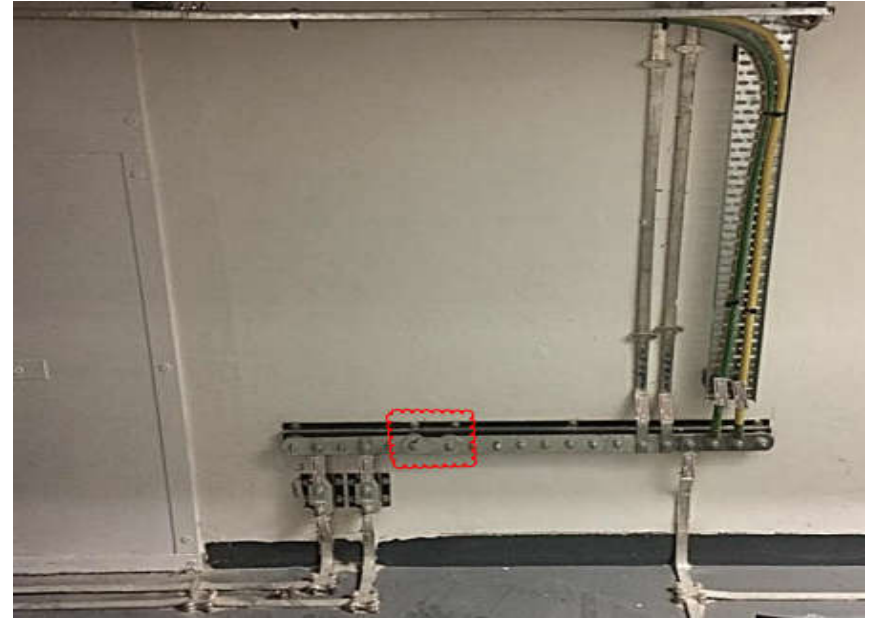
## TT system

Incoming supply does not incorporate an earthing conductor; local earthing is created on site (e.g. by earth electrode rods)

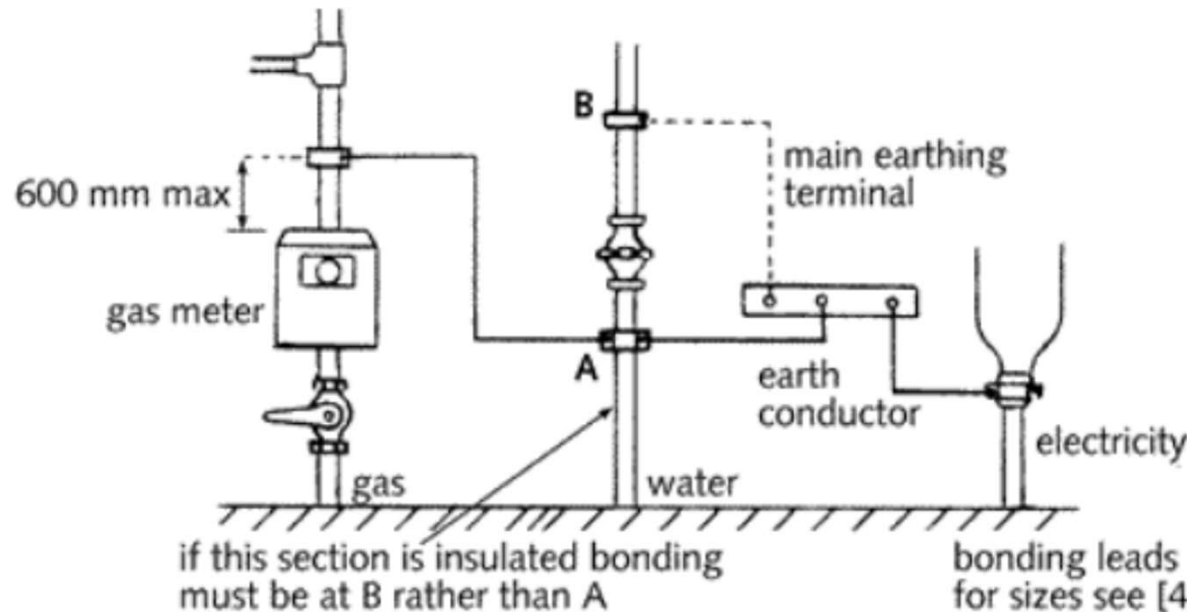
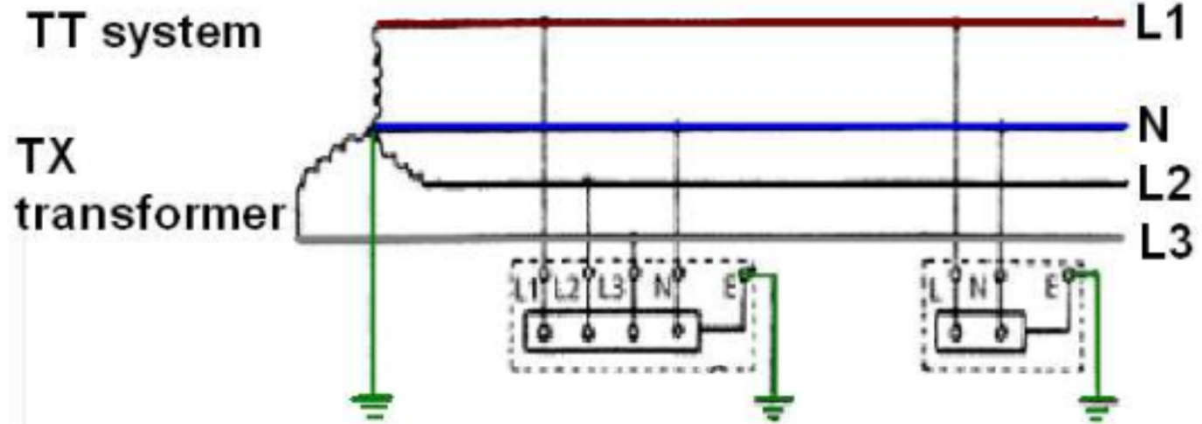
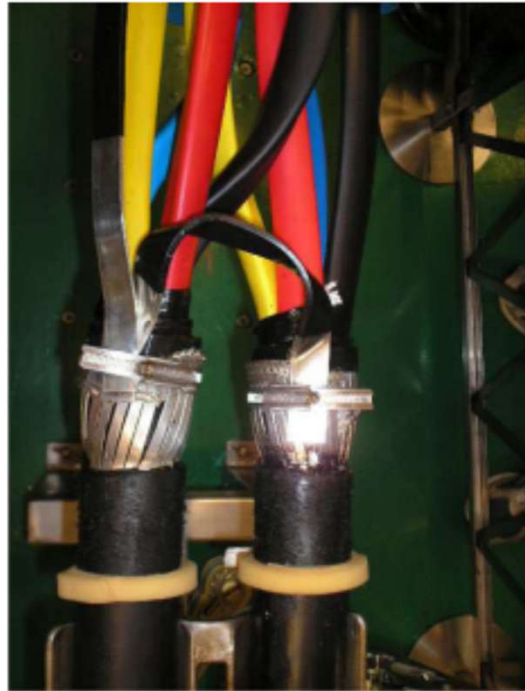


