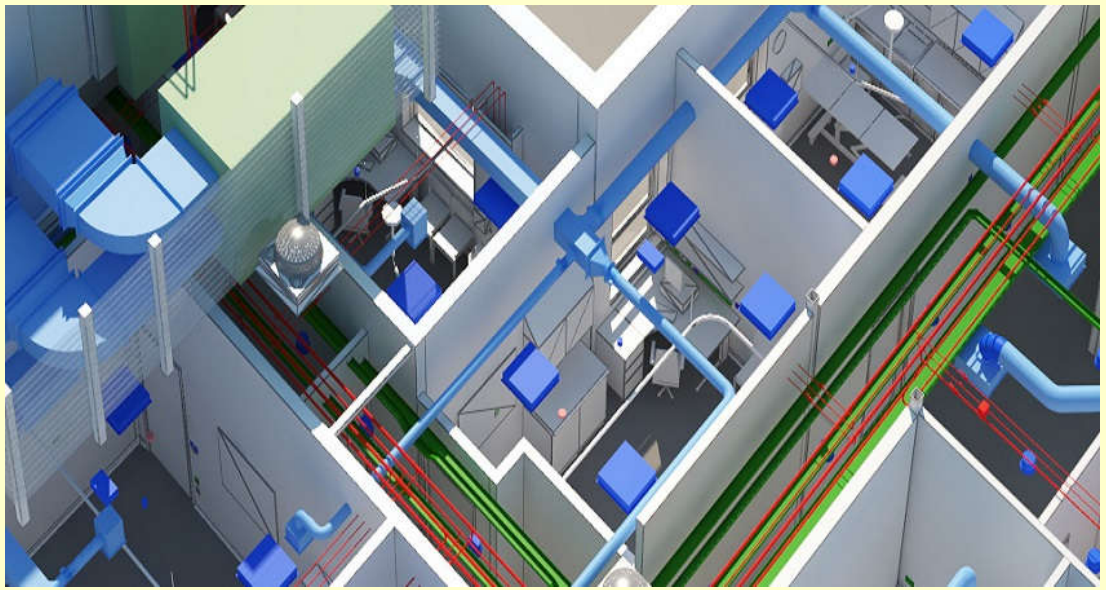


9. Electrical Services Part 2

9.1 Standby power and testing

Ir Dr. Sam C. M. Hui
Department of Mechanical Engineering
The University of Hong Kong
E-mail: cmhui@hku.hk

Jul 2021

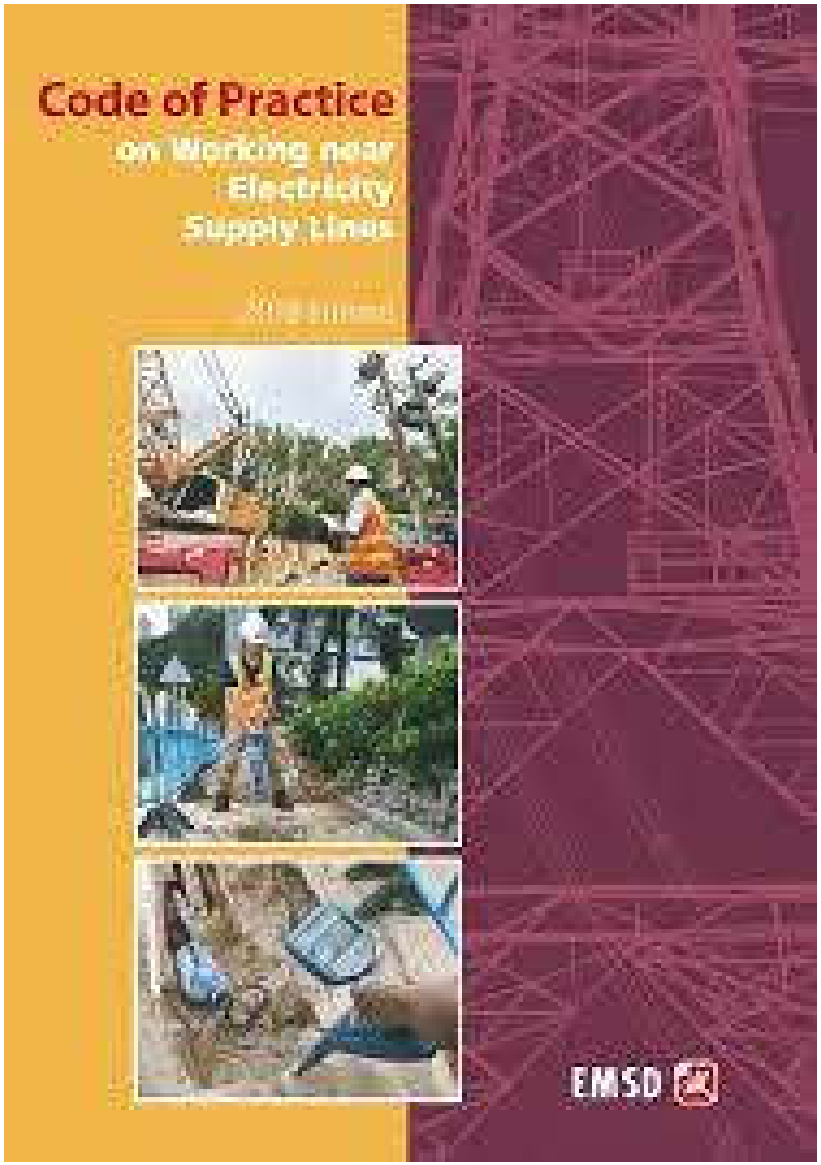
Contents 內容

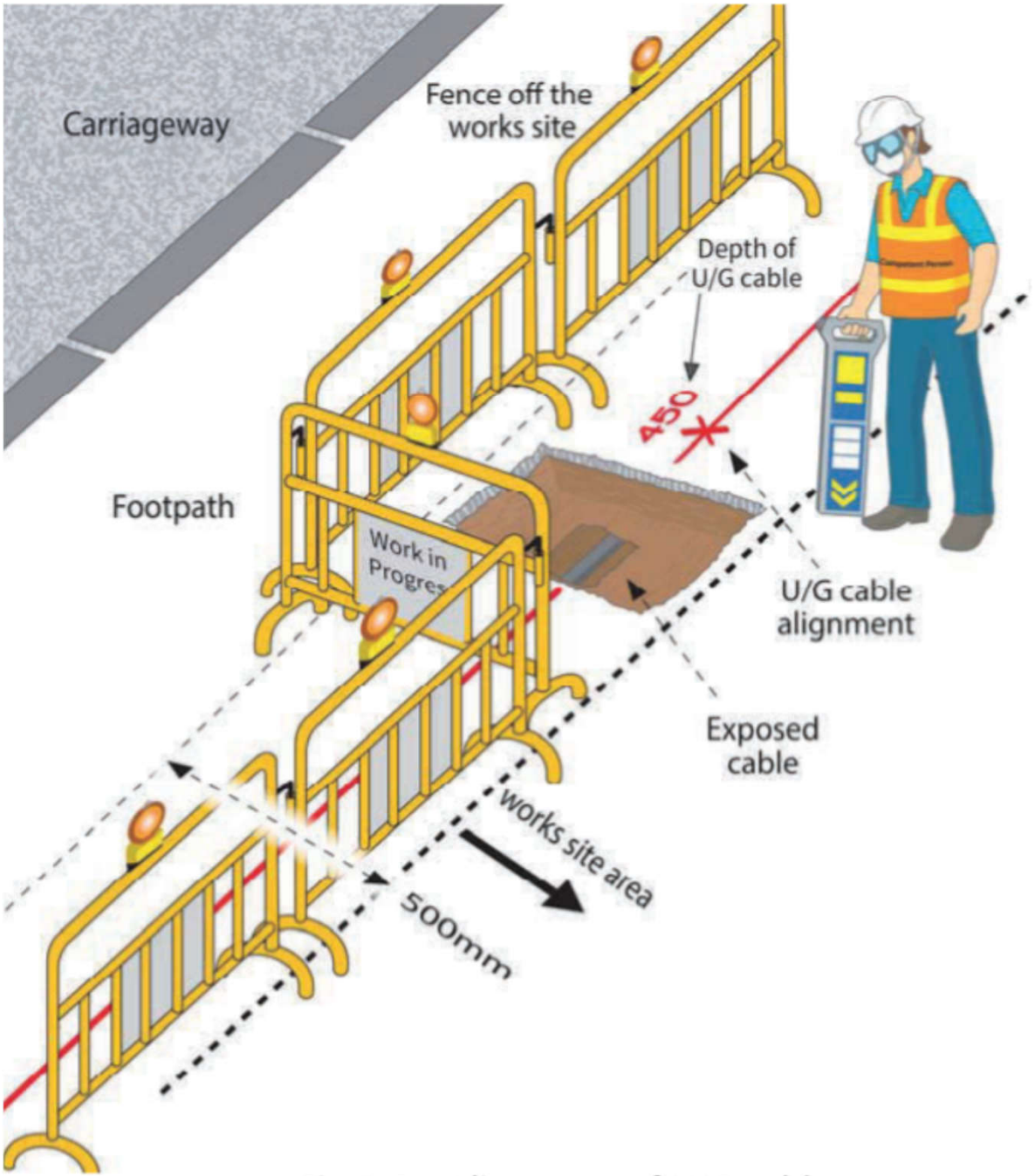
- Power outage & quality 停電和電能質量
- Backup of normal supply 備用電源
- Standby generator 後備發電機
- Testing of electrical systems 電氣系統測試

Power outage & quality

- Common causes of power supply interruption
  - Underground cable damage (e.g. excavation work)
  - High voltage (HV) supply cable is faulty/damaged
  - Low voltage (LV) network fault
  - Equipment failures in the customer installations
    - 1. Overload or under-rated equipment
    - 2. Improper connections
    - 3. Deteriorated insulation or faulty switchgear
    - 4. Defective electrical appliances
    - 5. Improper setting of protection devices

Code of Practice on Working near Electricity Supply Lines
有關在供電電纜附近工作的實務守則





[Source: https://www.emsd.gov.hk/filemanager/en/content_443/CoP-WorkingNearElectricitySupplyLines2018.pdf]

Locating underground electricity cable 確定地下電纜所在

[Source: https://eld.emsd.gov.hk/eic/tc/guideline-for-trade/]

