

	Requirement	Recommendation
E1. Labels and notices	<p>1. All electrical components must carry labels describing their function. This applies particularly to switches and protection trips, circuit breakers, and fuses.</p> <p>2. A block diagram showing the overall electrical layout must be available in the power house, accessible, and durable. It should correspond to the labeling provided.</p> <p>3. Individual units such as the controller should have major internal connections and components labeled and should carry inside a circuit diagram corresponding to labels.</p> <p>4. An illustrated notice in local language warning people of danger of electrocution should be within easy view, and durable. It should contain practical information on preventing and coping with electrocution and electric shock (eg not working standing in water; use of insulated shoes and mats, one hand working, not working alone, etc).</p> <p>5. High voltage warning labels should be placed on all cabinet doors and terminal covers enclosing equipment operating at above 50 volts.</p>	
E2. Shielding	<p>1. All live surfaces and points must be fully and reliably shielded from human contact. Cables and their connections to units must be shielded both by conduit and by their insulation, and connections must be all within closed casings. Door interlock isolators, to isolate supply when the door is open, are recommended on control gear with voltages above 50 Volts in order to ensure safe working.</p> <p><i>When visiting verify above and also:</i></p> <p>2. Shielding must be in use always.</p>	
E3. Tamper-proofing	<p>1. Individual units such as the controller box should be locked against unauthorised tampering and/or sealed for access only by designated specialist service technicians.</p>	
E4. Maintenance	<p>1. An electrical maintenance manual must be in place and in use.</p> <p><i>When visiting verify above and also:</i></p> <p>2. Check that all connections are tightened every 6 months to compensate for thermal expansion and contraction caused by varying load currents.</p>	
E5. Earthing	<p>1. The neutral of the generator and all metal casings (including generator, turbine, frame, controller and switchgear) and guards must be reliably and effectively earthed (see earth test details below).</p> <p>2. Acceptable earth electrodes are rods, mats, wires, plates and structural steelwork buried or driven into the ground.</p>	

	<p>3. Precautions must be taken to prevent corrosion due to electro-chemical effects; this can be done by using copper for the earthing conductor and electrode, by avoiding bi-metal joins, or by maintaining air and water exclusion from bi-metal joins.</p> <p>4. An earth leakage circuit breaker (ELCB) sometimes known as a residual current device (RCD) must be used for electrical safety as it is rarely practical on micro-hydro schemes to install a sufficiently good earthing system. The earth resistance must be low enough to cause the ELCB to operate (see test details below).</p> <p>5. A main copper earth terminal or bar must be provided to collect and connect together all earth connections.</p> <p>6. The connection from the earth terminal to the earth electrode is known as the earth conductor, and this should have a minimum cross-sectional area of 25mm². At the point of connection to the earth electrode there should be a clear permanent label 'Safety electrical connection - do not remove'</p> <p><i>When visiting verify above and also:</i></p> <p>7. Perform a thorough visual check on the earthing system.</p> <p>8. A test should be made of the actual earth resistance, to ensure that it does not exceed the value 50 / I_{leakage}, where I_{leakage} is the sensitivity of the ELCB, usually 30 mA. The recommended method is to use a dedicated Earth Resistance Tester.</p>	
<p>E6. Lightning protection</p>	<p>1. Lightning arrestors must be fitted to protect the power house and consumers. They are recommended on each phase as follows: One arrestor on the first pole outside the power house (or a varistor inside the power house), one arrestor per kilometre of distribution and additional arrestors to ensure that no consumer is more than 500 metres from an arrestor. Arrestors are to be installed and earthed according to the manufacturers instructions.</p>	
<p>E7. Over-current and earth fault protection</p>	<p>1. Over-current trip. Excessive currents in the cabling due to faults such as short-circuits or overloads may damage cables and the generator windings, and create a fire risk. Proper protection is required, in the form of a MCB (miniature circuit breaker) or MCCB (moulded case circuit breaker) placed as close as possible to the generator terminals.</p> <p>2. Earth-fault protection (ELCB). In order to protect people from electric shock at any location throughout the distribution system and in the power house, an earth leakage circuit breaker (ELCB) must be fitted as close to the generator terminals as possible. The standard sensitivity for human protection of 30mA should be used except for larger schemes where the number of consumers is so great that cumulative earth leaks due to normal insulation resistance leakage and stray capacitance currents would cause spurious tripping. In this case consumer clusters (typically around 15 houses or 1.5 kW) should be protected by 30mA ELCBs within the distribution system and the power house can be protected by a less sensitive and slower-acting ELCB.</p> <p>3. Ratings. The OC trip and ELCB current carrying capacity ratings should be suitable to carry the current marked on the original nameplate</p>	