# Earthing requirements

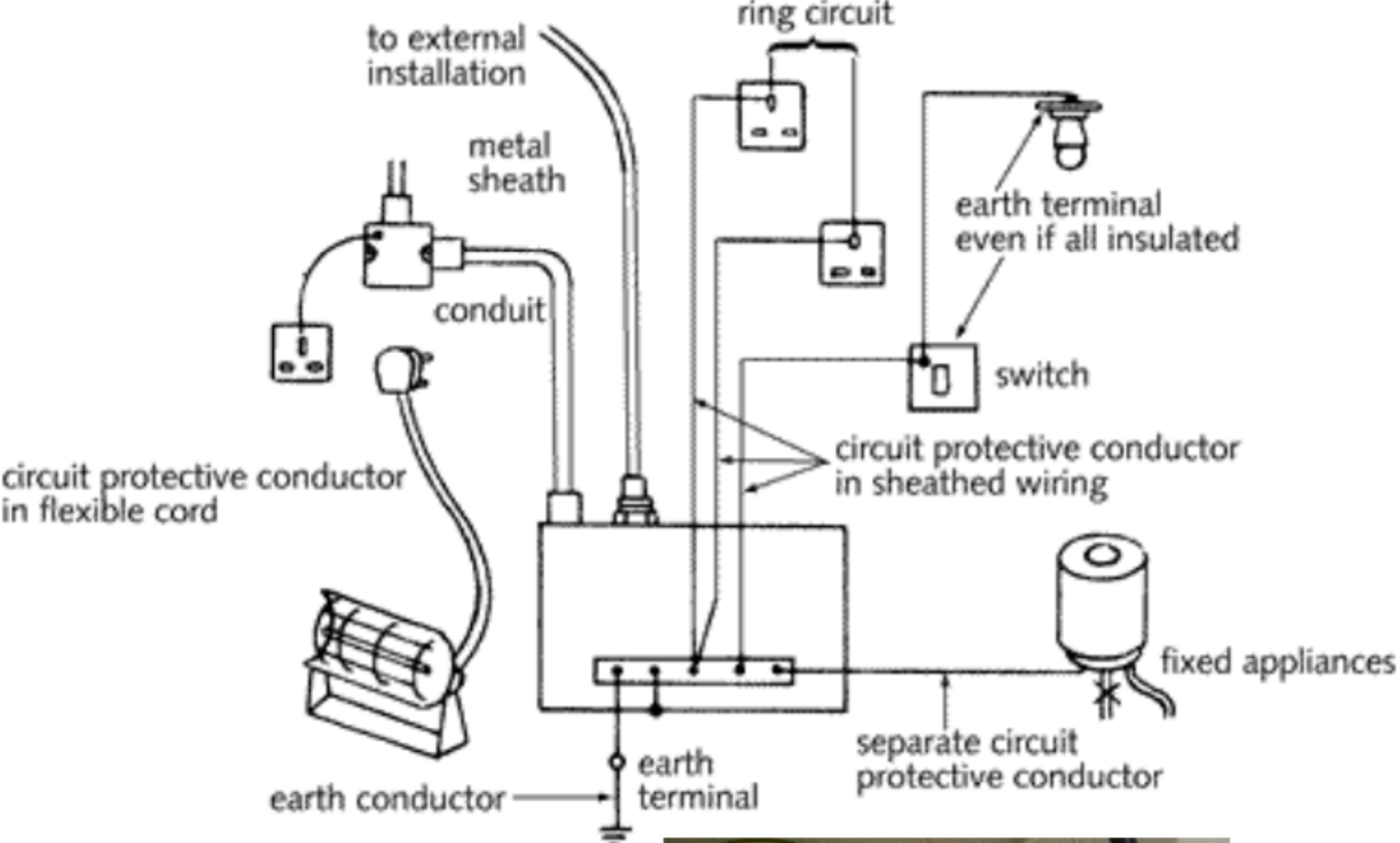
- Customer provide own effective earthing system including connection to earth electrodes
- Exposed conductive parts connected to earth (CLP Supply Rules & COP for Electricity (Wiring) Regulations)
- Not less than 70mm<sup>2</sup> copper or equivalent earthing conductor to all units via earthing terminal block at each floor
- For HKE, if the customer main earthing system is bonded to its main earthing system, an insulated disconnection link should be provided



# Earthing & bonding conductors 接地和接駁導體

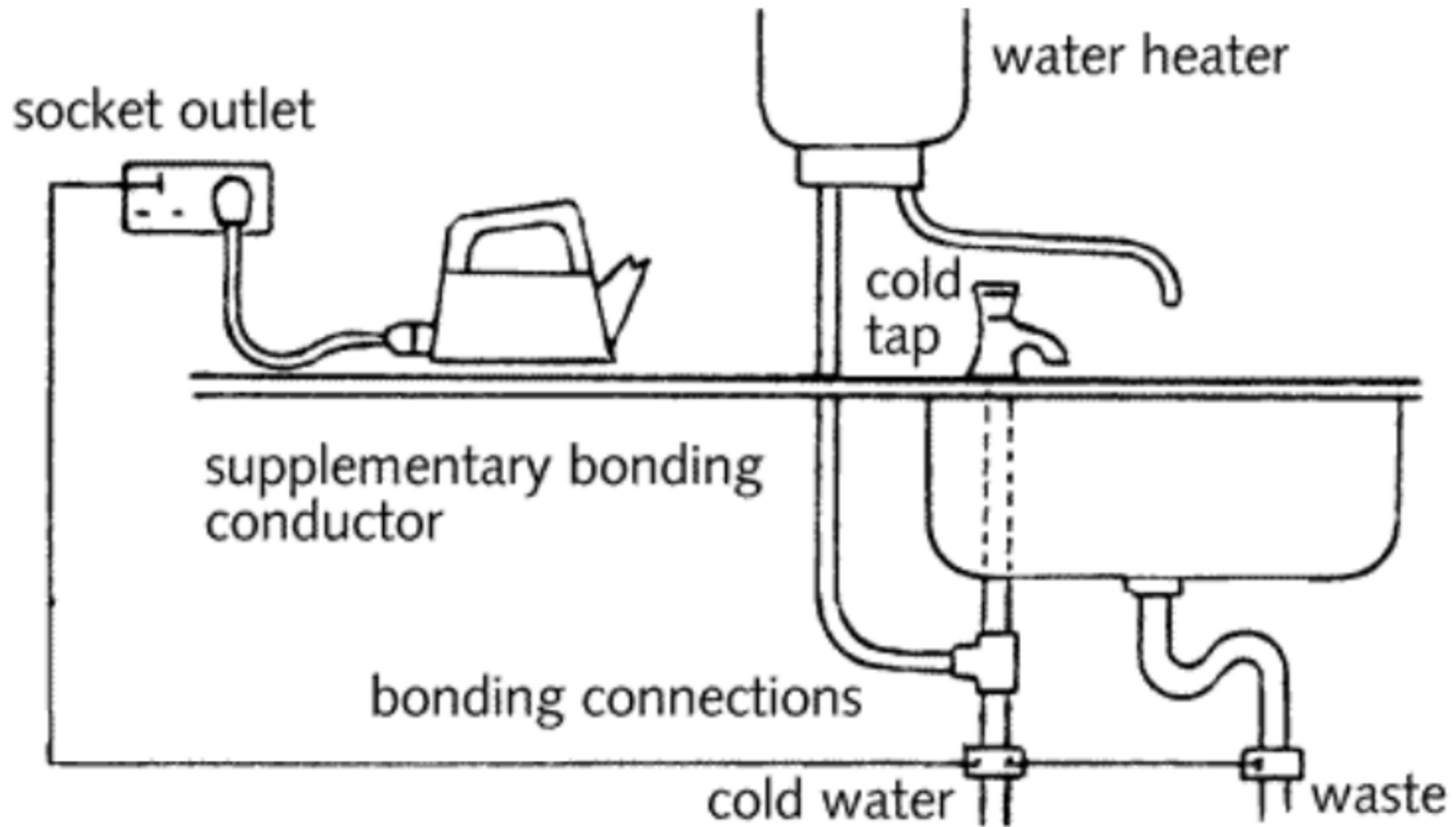


# From main earth terminal to different circuits & appliances

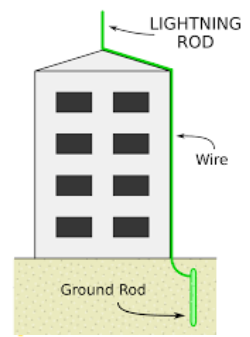


[Source: <https://www.eeunion.org.hk/>]