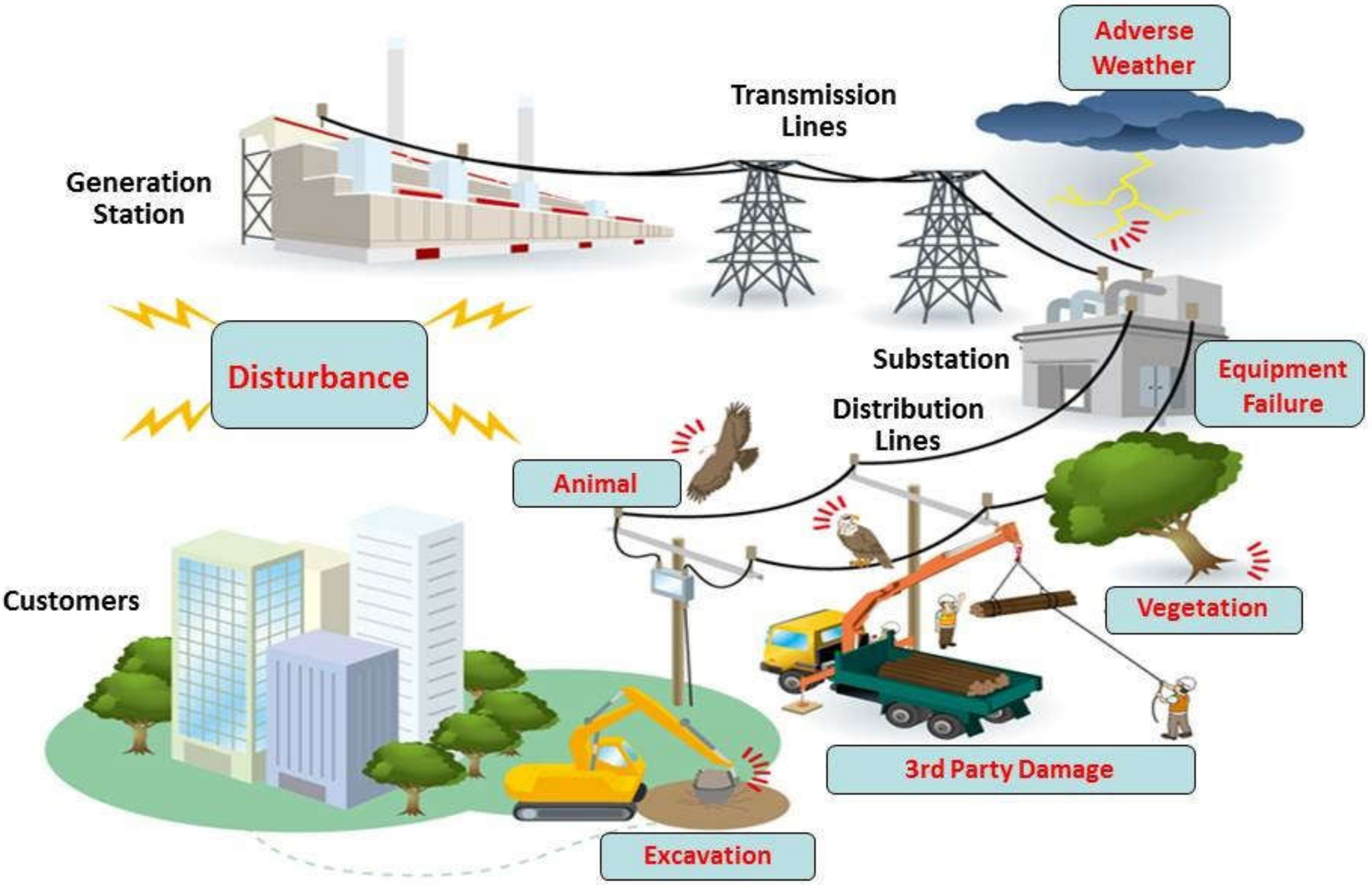
Power outage & quality

- Tips for handling power outage 供電中斷
  - If only your own electricity is off, check whether the main switch or circuit breaker has tripped or if the fuse has blown
  - If other people in your area are also affected, check whether the building's/estate's main switch has tripped or supply from the power company has been interrupted
  - If supply from the power company is off, contact the power company for assistance

Power outage & quality

- Power quality of electricity supply 電能質量
  - Voltage drips (momentary) 電壓驟降
    - Origins: faults in transmission power, excessive starting current of large motor or fault current
    - Can cause nuisance tripping of motor or HVAC system
    - Mitigation measures:
      - Motor circuit design consideration
      - Install voltage dip ride-through devices (e.g. for HVAC systems, lifts & escalators)
      - Protect high-pressure discharge lamps with higher voltage dip ride-through capability
      - Undervoltage protective & power conditioning devices

Causes of voltage dip 電壓驟降的成因

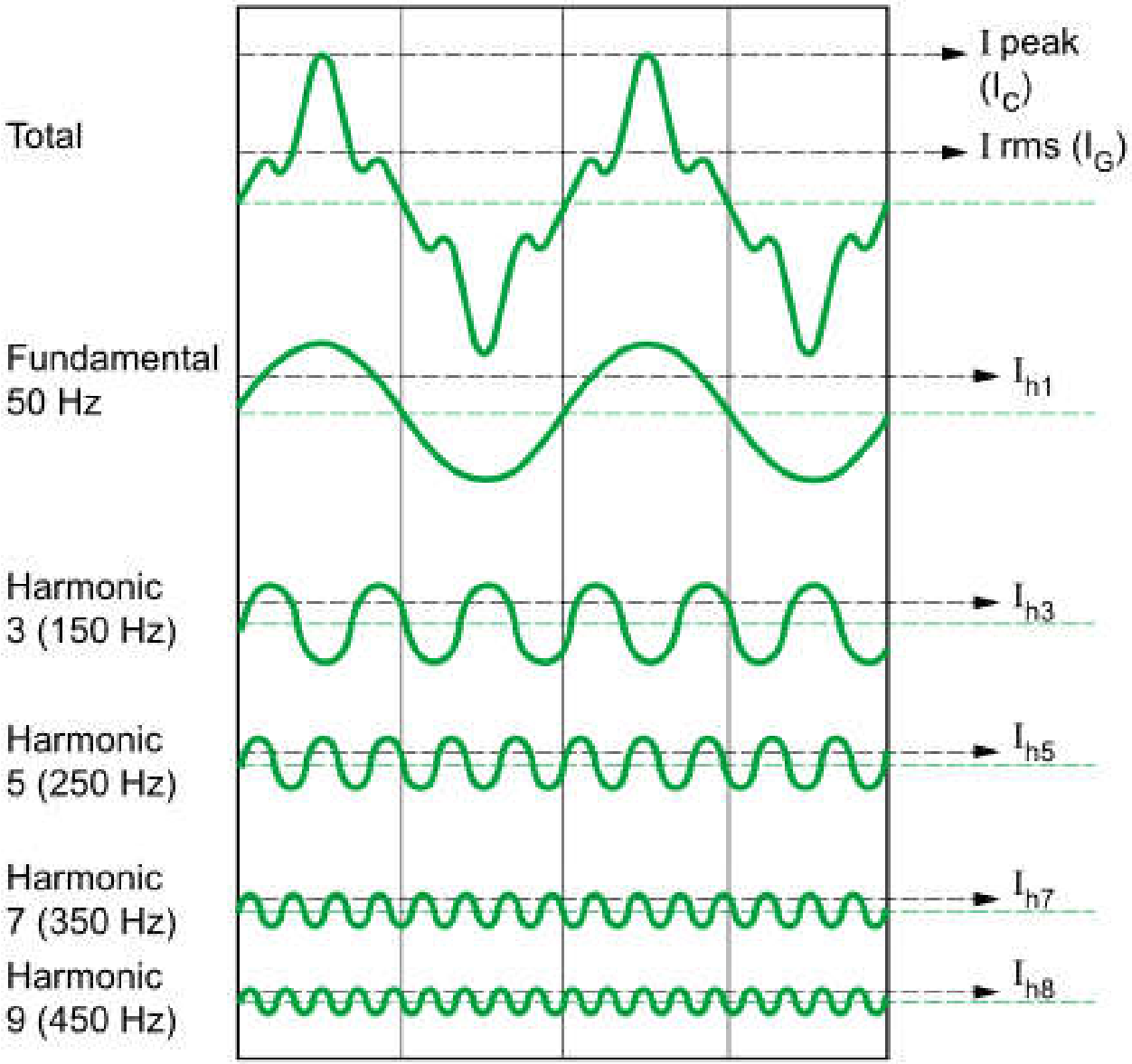


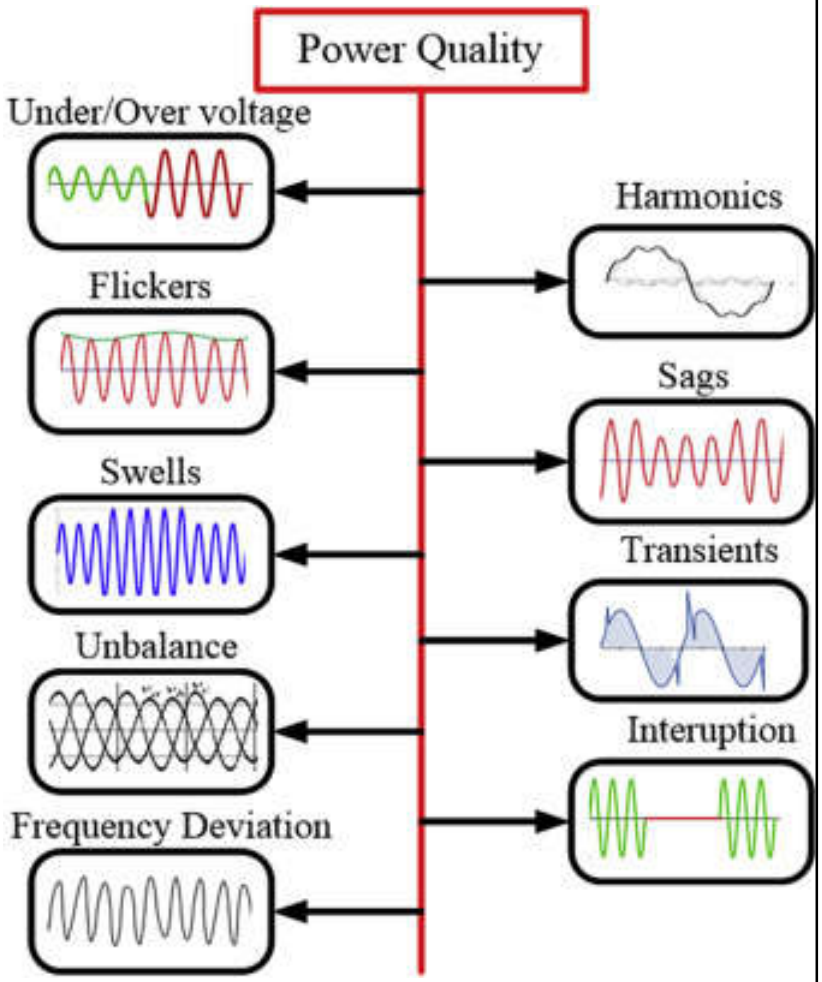
[Source: https://www.clp.com.hk/en/customer-service/electricity-knowledge/voltage-dip]

Power outage & quality

- Power quality of electricity supply (cont'd)
  - Harmonics (by non-linear loads) 諧波
    - Possible impacts:
      - Overheating of motors/transformers & capacitors
      - De-rating of electrical wiring & devices
      - Decreased motor performance
      - Improper operation of protection devices
      - Telecommunications interference
      - Improper operation of sensitive electronic devices
    - Mitigation measures:
      - Handling non-linear loads
      - Apply harmonics filters