	<p>of the generator or motor-as-generator. The maximum rating for the OC trip must be no more than 10% above the generator current rating.</p> <p>4. Location. The over-current (OC) trip and ELCB can be placed in the same box with each switch clearly labeled. They should not be mounted on the generator body itself to avoid vibration damage. They should be at least one meter above floor level, and as close to the generator as possible, with properly fixed and sealed conduit protecting the cable to the generator (which is not otherwise protected). The ELCB should be connected to the generator and then the OC trip should be connected to the ELCB. In small schemes where the controller box is placed close to the generator the OC trip and ELCB can be included inside the controller box to save expense, with switches accessible and labeled. Conduit must be correctly used and the conduit connections sealed. Resetting of trips must be possible without opening the box, to ensure that the box is left locked/sealed in normal operating conditions. This is not necessary if a door-interlock isolator is fitted.</p> <p><i>When visiting verify above and also:</i></p> <p>5. The ELCB must be in good working order. The test button should be used to verify this.</p> <p>6. Terminals and connections for both trips (and all other devices) must be checked for tarnish, loosening, dirt accumulation, moistness, signs of overheating, etc, and procedures must be in place to make good.</p> <p>7. Verify that operators can locate and correct an earth fault without undue delay.</p>	
E8. Conduit and cables	<p>1. Strong conduit must be used to protect all cable in the power house from vermin attack to the insulation and knocks and blows, and to protect the end-of-cable terminals from yanks or pulling. It is essential that the conduit is strong and physically secured to all enclosures (trip boxes, controller boxes, ballast, etc) by means of threaded connectors secured to the enclosure, so that any yank to the conduit is not transferred to the cable connections. The conduit must also be sealed to the enclosure entrances in order to prevent insect and dust ingress.</p> <p>2. Special attention must be paid to the physical strength of the conduit from generator to OC trip/ELCB box, as the cable inside it is not protected from over-current and earth faults.</p> <p>3. Cable sizing. Current handling capacities of the cables should be 40% greater than the rating of the overcurrent protection device(s), after taking account of de-rating required for use in conduit and multiple cables.</p> <p><i>When visiting verify above and also:</i></p> <p>4. Cables should not feel over-warm to the touch. If so, cables are undersized and should be replaced or doubled-up.</p>	
E9. Sockets	<p>1. It is recommended to fit one or more electric sockets to allow use of electrical appliances and tools in the power house; these must be placed at least one meter above floor level to avoid danger of water ingress.</p>	
E10. Lighting	<p>1. The power house must have an installation-powered electric light fitted which gives adequate safe illumination (minimum 10 watts/m² of floor area incandescent or 3 watts/m² fluorescent)</p>	