# Examples of bonding connections

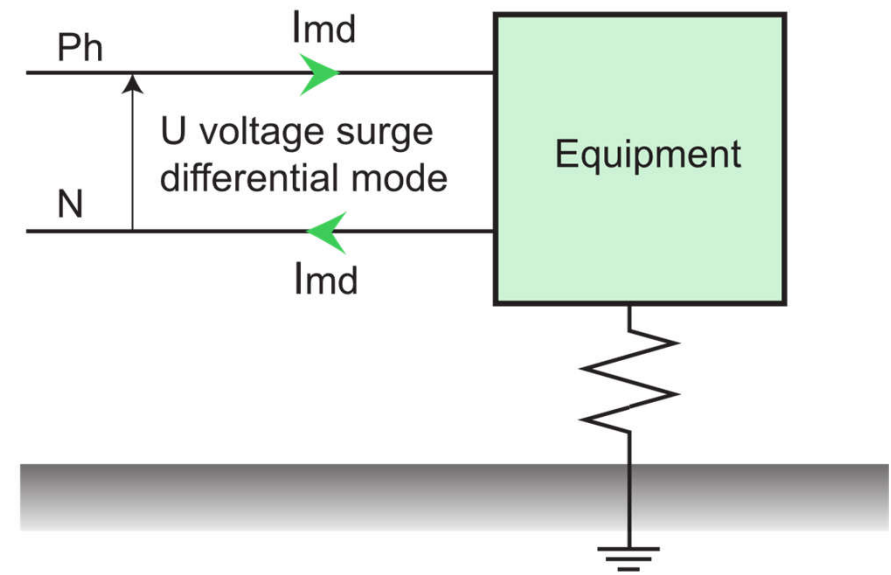
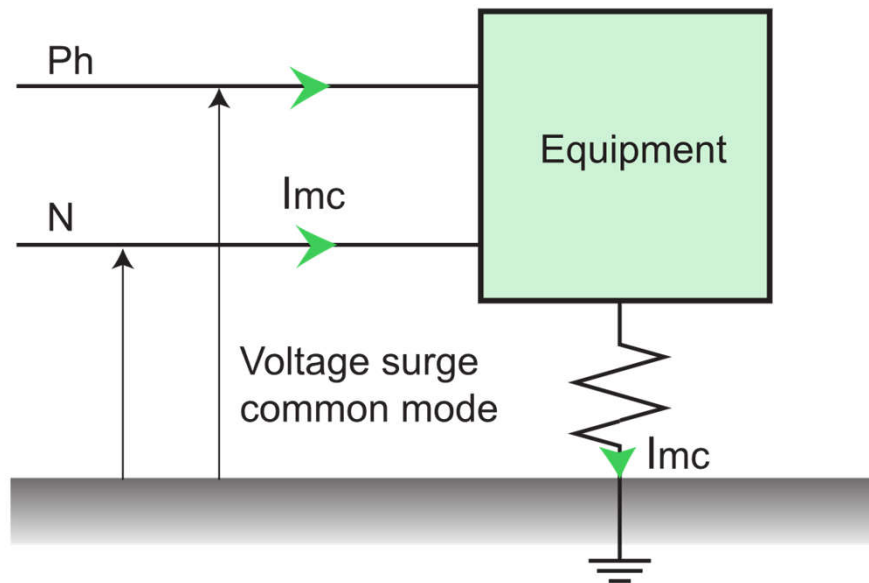
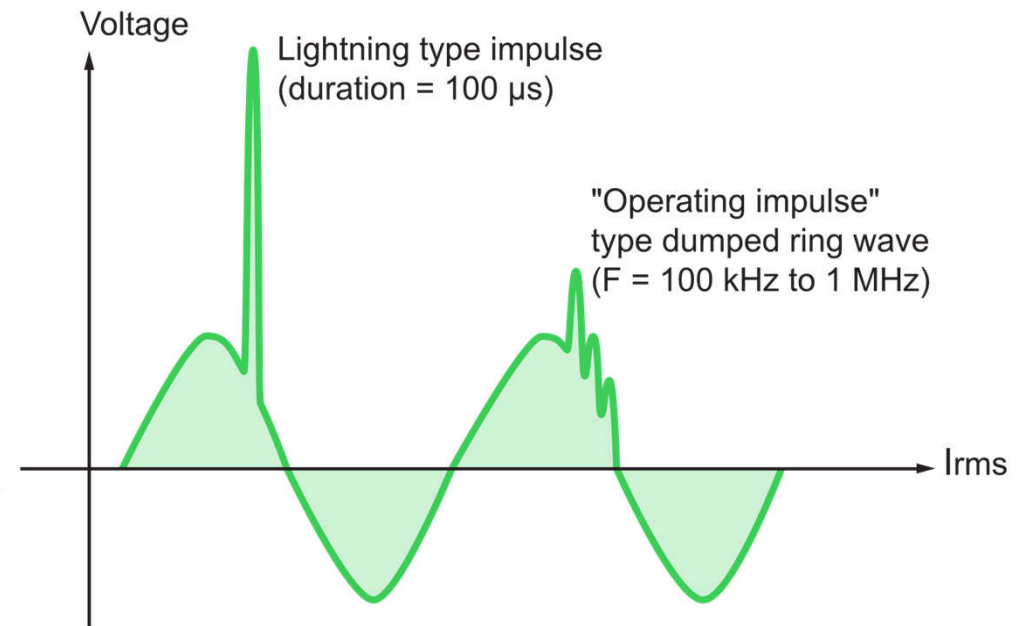
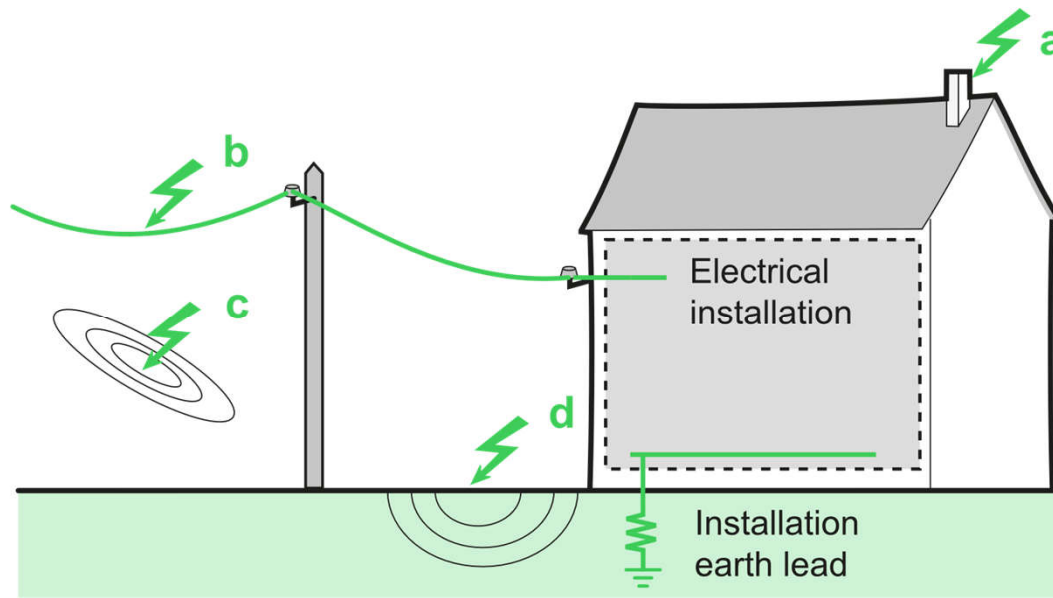


# Lightning protection system



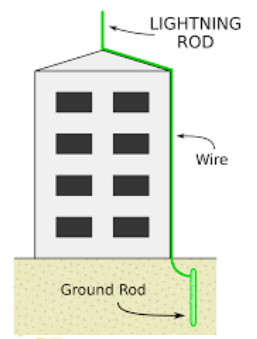
- CoP for the Electricity (Wring) Regulations
  - Code 26I Lightning Protection Installation
- Related standards\*
  - IEC/BS EN 62305, AS/NZS 1768, NFPA 780
  - IEC/BS EN 62305
    - Part 1: General principles
    - Part 2: Risk management
    - Part 3: Physical damages to structures & life hazard
    - Part 4: Electrical & electronic systems within structures