Harmonics and power quality issues





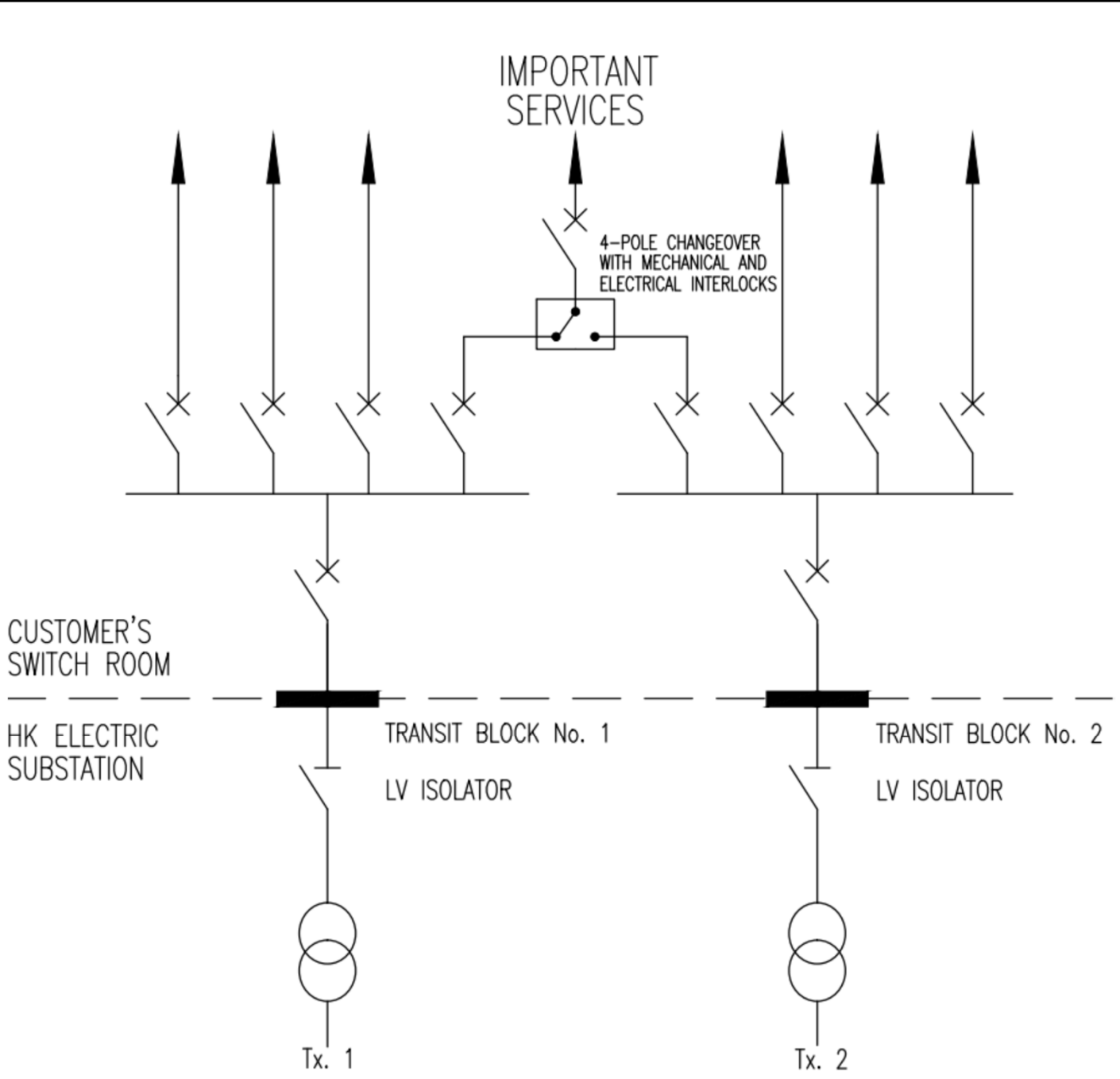
$$THD = \frac{\sqrt{\left(I_2^{\,2} + I_3^{\,2} + \ldots + I_n^{\,2}\right)}}{I_1}$$

THD = total harmonic distortion 總諧波失真

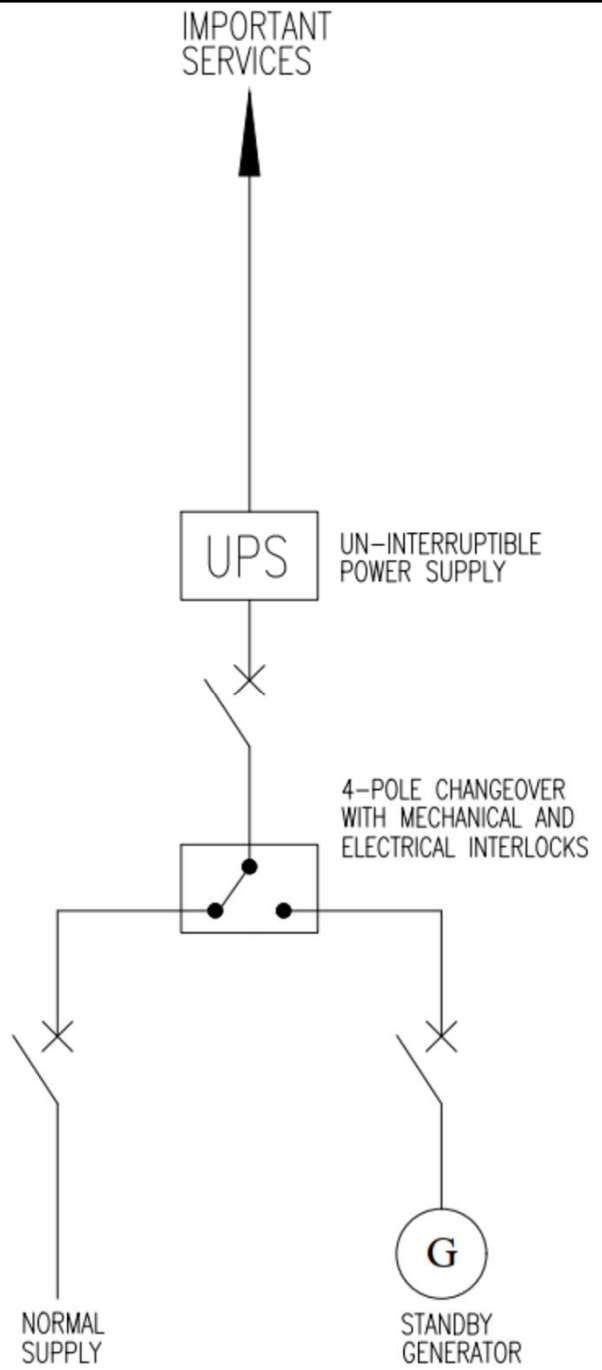
[Source: https://cauk.tv/articles/power-quality-issues-harmonics/]

Power outage & quality

- To enhance the reliability of power supply
  - Interconnection between different transformers/ 11-kV/22-kV sources on customer side
    - Dual feed/dual source 兩個供電 / 兩個電源
  - Un-interruptible power supply (UPS), standby generator & other automatic backup supply (ABS) for important services
  - Regular inspection & preventive maintenance of customer installations
  - The discrimination of protective devices



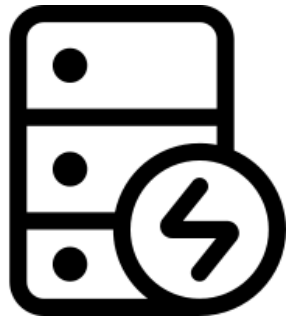
Interconnection between transformers at load side



UPS plus standby generator for important services

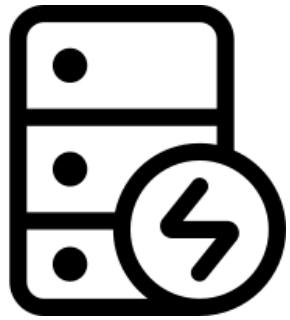
[Source: HEC, 2017. *Guide to Connection of Supply*, 6th Edition, Hongkong Electric Co., Ltd. (HEC), Hong Kong.]

Backup of normal supply



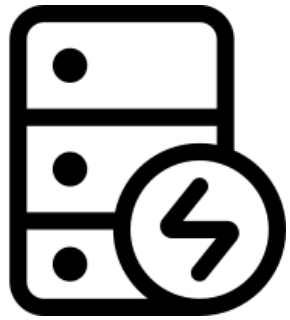
- Need for standby power supply
  - To satisfy statutory fire services requirements
  - To maintain essential control & safety systems
- Possible ways of alternative sources to backup the normal supply during power failure:
  - 1) Duplicate mains supply (dual feed)
  - 2) Battery supply
  - 3) Uninterruptible power supply (UPS)
  - 4) Standby/emergency generating supply

Backup of normal supply



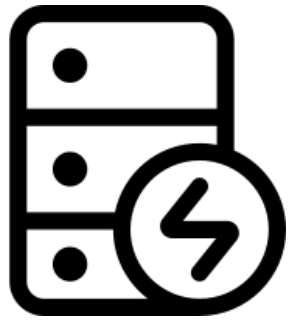
- 1) Duplicate mains supply 重複主電源
  - A consumer may require a duplicate supply for added security and the supply company may agree to install an extra mains supply cable
  - This additional cable will operate in fully in parallel with the original supply or just as standby. The additional cable may be fed from a different point of the supply network of the supply company (dual feed)

Backup of normal supply



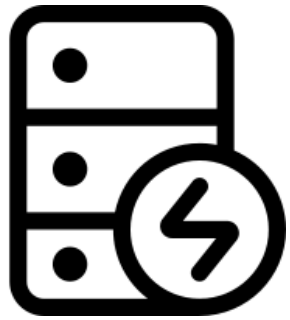
- 2) Battery supply 電池供電
  - A battery can be used to provide standby power
  - Even for generators, batteries usually provide the starting power, and are often used to provide power to essential loads for the initial period, while the generator is running up to speed
  - When a large amount of rechargeable batteries are used in the installation, usually a separate battery room is provided
  - Batteries are also commonly used in those stand-alone emergency lighting systems

Backup of normal supply



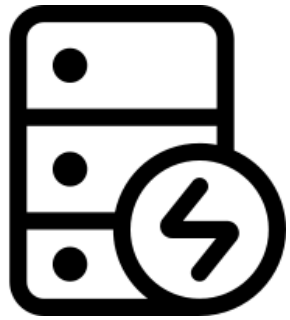
- 3) Uninterruptible power supply (UPS)
  - For applications where no interruption of supply can be tolerated even for a fraction of a second, an UPS is needed (不間斷電力供應系統)
  - Typical applications are computer systems and information systems
  - UPS has been developed rapidly so that its capacity can up to several hundred of kW
  - Many systems available but they broadly follow the same concept of an AC supply backed to a DC supply and the use of static changeover switch

Backup of normal supply



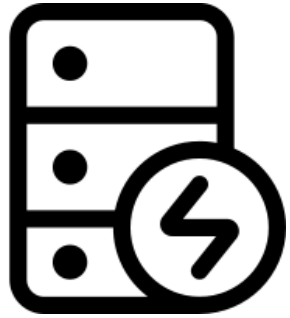
- 4) Standby generating plant 後備發電機
  - Money spent on standby generating plant can be described as a non-productive expenditure of capital. It is therefore in the consumer's interest to keep the capital expenditure to a minimum and also to minimize the amount of fuel that needs to be stored
  - The most commonly used prime mover for standby set is diesel engine. Today it is more usual for them to drive AC generator

Backup of normal supply



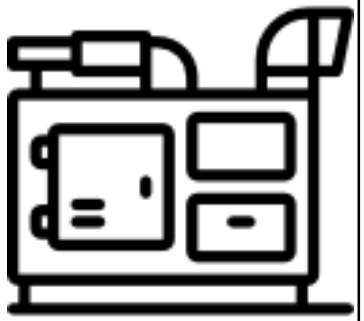
- 4) Standby generating plant (cont'd)
  - Alternative starting techniques are possible, depends on the applications, the requirements and the availability of other means of standby supplies:
    - Started automatically, following the failure of the mains supply, with the generator being run up to speed and switched in immediately
    - Started automatically, following the failure of the mains supply, with the generator being run up to speed, but standby supply is switched in system only when required

Backup of normal supply



- 4) Standby generating plant (cont'd)
  - Started manually, from a push button on a control panel adjacent to the generator
  - Started manually, form a remote push button, say located in the main control room of the building
  - Start manually & mechanically by using a starting handle (only for small portable sets)