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	<p>2. Inclusion of a battery-charging type lantern (“emergency lamp”) on the tool display board, in charged or charging state, is recommended but not essential.</p> <p>3. An installation-powered light outside the power house above the door is recommended.</p>	
E11. Powerhouse-consumer isolation switch	<p>1. All schemes must have a switch allowing the distribution system to be isolated from the generator and controller. This should be located inside the powerhouse and clearly labeled. On smaller schemes the isolation switch can be included in the controller box to save cost; on larger schemes it should be in a separate box placed after the controller.</p> <p>2. The switch must have a current rating equal to or higher than the rating of the OC trip.</p>	
E12. Voltage and Frequency trips	<p>1. Trips are required to protect consumer loads from unacceptable voltage and frequency conditions.</p> <p>2. Overvoltage trips should be fitted on all schemes</p> <p>3. Undervoltage trips should be fitted on all schemes where motors are used by consumers and it is recommended that they are fitted on all schemes above 5kW.</p> <p>4. Over and underfrequency trips are required on all schemes where motors are used by consumers and are recommended on all schemes above 25kW</p> <p><i>When visiting verify above and also:</i></p> <p>5. Check that appropriate trips are fitted; check that they are working, and in good condition.</p>	
E13. Synchronous generators and induction motors as generators	<p>1. Brand. The brand and power rating of the generator or motor should be approved by the manufacturer of the controller.</p> <p>2. Name plate. The original manufacturer’s name-plate for the generator or motor must be retained. New name plates can be added but must not replace the originals.</p> <p>3. Over-rating. The power rating given on the original name plate must be at least 25% more than the scheme rated power (as defined in General Requirements).</p> <p>4. Generator voltage. The “power house voltage” is the voltage at the generator terminals with powerhouse-consumer isolation switch in off position. This must be between the nominal national voltage (nnv) and +10% of nnv. An exception can be made where the controller is distant from the generator and no consumer or other loads will be attached to the connecting cable; in this special case the power house voltage can be between nnv and nnv + 15%.</p> <p><i>When visiting verify above and also:</i></p> <p>5. The generator voltage should be adjustable by tuning of the controller or AVR voltage potentiometer setting. Check that the voltage is</p>	

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	<p>maintained within prescribed limits.</p> <p>6. Check that the air vent is not obstructed and the fan is functioning normally. Touch the generator to see whether it is over-heating.</p>	
E14. Synchronous generators	<p>1. Frequency. The operating frequency should be between 50 and 52.5 Hz.</p> <p>2. Pf. The power factor rating should be 0.8 when an ELC is in use except where all loads and the ELC present a unity power factor.</p> <p>3. The sync. generator must be overspeed protected by either:</p> <ul style="list-style-type: none"> • manufacturer-approved strengthening of the rotor to withstand run-away speed conditions or: • protected by a reliable over-speed shut-down mechanism (such as speed-triggered jet deflectors on a Pelton) • <p>4. It is highly recommended that brushed generators are not used because these are vulnerable to dusty environments and require considerable maintenance attention.</p> <p><i>When visiting verify above and also:</i></p> <p>5. The correct frequency should be obtainable with adjustment provided on the ELC.</p>	
E15. Induction motors as generators	<p>1. Frequency. The frequency should be between 50 and 55 Hz. The frequency should be within this range under all operating conditions, including minimum and maximum power output, zero consumer load and worst case consumer load power factor.</p> <p>2. The induction generator must be overvoltage protected because at overspeed the voltage will increase and cause excessive currents to flow through the excitation capacitors and induction machine. A protection system is required that disconnects all or some of the capacitors, to limit the currents flowing to below the limits for the induction machine windings and the capacitors. The recommended method is the use of MCBs of suitable current rating in the series with excitation capacitors.</p> <p><i>When visiting verify above and also:</i></p> <p>3. Adjust frequency. If the frequency is too high power factor correct consumer loads and/or add excitation capacitance. If the frequency is too low reduce the excitation capacitance.</p> <p>4. Check operation of overvoltage protection by removing consumer load and ballast load. (Allow at least ten minutes for MCBs to trip as they are usually thermal devices).</p>	
E16. Controllers and governors, flow regulators	<p>1. It is strongly recommended that where synchronous generators are used, an electronic load controller (ELC) is fitted, or a combined electronic and flow governor. Purely mechanical governors can be used, especially in storage-type schemes, but are not recommended since their maintenance requirements are likely to pose problems.</p> <p>2. It is strongly recommended where induction generators are used, that electronic load controllers (induction generator controllers - IGCs) are</p>	