# Lightning effects on electrical installations



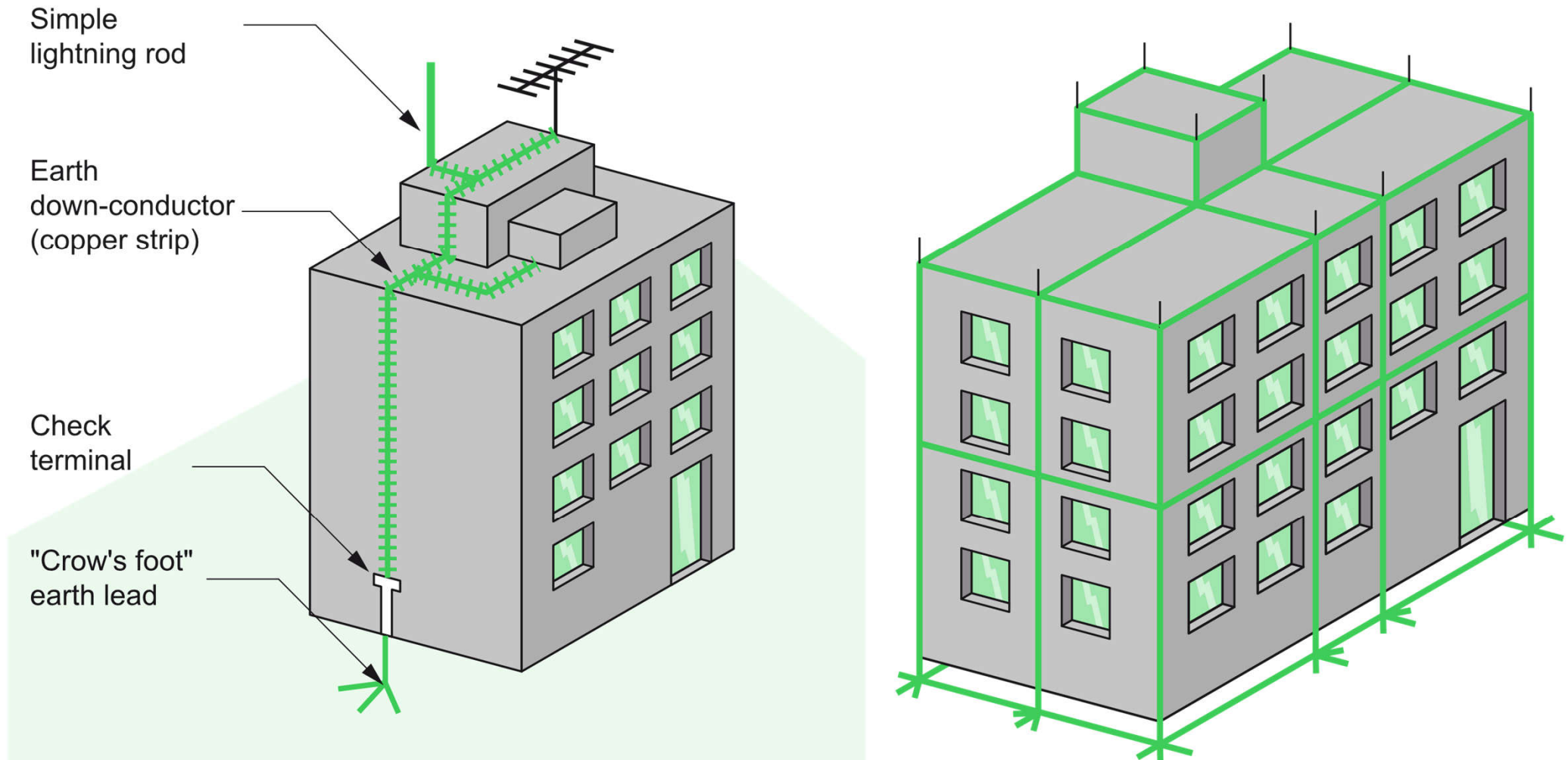


# Lightning protection system

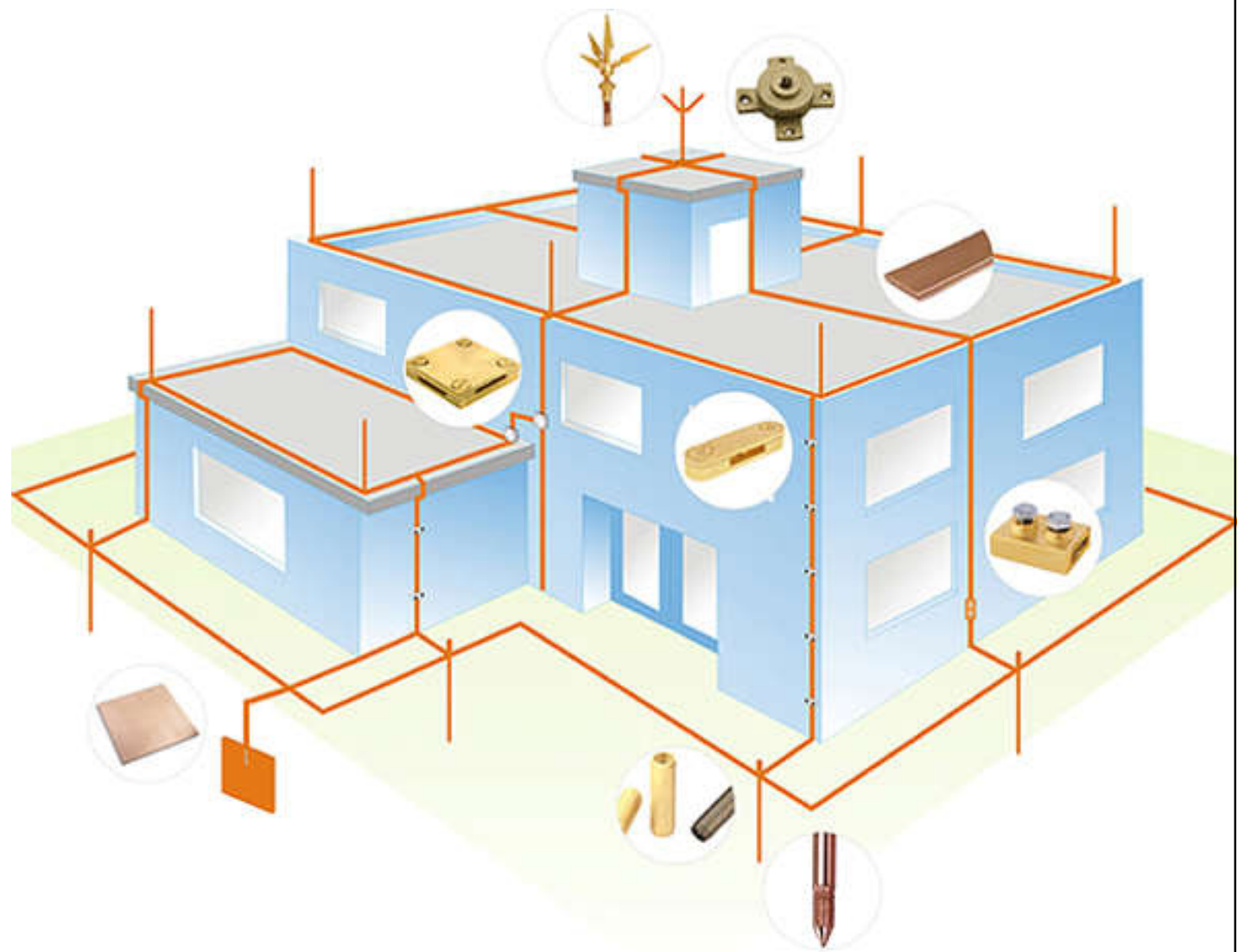
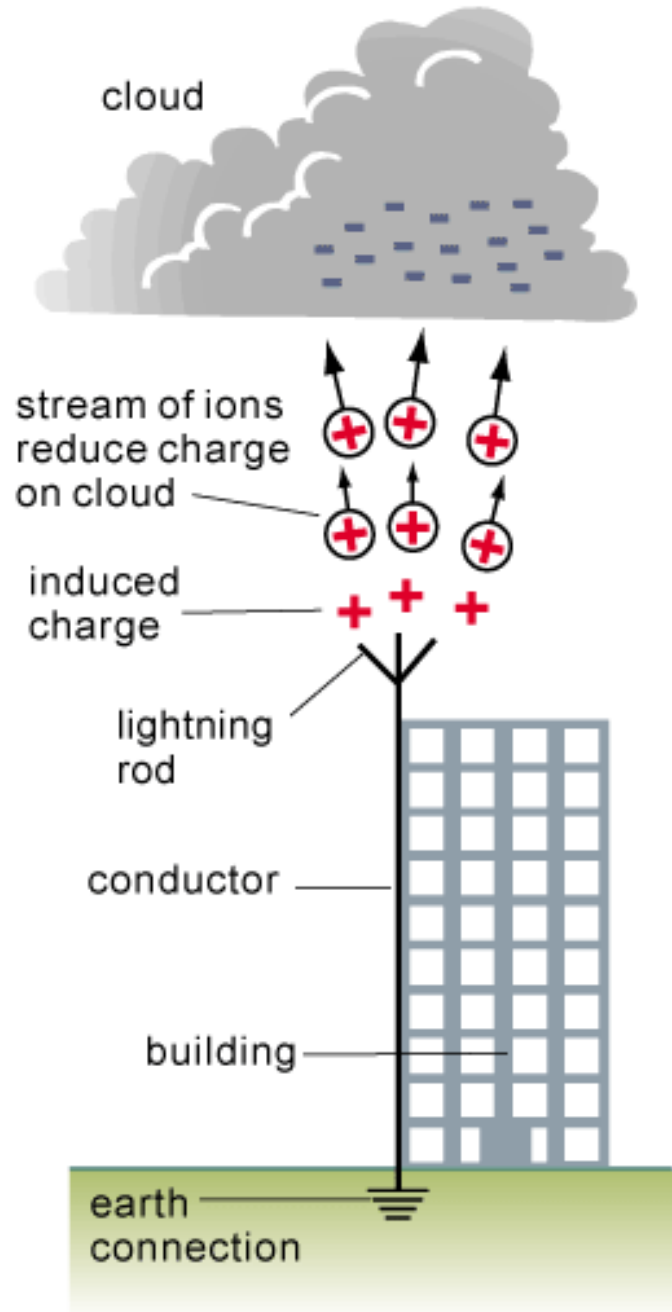


- Basic principles
  - Protect structures against direct lightning strokes
    - Capture the lightning current & channel it to earth via the most direct path
  - Protect electrical installations against direct & indirect lightning strokes
    - Perform equipotential bonding of the installation, supplemented by Surge Protection Devices (SPDs) or spark gaps (e.g., antenna mast spark gap)
    - Minimize induced & indirect effects by installing SPDs and/or filters