Standby generator

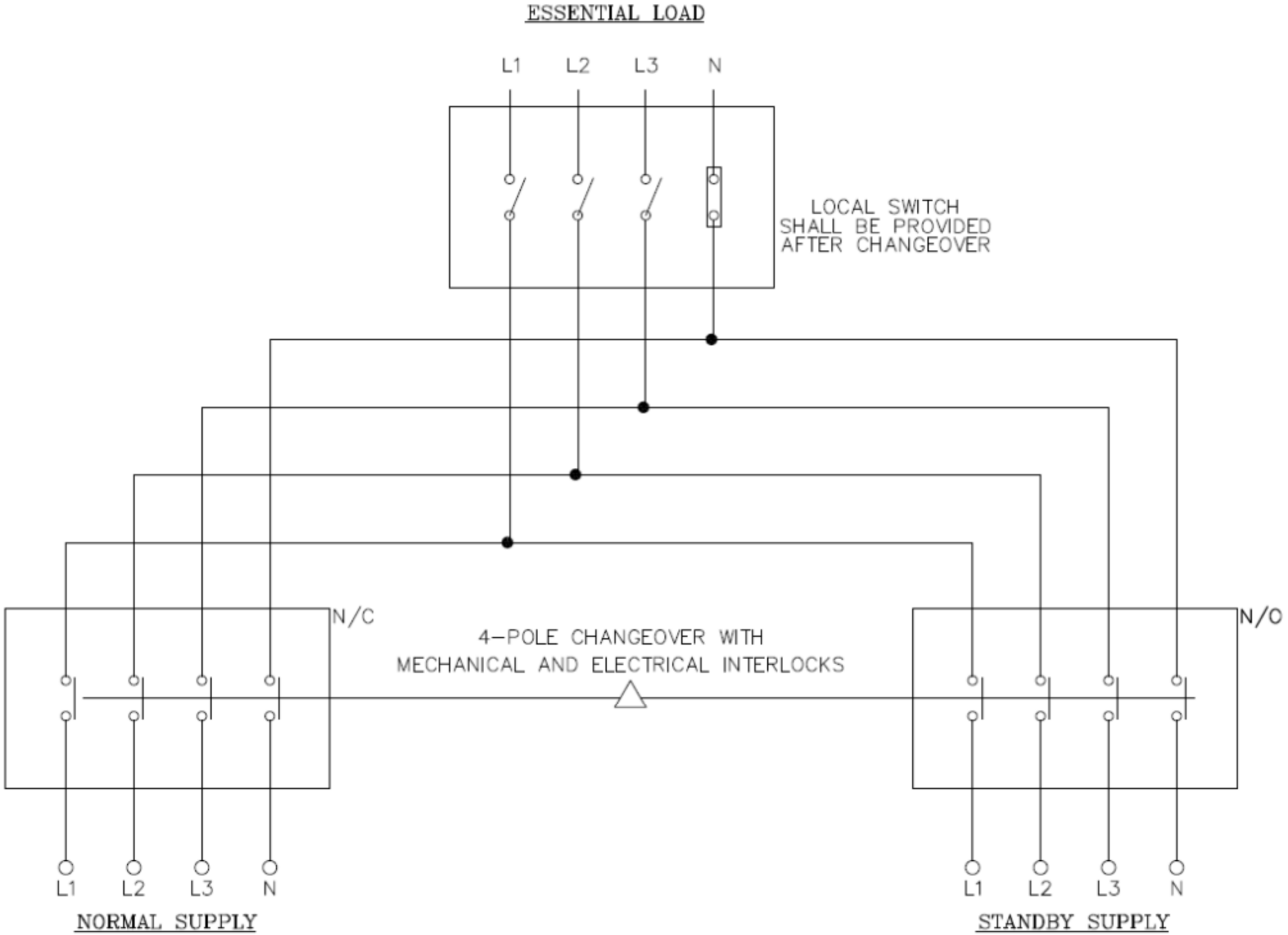


- Sizing of standby generator
  - To determinate the power rating of the “genset”, not only the total essential loading of connected electrical equipment needs to be catered for
    - Since the starting of a larger motor load may give rise to an unacceptable voltage drop, thus causing momentarily dimming of light or the connected motors may cease to run
    - Therefore, the rating of the generator shall cope with the steady state loading condition as well as the starting of these loads

Genset examples

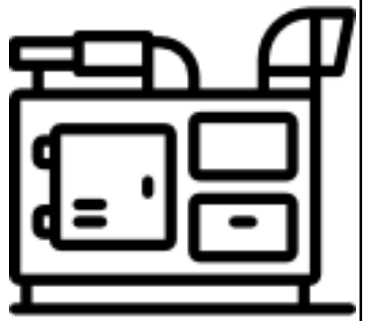
Q: What is this for?

Typical changover arrangement for standby supply



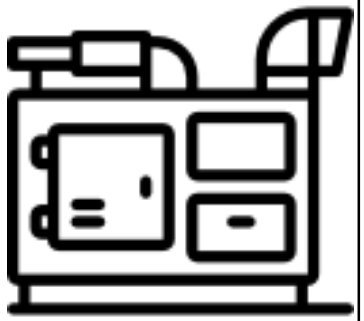
[Source: CLP's Guide to Supply and Metering Arrangement on Customer's Internal Distribution System, Version 9 – 09/18]

Standby generator



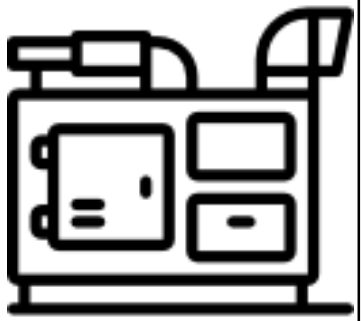
- Major issues on standby generator
  - Fuel supply & cost (e.g. diesel)
  - Availability & fuel storage
  - Noise (noise attenuation & acoustic enclosure)
  - Maintenance & testing
  - Emissions (from exhaust)
  - Space requirements & location
  - Safety (fuel & electrical)

Standby generator



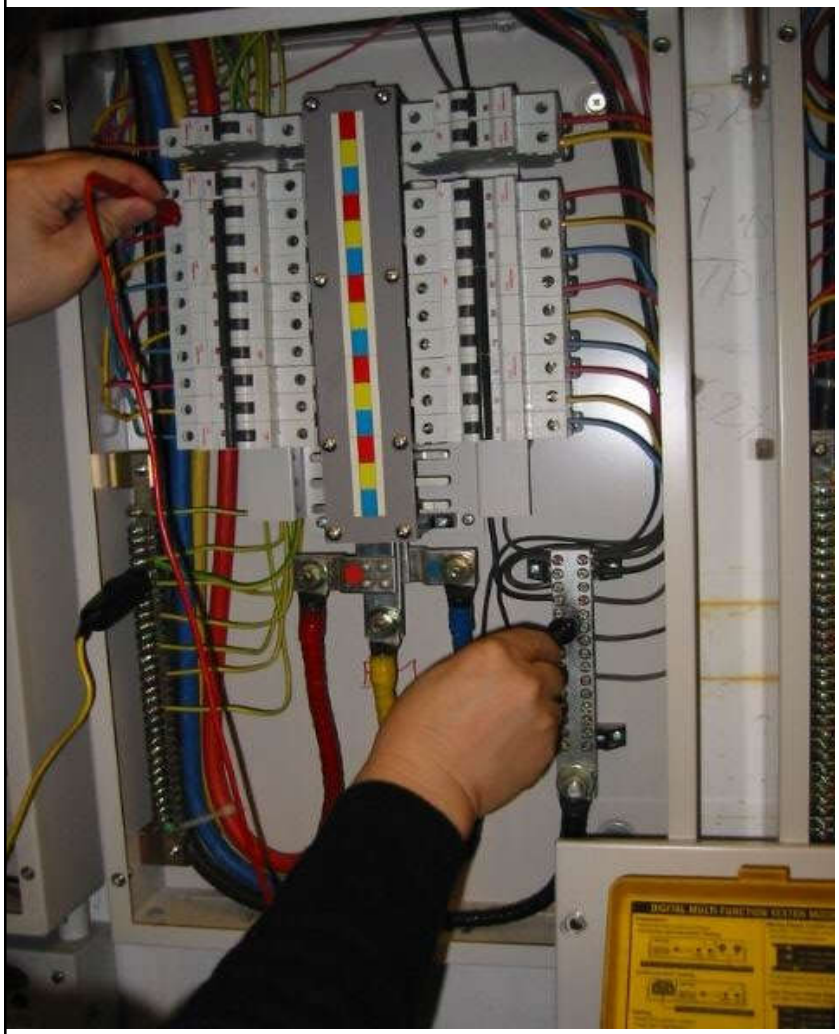
- Location of standby diesel generator
  - It should be located in a well ventilated room with adequate space between machines to allows for easy repair, checking and maintenance
  - It is normally supplied with the engine and alternator on a common base plate but massive concrete foundations are neither necessary nor recommended
  - As a rule the machine should be supported in anti-vibration mounting to reduce the transfer of vibration through the structure of the building

Standby generator



- Requirements of Fire Services Department (FSD)
  - In the CoP for Minimum Fire Service Installation and Equipment, it lists statutory requirements on standby generator, the diesel engine, fuel storage, installation of the genset, engine starting, operation of the genset, maintenance & testing, generator room, service tank room, and also on controls, safety devices & control panel/ cubicle of the genset

Testing of electrical systems and installation



Testing of electrical systems

- First inspection, testing and certification 首次檢查、測試及發出證明書
  - For new work, alternation or addition
    - By a Registered Electrical Worker (REW)
  - Certification on the design
  - Certification on the installation
  - Work completion certificate 完工證明書
    - Before it is energised

Testing of electrical systems

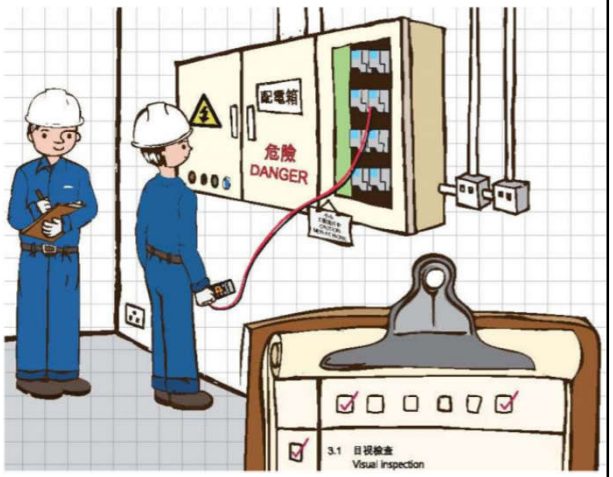
定期檢查、測試及發出證明書

- Periodic inspection, testing and certification
  - Fixed installation requiring annual inspection
    - Place of public entertainment
    - Premises for manufacturing/storing of dangerous goods
    - High voltage installations
  - Fixed installation requiring inspection every 5 yrs.
    - Factories & industrial undertakings > 200 A
    - Any premises > 100 A
    - Hotels, hospitals, schools/universities, etc.
  - Periodic test certificate (Form WR2)

(See also: Periodic Test for Fixed Electrical Installations
http://www.emsd.gov.hk/emsd/eng/pps/electricity_feipt.shtml)

Testing of electrical systems

- Periodic inspection, testing & certification (PITC)
  - 1. Employ Registered Electrical Worker (REW) of appropriate grade
  - 2. Arrange power suspension
  - 3. PITC work for distribution circuit
  - 4. PITC work for low voltage switchboard
  - 5. Record all inspection & testing results
  - 6. Resume power
  - 7. Issue periodic test certificate & testing records
  - 8. Submit to EMSD for endorsement