	<p>used, in order that voltage is controlled.</p> <p>3. The controller must be located in the power house, together with the ballast, to ensure the ballast is never disconnected.</p> <p>4. Instrumentation must be as specified below.</p>	
E17. Ballast	<p>1. Below 5 kW, air resistance heaters are recommended as opposed to water-cooled heaters. (Reliability in water cooled ballasts is expensive to ensure and the cost is not justified in small systems). Natural convection heaters are generally preferable because they are more reliable and durable than radiant heaters, but availability or cost considerations may dictate radiant type heaters.</p> <p>2. Above 5 kW, water-cooled ballasts are recommended. This is because air heat outputs of more than 5 kW are likely to overheat the power house and endanger its equipment.</p> <p>3. Location. The ballast must be located in the power house to ensure that it is never disconnected. Air cooled ballasts must be kept away from electrical and mechanical equipment so as not to radiate heat toward them. Wall-mounted units should be mounted high on a wall but not closer than one meter to the roof.</p> <p>4. Cables to the ballast must not be too long and must be arranged to be secure and tamper-proof so that there is no danger of disconnection of the ballast - no method of disconnection must be present. Connections to radiant heaters should be made from below and cable in close proximity to the heater covered with high temperature insulation.</p> <p>5. Reliability of water-cooling. Every care must be taken to ensure that the water flow is not impeded or the ballast will overheat and fail. The design must include reliable protection against the effects of a water flow blockage: for instance there must be sufficient water capacity to absorb ballast heat for the maximum time between operator inspections. In addition it is strongly recommended to fit alarms for high water temperature and low water level. Since such alarms may be out of hearing distance, an automatic disconnection of the generator field can be arranged in the case of a synchronous generator. Ballast tanks should be made from corrosion-proof materials, or be regularly repainted. They should have an overflow channel provided, to direct spill water away from electrical apparatus in the case of an out-flow blockage. An arrangement for easy flushing out of silt deposits is recommended.</p>	
E18. Instrumentation	<p>1. All instrumentation, except kWhr meters, can be included on the controller box. Instrumentation should be at eye level or 1.5 meters from floor level.</p> <p>2. Ballast meter (indicating power dissipated in ballast). There must be a method of reading approximate electrical power output in the power house. The recommended method is the use of a ballast meter, which must always be fitted. In 3-phase ELC systems 3 ballast meters, one for each phase, are necessary. The reading(s) will be approximate because they depend on the power rating of the ballast elements. Changes in the reading(s) may indicate failure of one or more ballast elements or variations in the power output of the turbine-generator. (The ballast meter gives percent of power to ballast and can be additionally labeled with</p>	

	<p>power to consumer markings. It can be used to show any difference in actual power and commissioned power at any stage of the life of the scheme).</p> <p>3. Voltage. A voltmeter is essential, because this indicates whether the system is running safely and effectively. On a 3-phase system it is recommended that voltages on each phase can be read.</p> <p>4. Current. On a 3-phase system an ammeter on each separate phase is strongly recommended, in order to monitor load imbalance. On a small 1-phase system an ammeter is not essential but is useful; on a larger 1-phase system it is worth installing an ammeter. Where ammeters are fitted to read currents of 30 Amps or more, current transformers must be used for safety and reliability</p> <p>5. Frequency. On small schemes, the expense of a frequency meter is usually not justified, although it is a useful instrument nevertheless. On larger schemes it is recommended. On induction generator systems, a frequency meter is highly recommended, to facilitate adjustment of the excitation capacitance and to indicate whether capacitors have failed.</p> <p>6. KWhr meters. Not essential, and the expense is not justified on small schemes. Nevertheless these meters are very useful to monitor scheme performance. If one meter is fitted, it is best placed after the powerhouse-consumer isolation switch and labeled "consumer power". For thorough monitoring, a second meter can be fitted between the OC trip and the controller, to record total generator power to both ballast and consumer.</p>	
E19. Power output	<p><i>When visiting:</i></p> <p>1. Measure power output and record and date the reading. Use the ballast to do this, or in the absence of a ballast bring a portable ballast to the site.</p>	