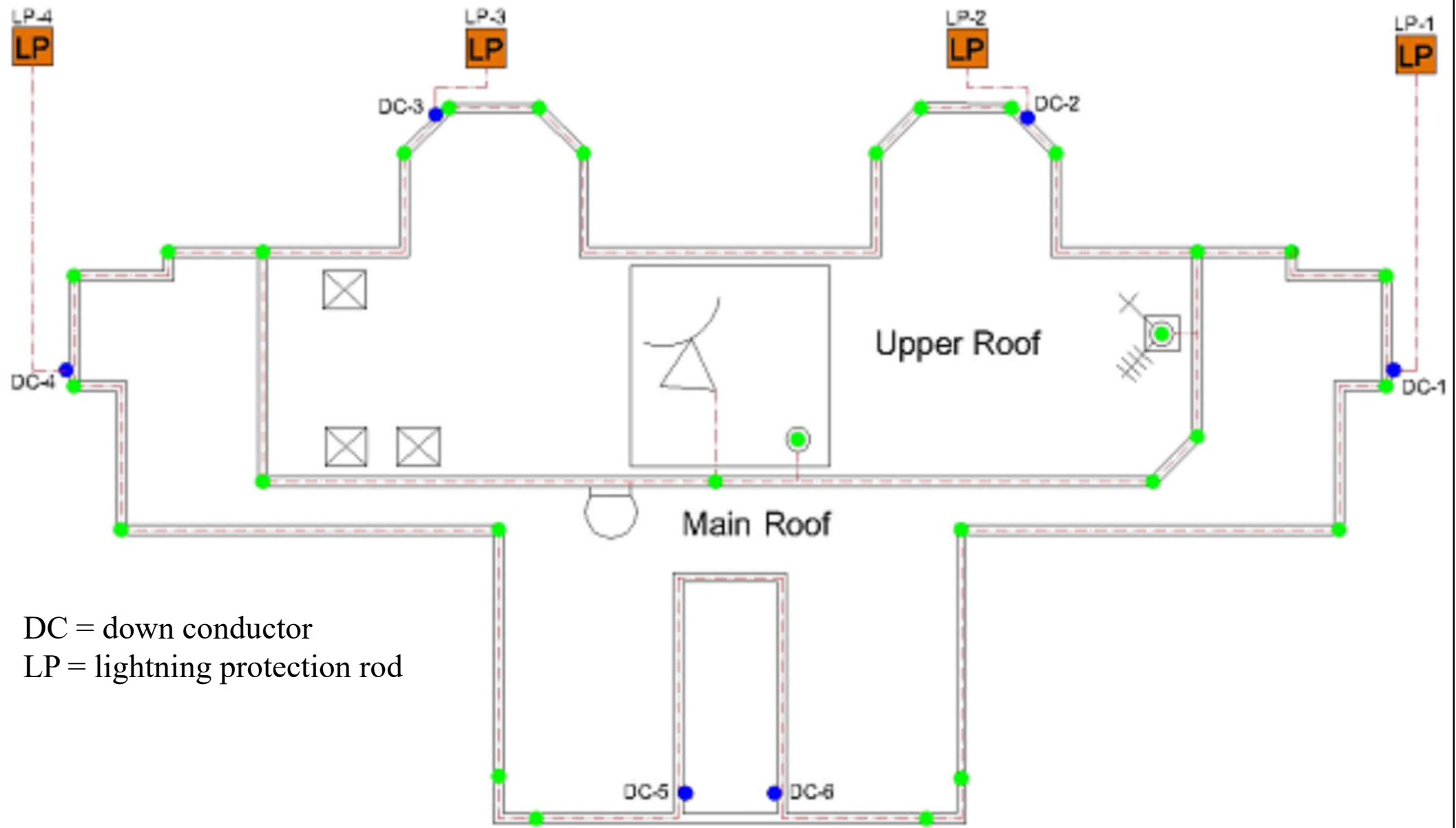
# Lightning rod & lightning conductor with meshed cage (Faraday cage)



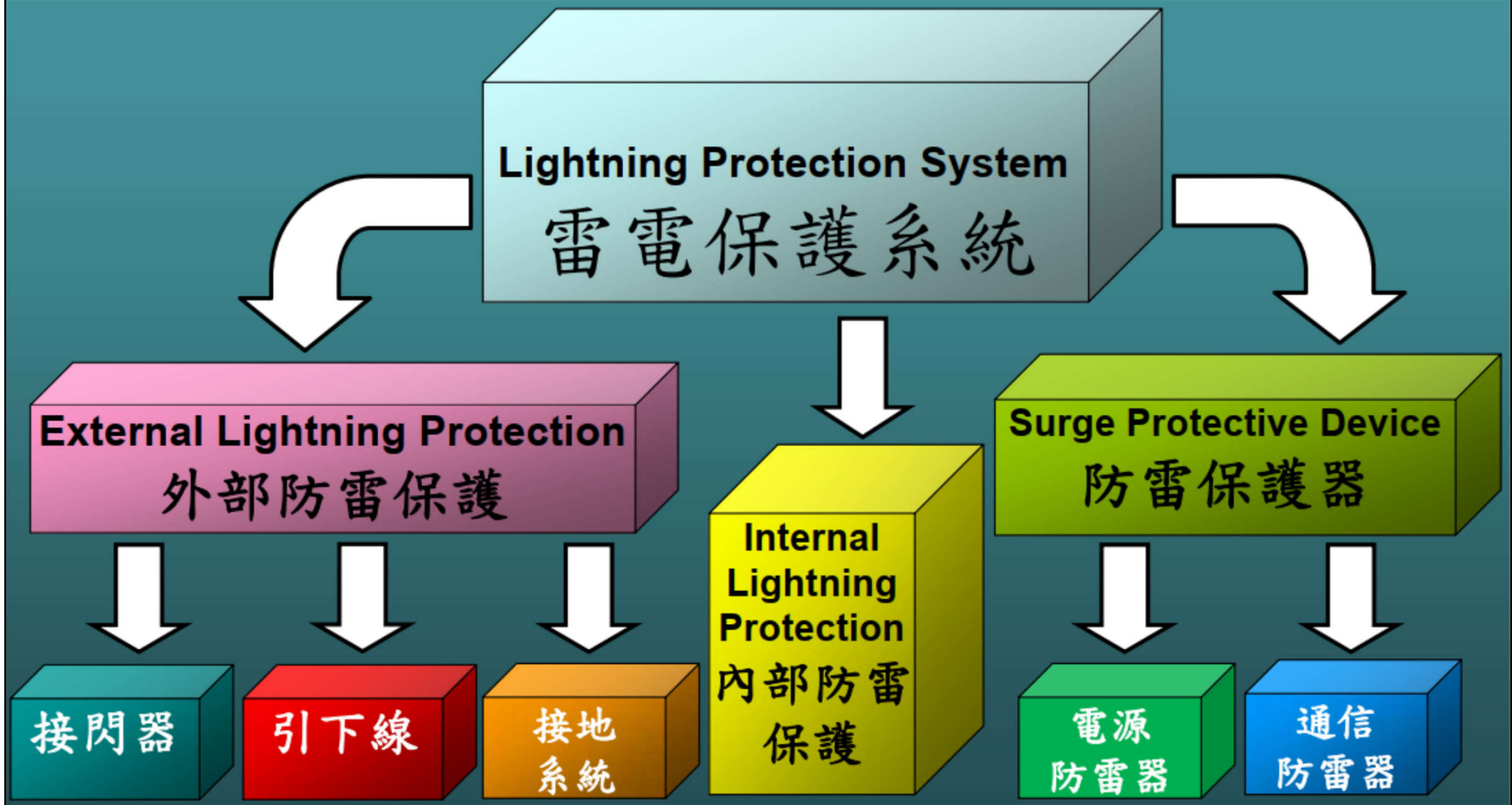
# Basic principle & components of lightning protection system