[Source: https://www.emsd.gov.hk/filemanager/en/content_440/Leaflet_PITC.pdf]

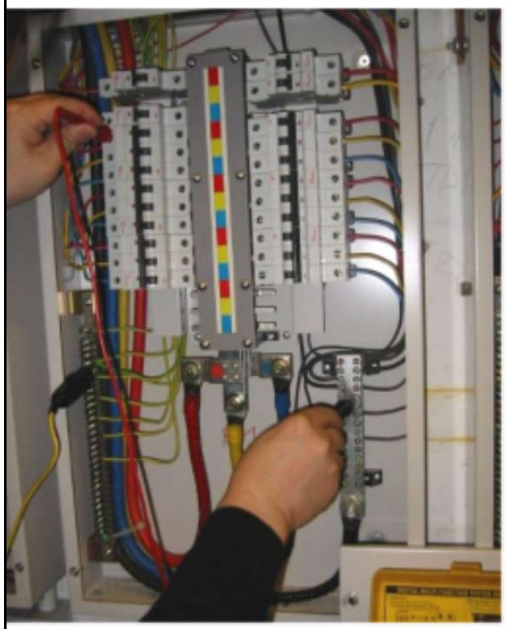
Testing of electrical systems

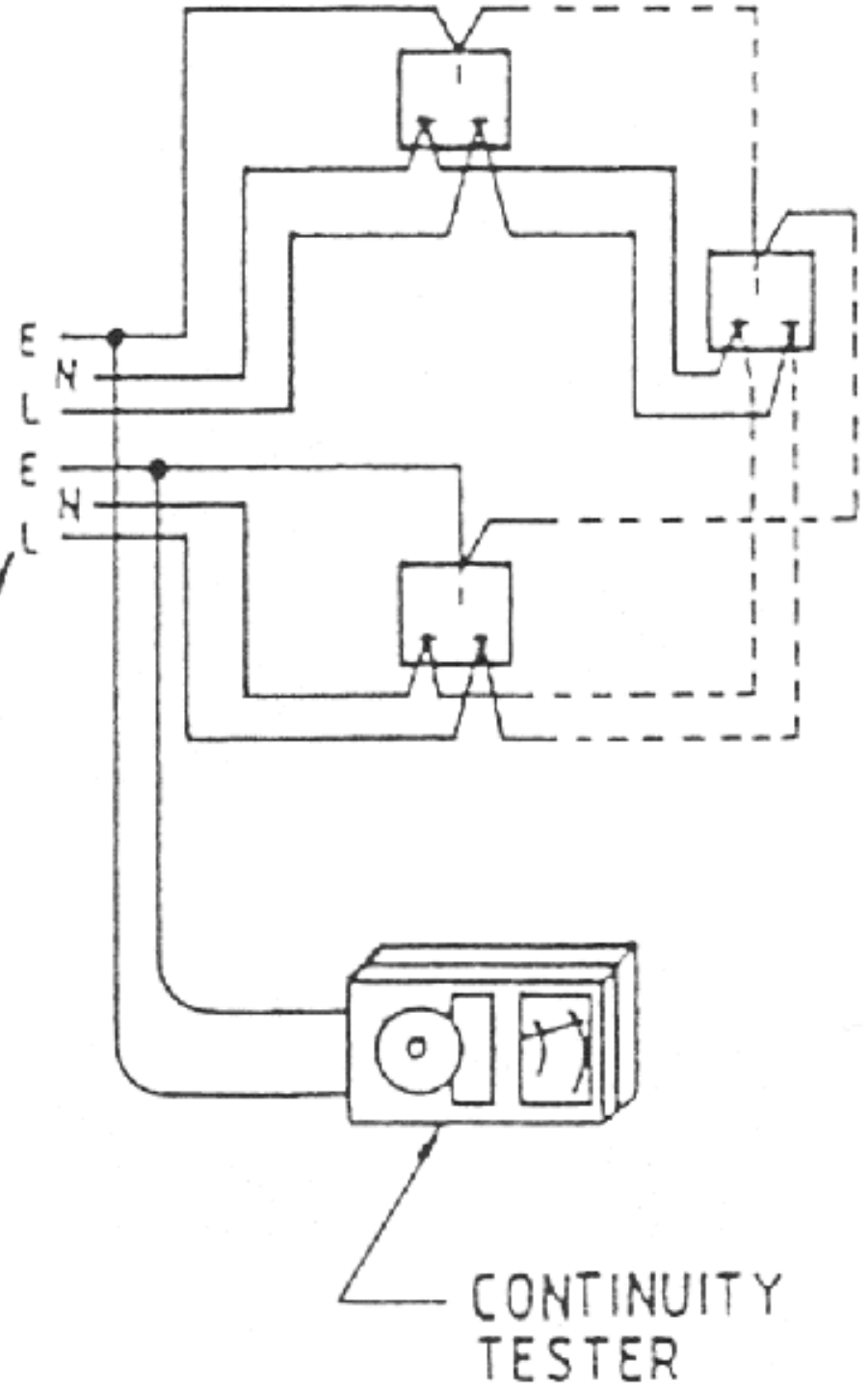
- Inspection of L.V. installations, e.g.
  - Adequacy of working space & access
  - Connection & sizes of conductors
  - Fire protection
  - Protection against electric shock
  - Isolation & switching
  - Overcurrent protective devices
  - Warning notices and labels
  - Diagrams, instructions & other info.

Testing of electrical systems

- Testing procedures (in correct sequence)
  - Continuity of ring final circuit conductors
  - Continuity of protective conductors, including main and supplementary equipotential bonding
  - Earth electrode resistance
  - Insulation resistance
  - Polarity
  - Earth fault loop impedance
  - Functions of all protective devices
  - Functions of all items of equipment

Continuity test of ring final circuit 環形最終電路的電氣連續性測試

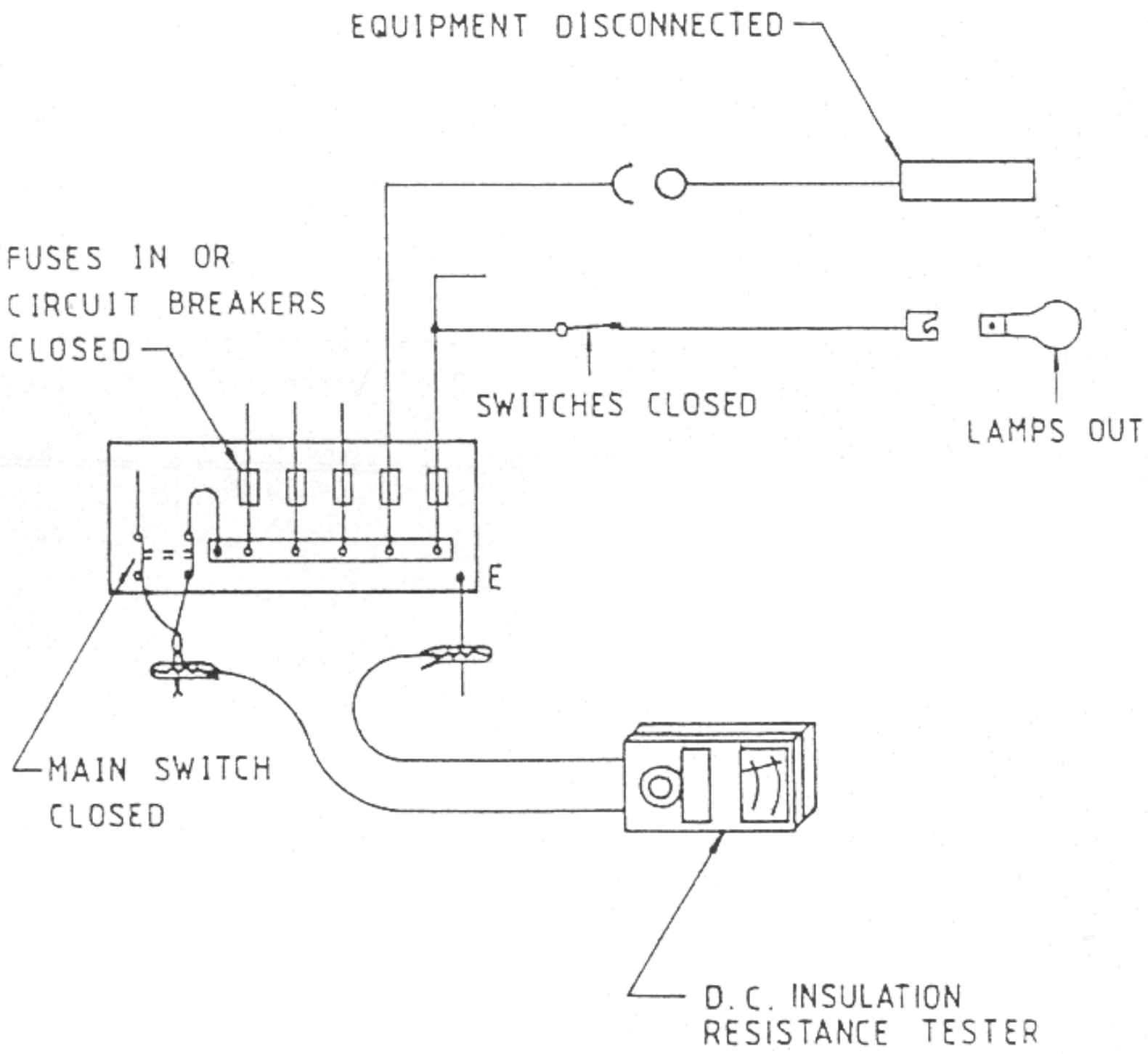




Continuity Testers

Digital Multimeter

Insulation resistance to earth test 絕緣電阻測試



Minimum values of insulation resistance

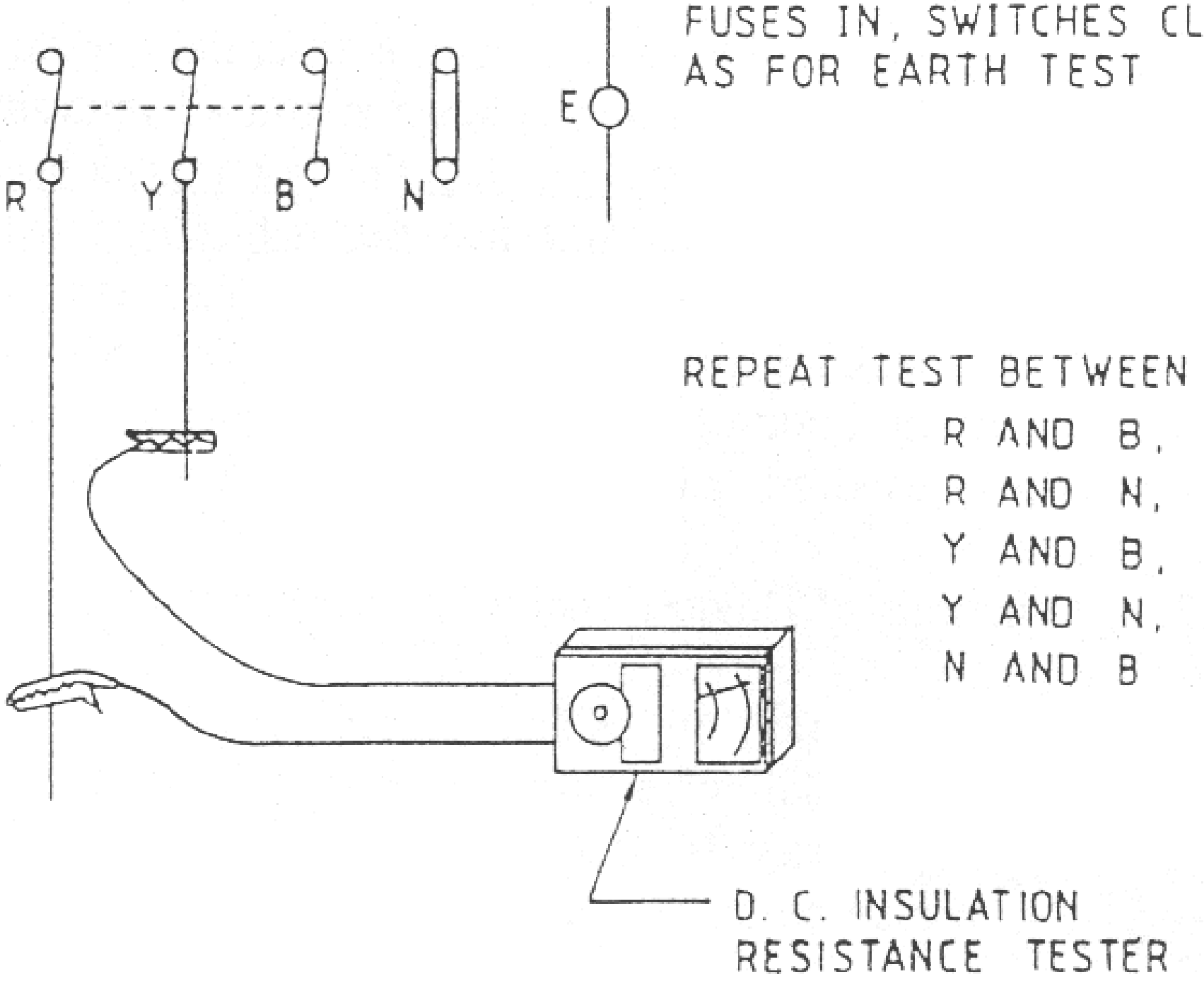
Circuit nominal voltage (Volts)	Test voltage d.c. (Volts)	Minimum insulation resistance (megaohms)
Extra-low voltage *	250	0.25
Up to 500 V	500	0.5
Above 500 V	1,000	1.0

* When the circuit is supplied from a safety isolating transformer or safety extra-low voltage (SELV).

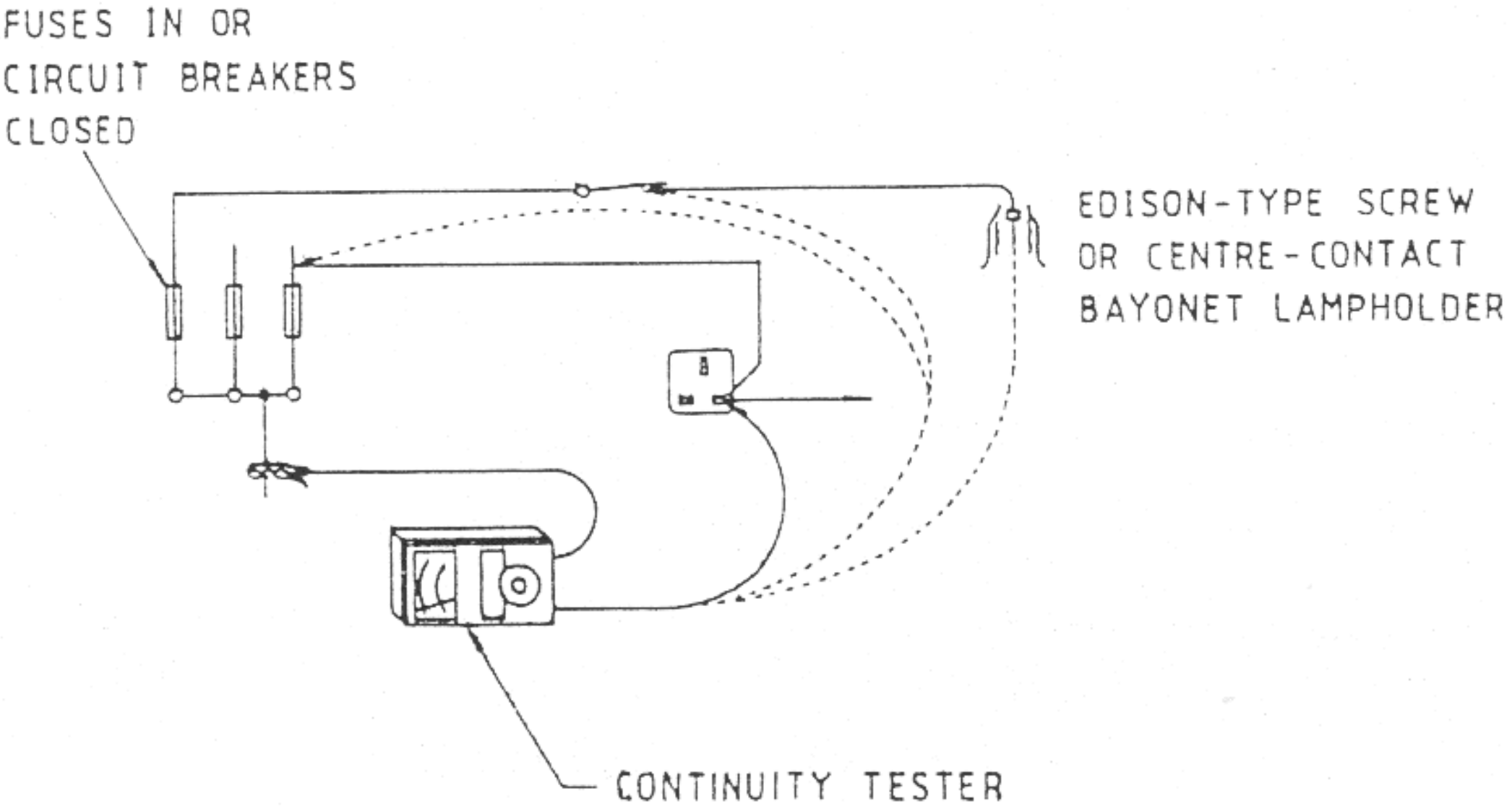
Insulation Tester (MegOhmMeter) 絕緣測試儀表

Earth Bonding Resistance Meter
接地接駁電阻測試儀表

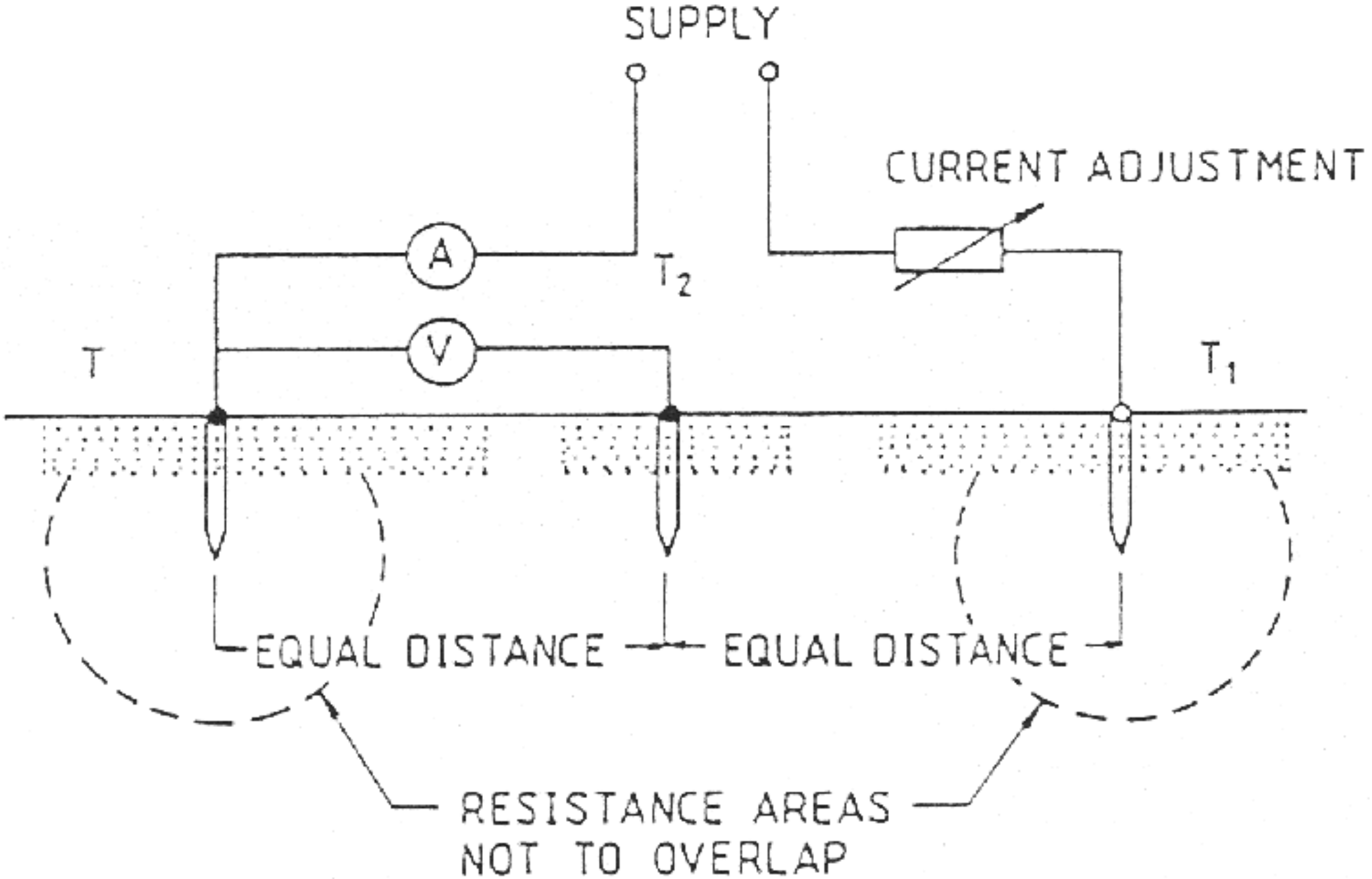
Insulation resistance test between phases 絕緣電阻測試