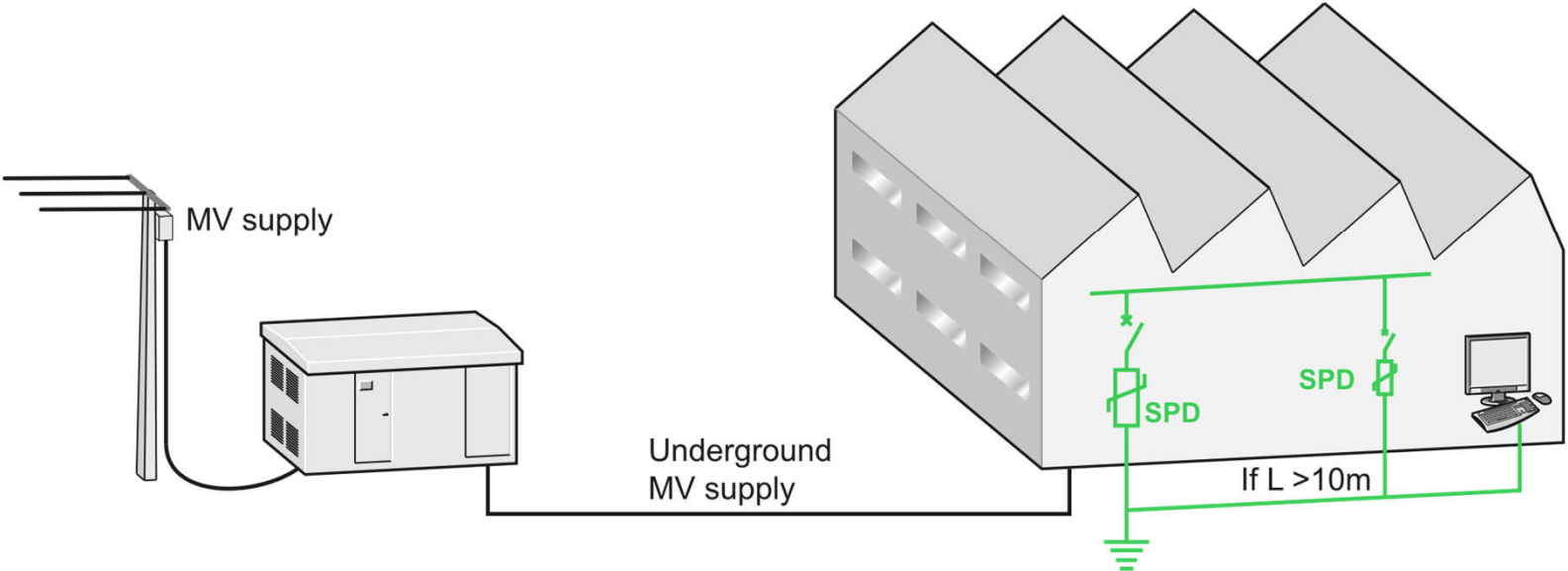
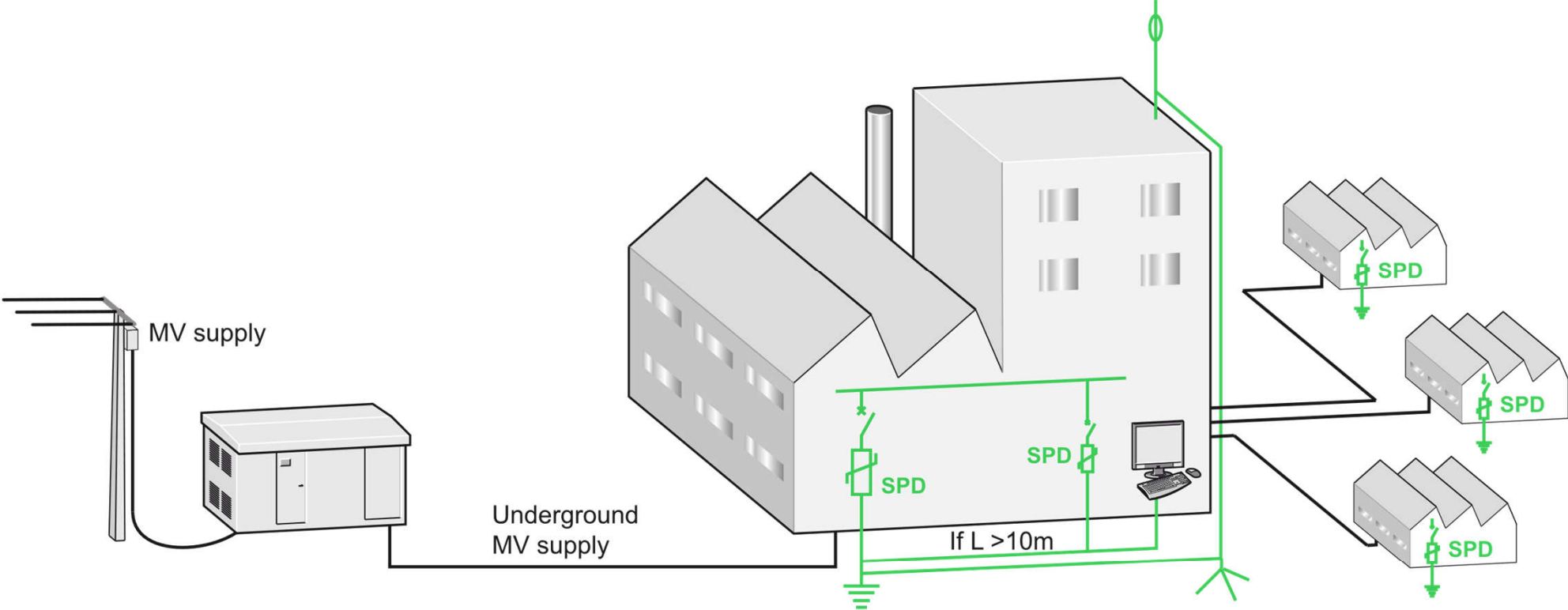
# Example of lightning protection for a high-rise building



# Comprehensive design of lightning protection system

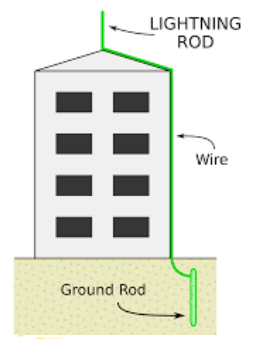


# Example of protection of a large-scale electrical installation



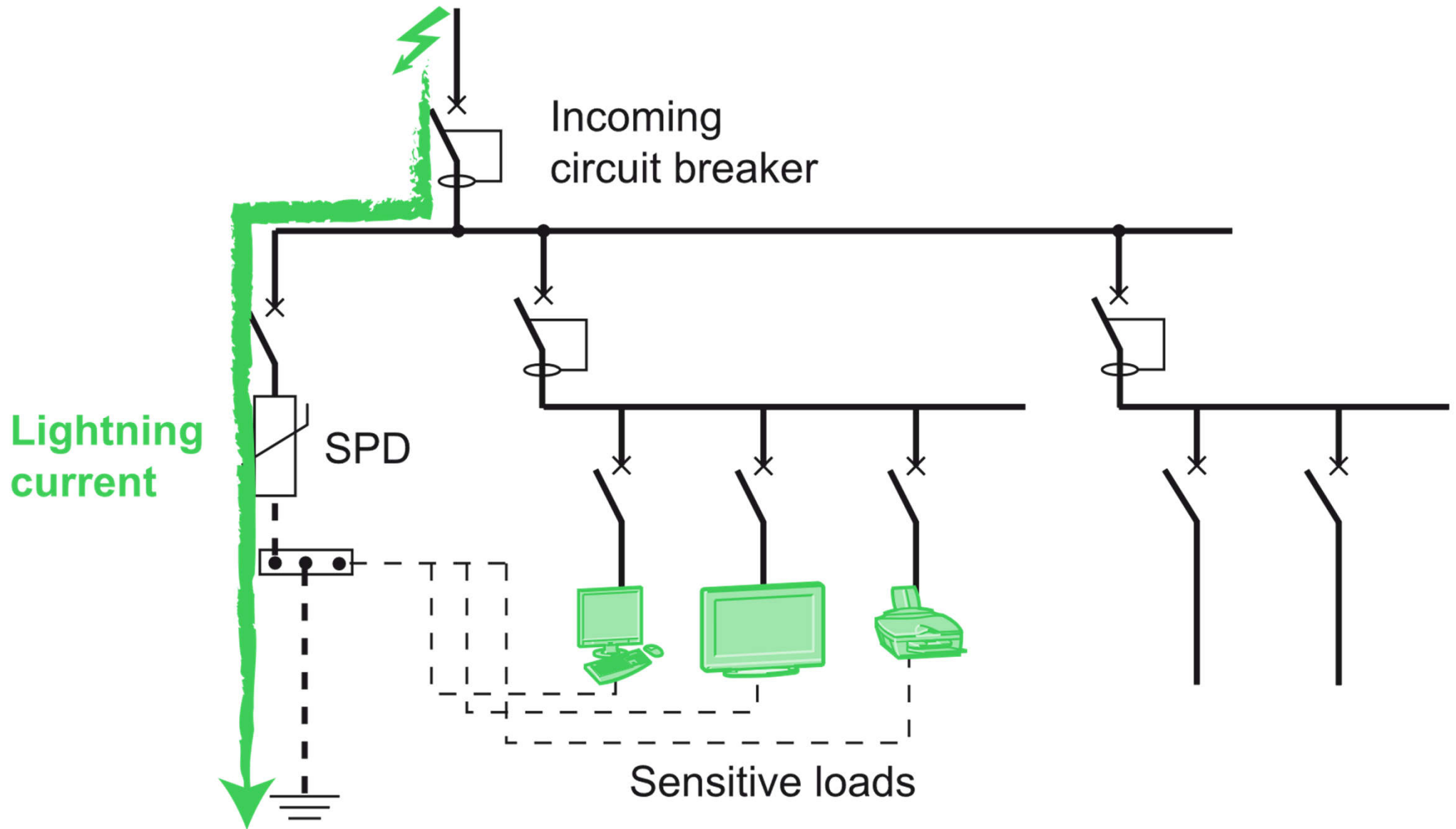
[Source: [https://www.electrical-installation.org/enwiki/Lightning\\_protection - Electrical installation protection system](https://www.electrical-installation.org/enwiki/Lightning_protection_-_Electrical_installation_protection_system)]