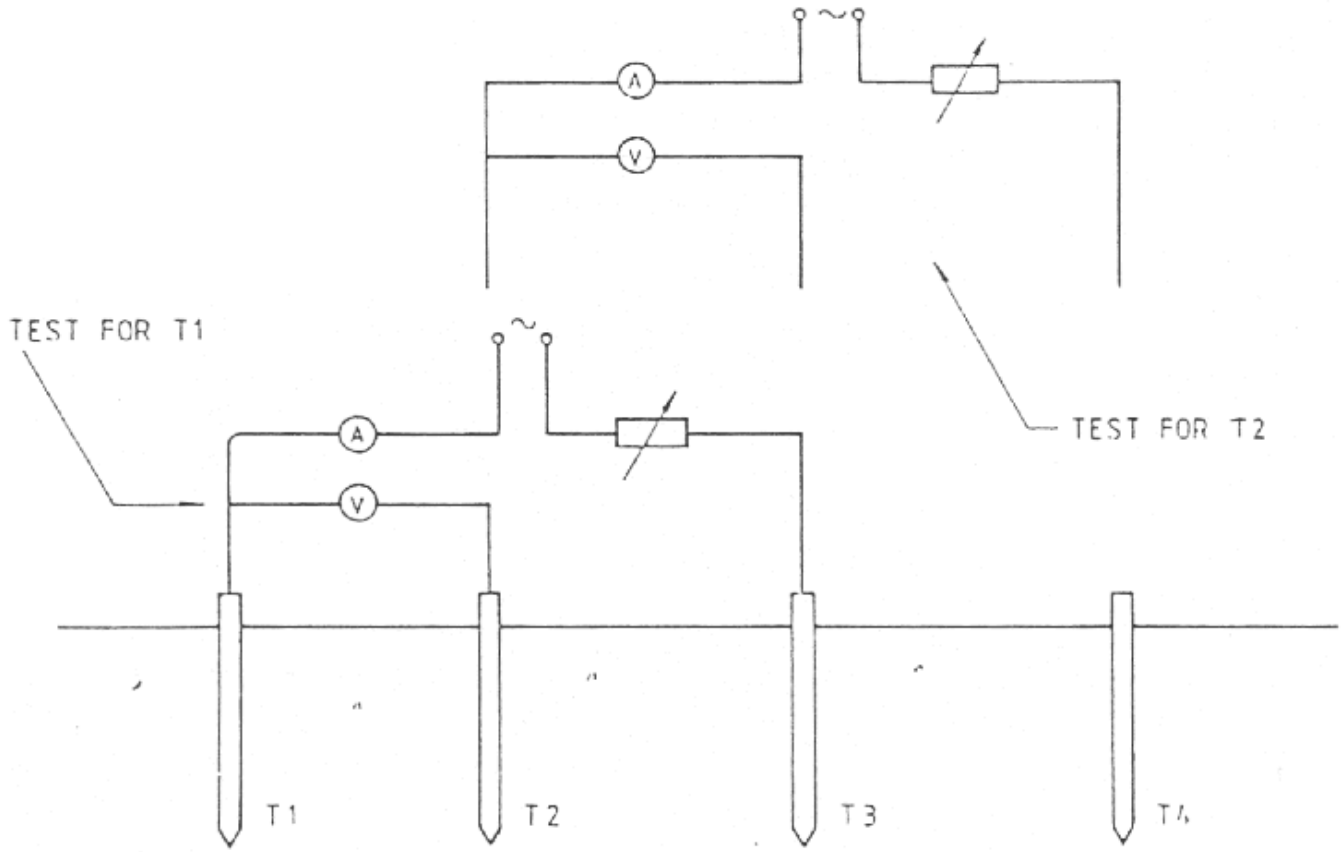
Polarity test 極性測試



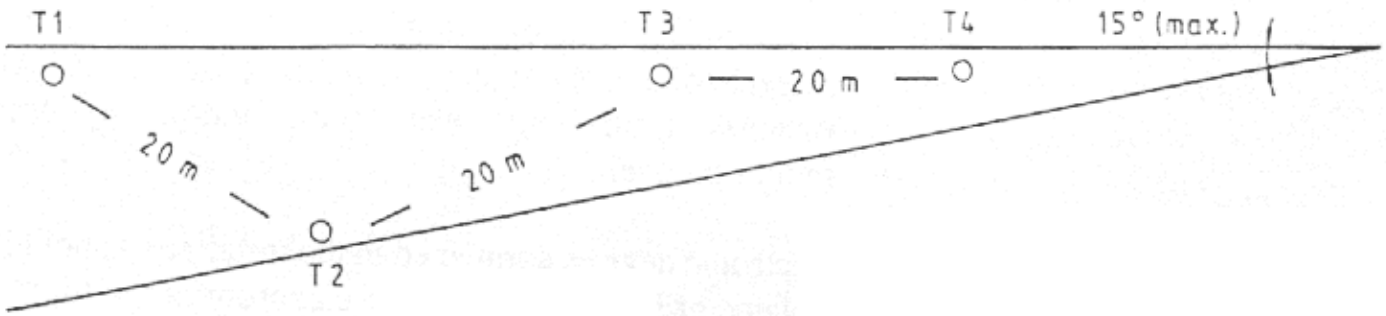
Earth electrode resistance test 接地極電阻測試



Test of earth electrode resistance having four or more electrodes



ELEVATION



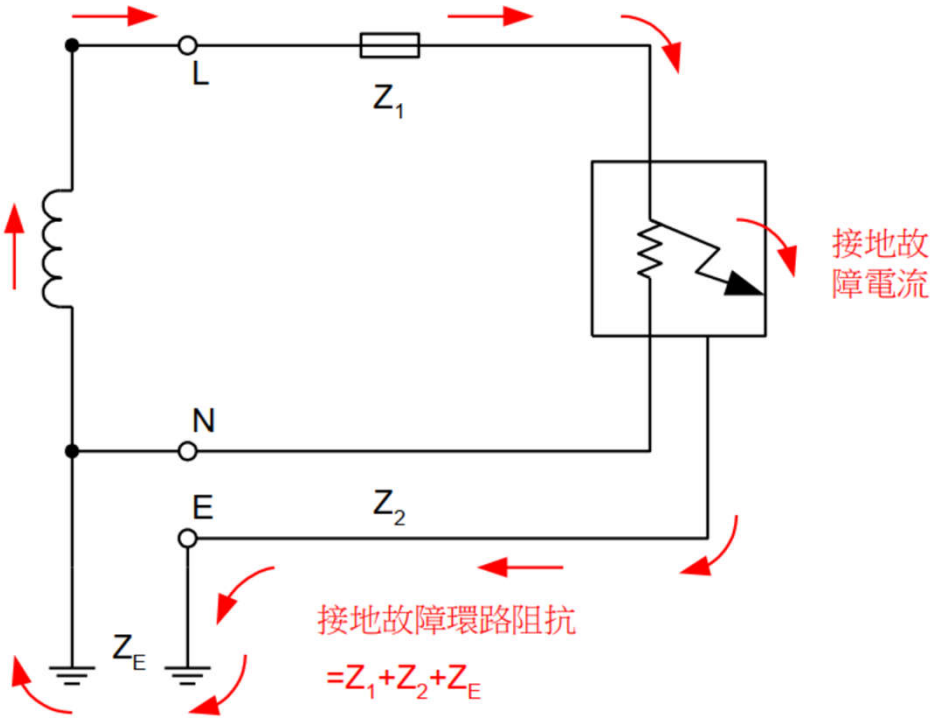
PLAN

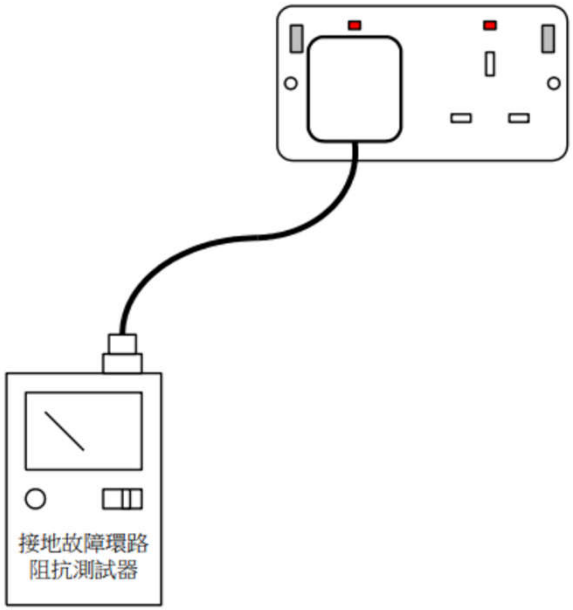
Testing of electrical systems

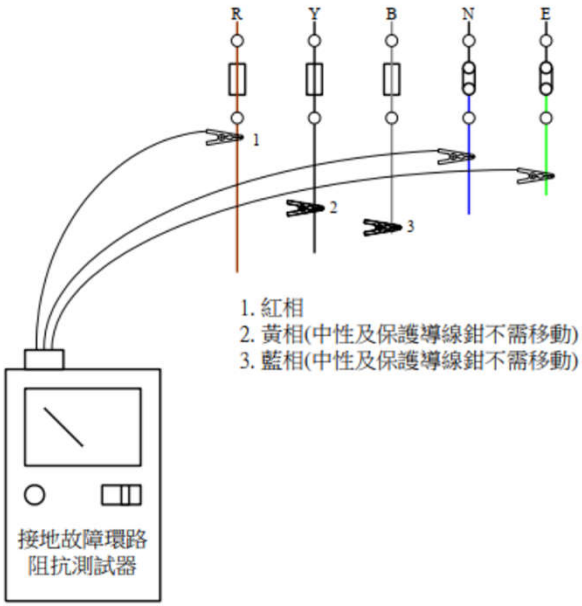
- Earth fault loop impedance 接地故障環路阻抗
  - Measured by a phase-earth loop tester

- Functions of all protective devices
  - Checked by residual current device tester (built-in)
  - Checked by hand operation (MCB, MCCB, ACB)
- Additional checks for hazardous environment
  - Such as dangerous goods (DG) stores & industrial process

Earth fault loop impedance test 接地故障環路阻抗測試

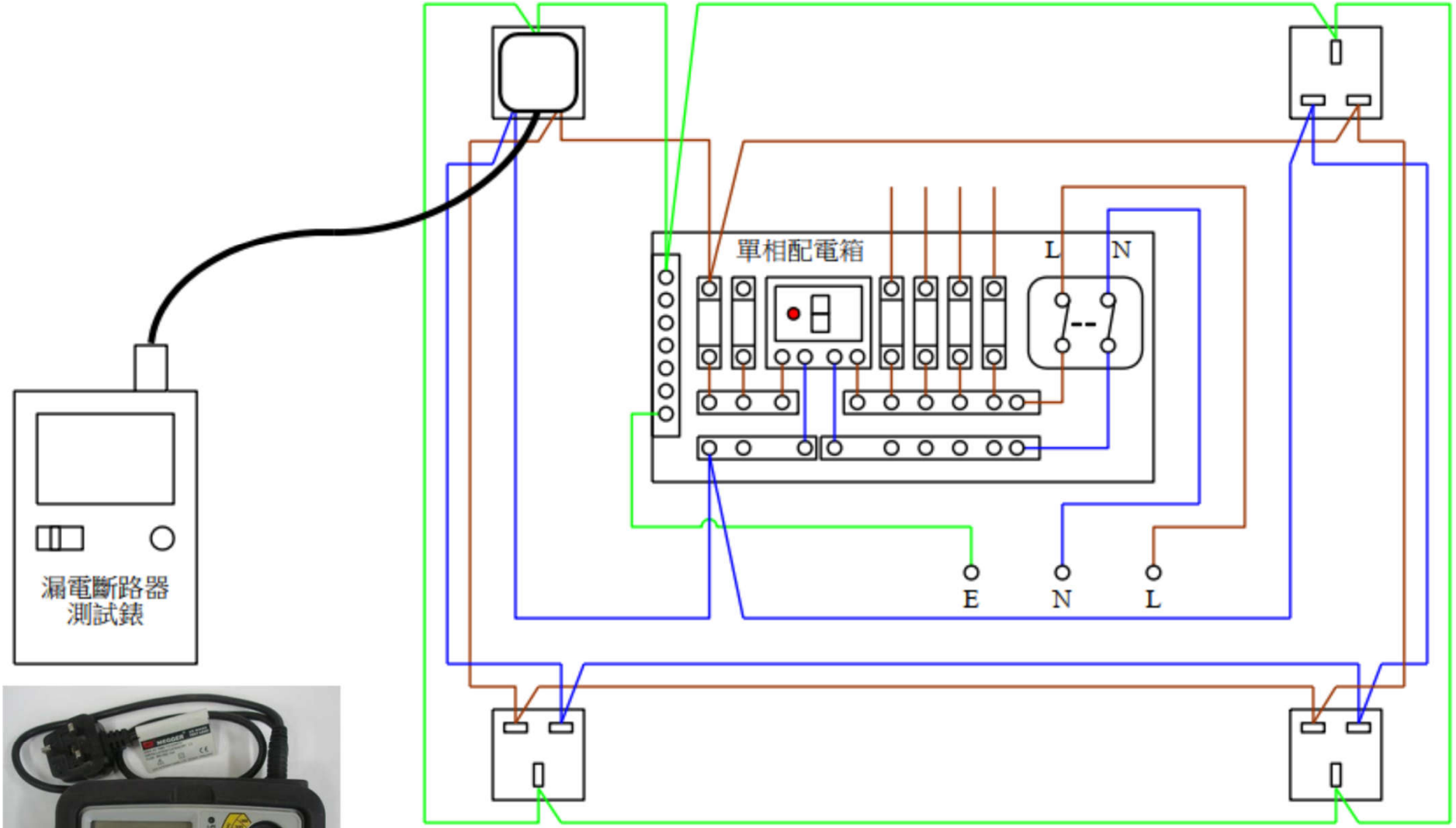






[Source: http://www.ksmak-sir.com/pdf/EIT.zip]