# Lightning protection system



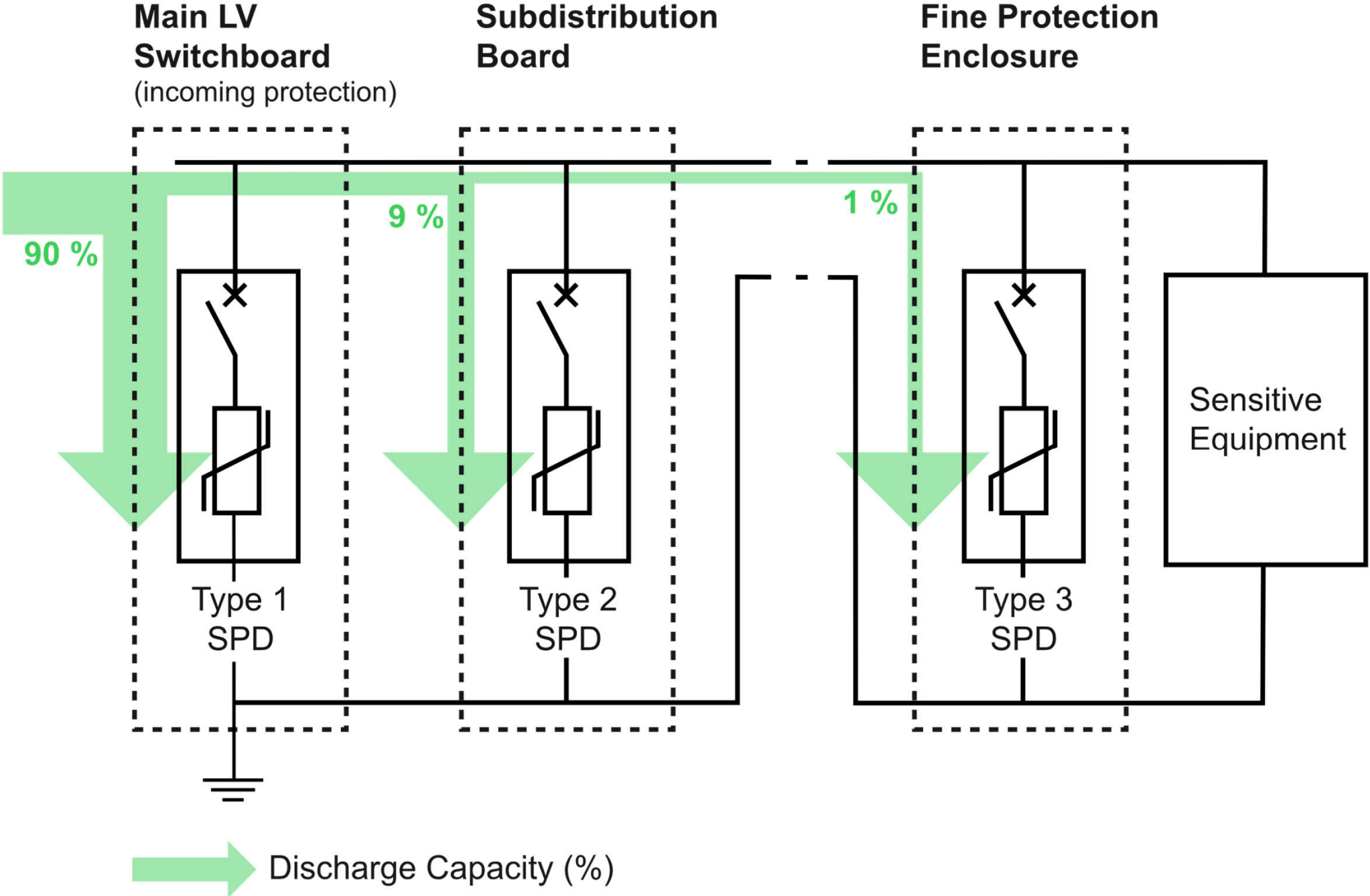
- Surge protective device (SPD) 電湧保護器
  - To protect electrical devices from surge events by limiting transient voltages & diverting surge currents
  - For electric power supply networks, telephone networks, and communication & automatic control buses
- Three types of SPD:
  - Type 1: in the specific case/area of the building
  - Type 2: main protection system for all low voltage electrical installations (in each electrical switchboard)
  - Type 3: supplement to Type 2 SPD & in the vicinity of sensitive loads

# Principle of surge protective device (SPD)



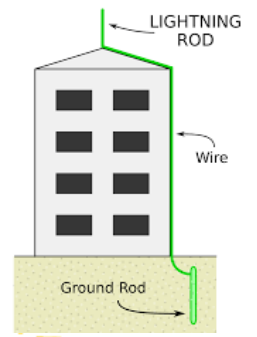


# Protection distributed levels of surge protective device (SPD)



[Source: [https://www.electrical-installation.org/enwiki/Elements\\_of\\_the\\_protection\\_system](https://www.electrical-installation.org/enwiki/Elements_of_the_protection_system)]

# Lightning protection system



- Test report/certificate
  - 1. Inspection items
    - Lightning rod base & air termination network
    - Down conductor system
    - Earth termination system
    - Lightning strike counters
    - Circuit lightning protection
      - Lightning current arresters
  - 2. Testing items
  - 3. Report & results



# Best Practices for Operation & Maintenance Service

## Best Practices for Operation and Maintenance Service of ELECTRICAL INSTALLATIONS



機電工程署  
EMSD



## Best Practices for Operation and Maintenance Service of LIFT AND ESCALATOR INSTALLATIONS



機電工程署  
EMSD



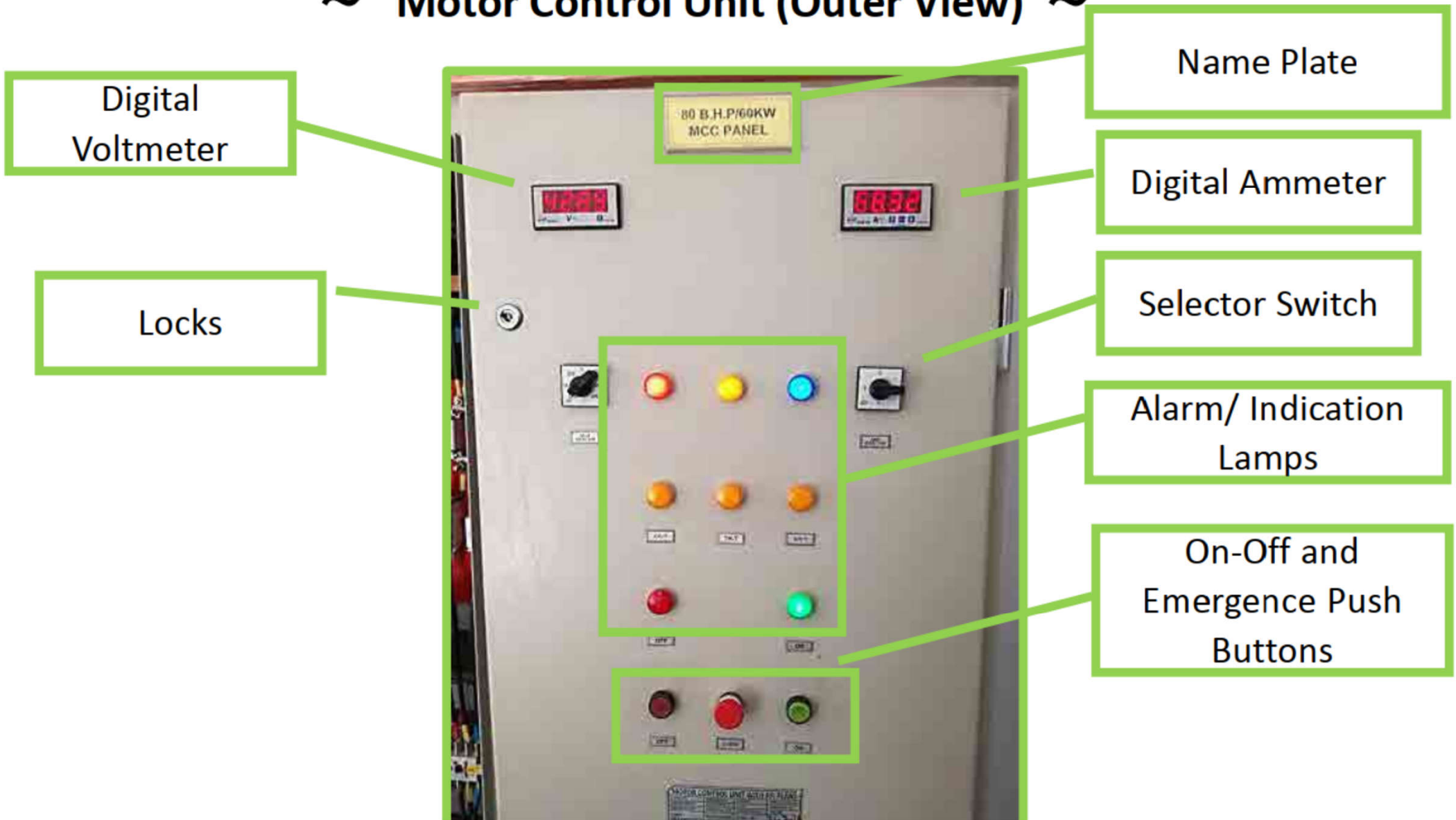
# Operation & maintenance



- Documentation (or asset information) 文檔
  - For all major items of electrical installations
- Operation procedures 操作程序
  - Standardised checklists
  - Safety guidelines & training
- Emergency preparedness 應急準備
  - Planning & response, regular review & training
- Preventative maintenance 預防性維護
  - Planned maintenance activities, check & testing

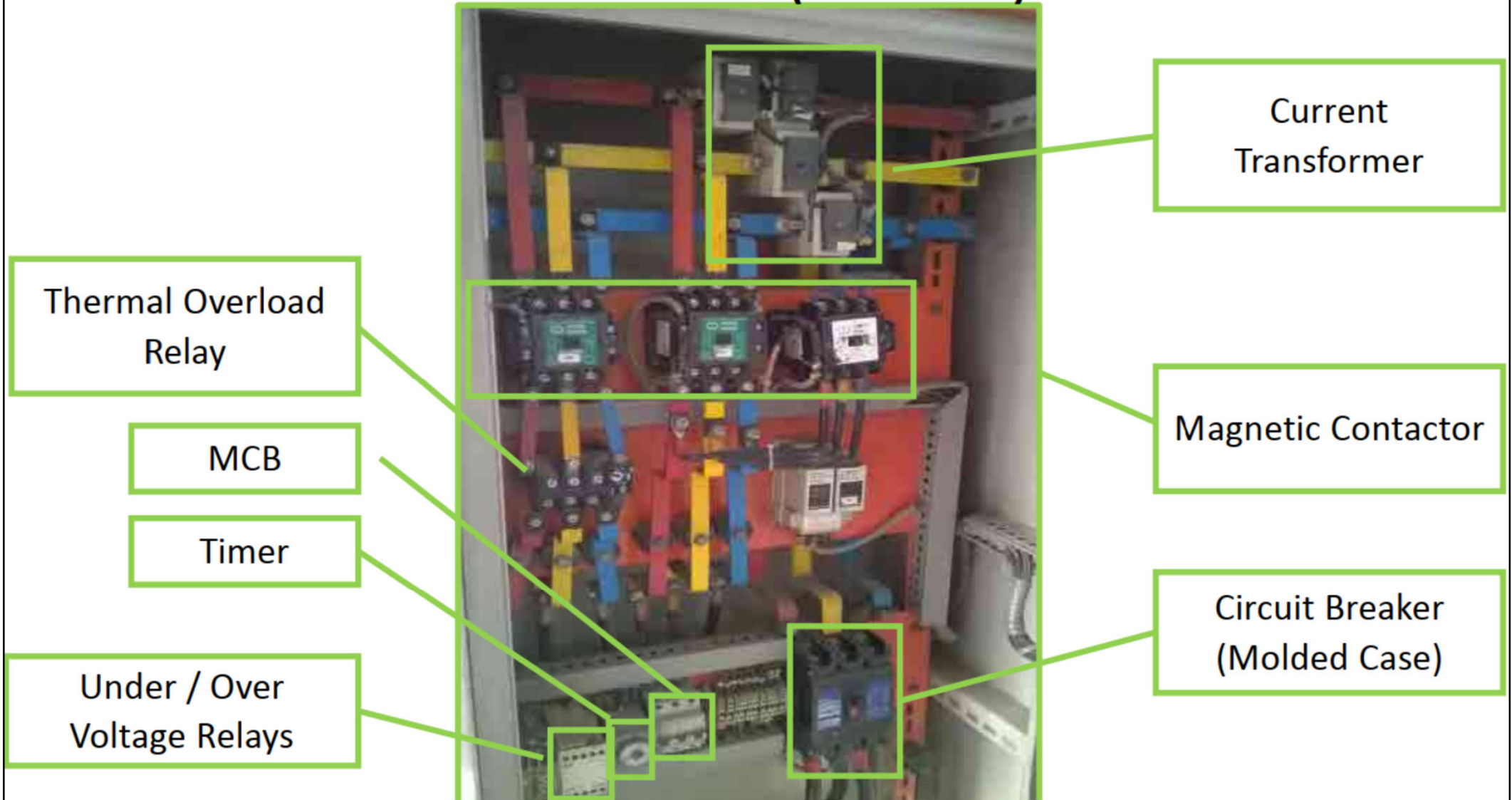
# Components of electrical control panel (outer view)

## ~ Motor Control Unit (Outer View) ~



# Components of electrical control panel (inner view)

## ~ Motor Control Unit (Inner View) ~



# Operation & maintenance



- Typical maintenance & repair works for electrical installations 典型維護和維修工作
  - Lubrication for mechanical operation parts
  - Fastening of busbar bolts, nuts & connections
  - Cleaning & repair of busbar & connections
  - Repair contacts for damaged air circuit breakers
  - Replace/repair of damaged/faulty devices
  - Inspect & repair faulty control circuits

# Main components for maintenance & inspection (1 of 6)

空氣斷路器



Air Circuit Breaker

熔斷器開關掣



Fuse Switch

開關熔斷器掣



Switch Fuse



# Main components for maintenance & inspection (2 of 6)

隔離器



Disconnecter

模製外殼斷路器



MCCB

微型斷路器



MCB

# Main components for maintenance & inspection (3 of 6)

漏電斷路器



RCD

接觸器



Contactor

電容器



Capacitor

# Main components for maintenance & inspection (4 of 6)

功率因數控制器



Power Factor Controller

保護繼電器



Protection Relay

儀錶



Meters

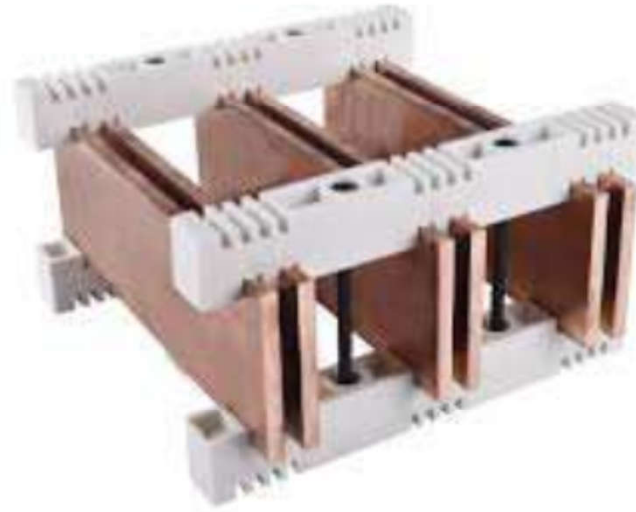
# Main components for maintenance & inspection (5 of 6)

電流互感器



Current Transformer

匯流排及絕緣夾



Busbar & Support

電池



Battery

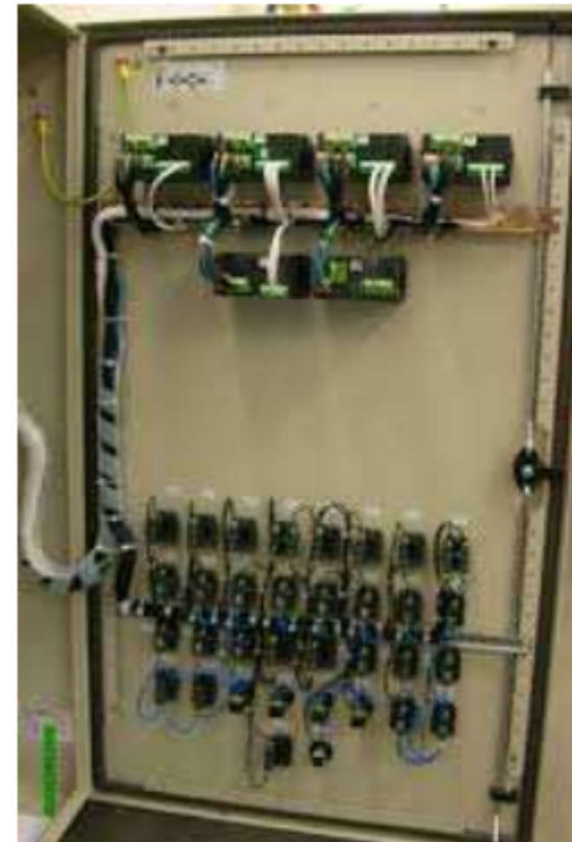
# Main components for maintenance & inspection (6 of 6)

直流充電機



Battery Charger

控制線路及配件



Control Wiring & Components

# Operation & maintenance



- Corrective maintenance 修復性維修
  - Breakdowns of critical plant & equipment
- Maintenance record management 維修記錄管理
  - O&M manuals, documents & records
  - Filing system & statutory compliance
- Spare parts management 備件管理
  - Spare part list & inventory control
- Addition, alternation & replacement 添加, 變更及更換
  - Planning & implementation