Test of residual current device (RCD) 電流式漏電斷路器的測試



[Source: http://www.ksmak-sir.com/pdf/EIT.zip]

Electrical wiring test record form 電力線路測試記錄表

電力線路測試記錄表

配電箱位置及編號 ： 荔枝角道 702 號 7 樓 777 室（廚房），編號： 0777 (單相供電)

測試儀器資料 ： KYORITSU-INSULATION TESTER (MODEL: 3111V)，KYORITSU-Digital RCD (ELCB) (MODEL: 5406A)，KYORITSU-Digital RCD (ELCB) (MODEL: 4120A)

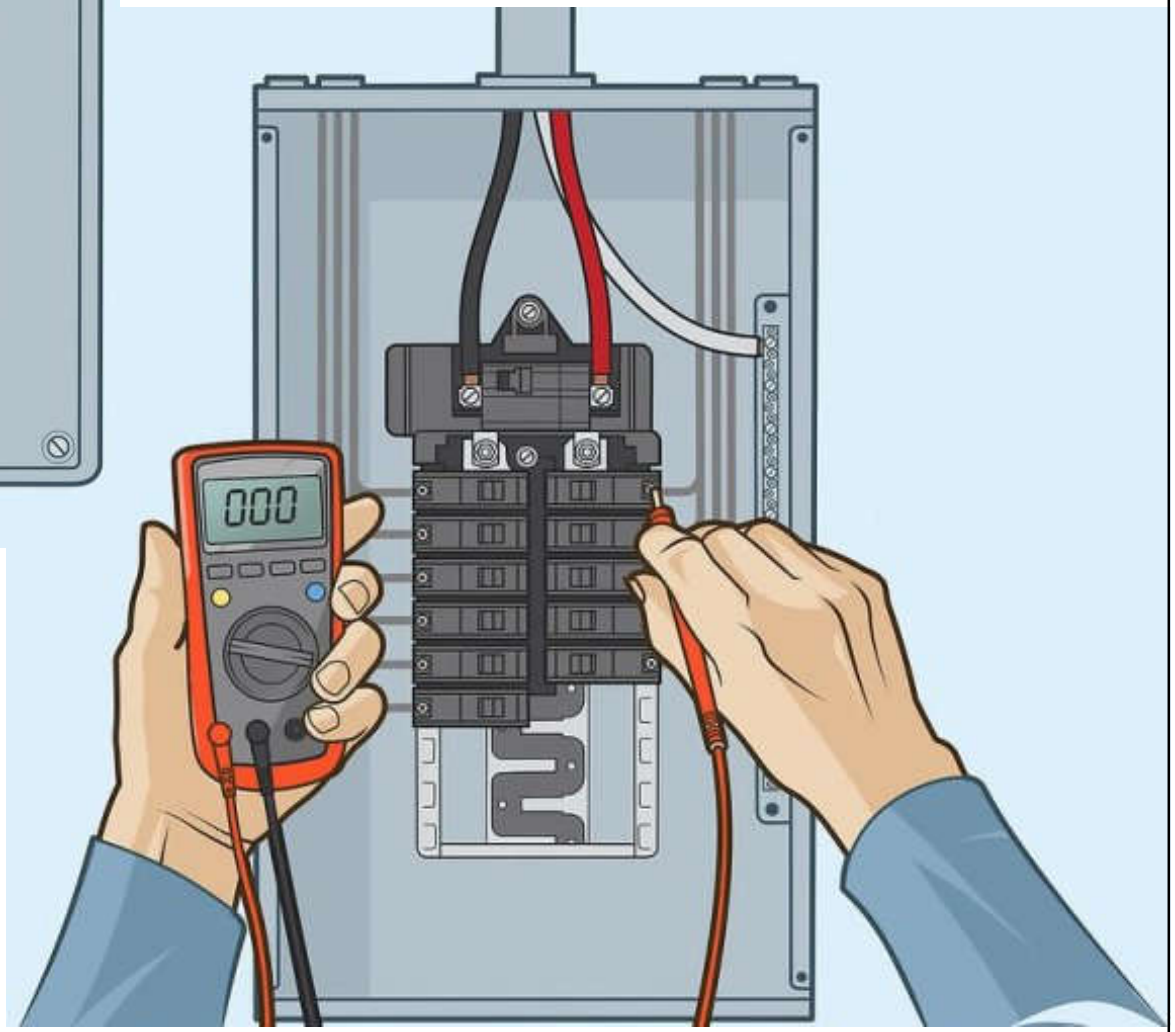
電路編號	保護器件		導體截面面積		測試結果								
					電氣連續性		絕緣電阻		極性	接地故障環路阻抗 (Zs)	功能測試		備註
	類別	額定值 (A)	相導體 (mm^2)	保護導體 (mm^2)	保護導體 (Ω)	環形電路 (Ω)	L-L (MΩ)	L-E (MΩ)		(Ω)	漏電斷路器時間 (ms)	其他	
1	MCB	15	1.5	1.5	0.11	-	100	100	Y	0.31	不適用	OK	睡房及浴室燈
2	MCB	15	2.5	2.5	0.22	-	100	100	Y	0.41	不適用	OK	廳及廚房光管
3	MCB	15	1.5	1.5	0.08	-	100	100	Y	0.41	不適用	OK	主人房冷氣
4	MCB	15	1.5	1.5	0.08	-	100	100	Y	0.38	不適用	OK	小孩房冷氣
5	MCB	20	2.5	2.5	0.06	-	100	100	Y	0.36	不適用	OK	客廳冷氣
6	MCB	15											備用
7	MCB	30	2.5	2.5	0.08	0.05	100	100	Y	0.41	22	OK	廚房及廳 13A 插座
8	MCB	30	2.5	2.5	0.08	0.05	100	100	Y	0.41	26	OK	廚房及廳 13A 插座
9	RCD	60	16	-	-	-	95	95	Y	-	-	OK	漏電斷路器
												測試者:	陳大文 (W888888)
												日期:	1-1-2011

聲明： 就本人所知及相信，上列資料全部屬實，本人明白，若本人明知而提供虛假資料，本人有遭刑事檢控之虞。

註： 本測試記錄表樣本可於機電工程署網頁 www.emsd.gov.hk 內下載(途徑：保障公眾安全▶電力▶刊物)。

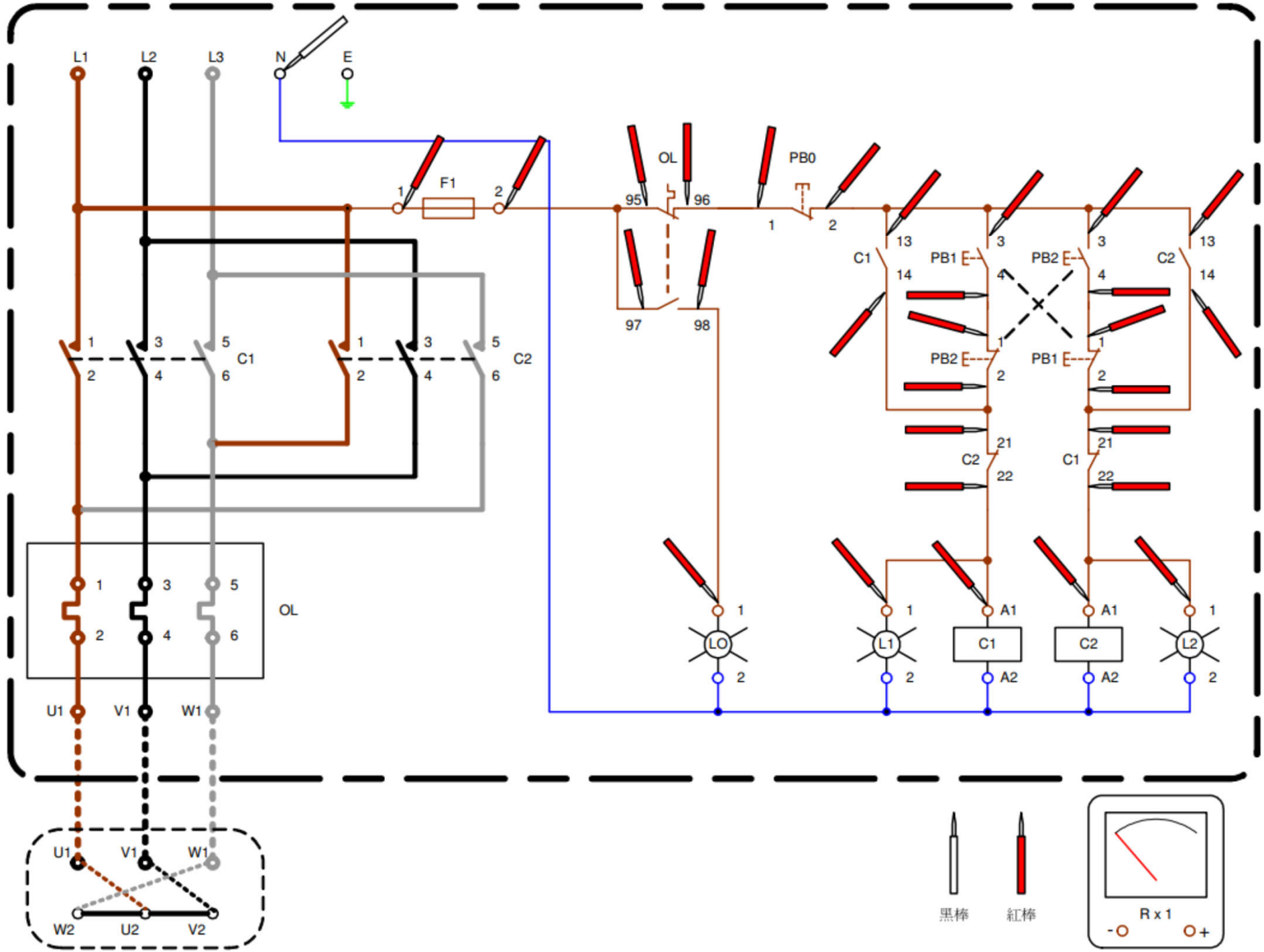
[Source: http://www.ksmak-sir.com/pdf/EIT.zip]

Circuit breakers test 斷路器測試



[Source: https://topcolighting.com/2020/01/22/circuit-breakers-test/]

Testing of motor control circuit using resistance tester



[Source: http://www.ksmak-sir.com/pdf/Note_control_wiring.pdf]