

# ***LE-450 Turbine***

## ***Installation & Operation Guide***



***1m Diameter Micro Wind Turbine for generating clean and renewable electricity anywhere the wind blows...***

***Leading Edge Turbines Ltd***

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### **Warranty Registration**

Please register your product with us so that we can administer your warranty entitlement.

Please register at **[www.leturbines.com/support/warranty-registration/](http://www.leturbines.com/support/warranty-registration/)**

Customers are required to keep an original copy of their invoice should questions arise requiring reference to purchase information.

## ***Read this first***

### **Don't connect the wind turbine in the wrong polarity**

Make sure you connect the +ve of the turbine to the +ve of the battery (red to red) and the -ve of the turbine to the -ve of the battery (black to black). Failing to do so will damage the equipment and invalidate your warranty.

### **Don't connect the Diversion Charge Controller in series with the turbine**

Always ensure that the turbine and the controller are connected to the battery separately.

### **Ensure the blades are fitted in the correct orientation**

Consult the diagram on page 9. Blades fitted back to front it will severely impair power production.

### **Don't allow the turbine to run without being connected to the battery**

Failing to do so will result in the turbine freewheeling causing premature wear and tear and unnatural blade noise. Failing to do so will invalidate your warranty.

### **The Tristar charge controller must be configured for Diversion mode**

Failing to do so will invalid your warranty as this can burn out the stator.



<http://youtube.com/c/LeadingEdgeTurbines>

Visit our YouTube channel for assistance in wiring up the equipment, configuring the Tristar charge controllers and more.

## Introduction

Please read this manual thoroughly before attempting to assemble, install or operate your *LE-450* small wind turbine. This will assure optimum performance and safety.

*Leading Edge Turbines* has spent many years developing the ideas and technology behind your turbine. The *LE-450* features an array of innovations and construction techniques as well as heavy-duty engineering to ensure optimum efficiency and a long operating life. All of these features have evolved from the long and successful history of the *LE-300* turbine.

The *LE-450* has been designed to be simple, economic, durable and yield excellent performance.

Specific *LE-450* turbine features:

- Innovatively designed axial flux alternator, using neodymium iron boron magnets
- A laser-cut aluminium chassis using 'Yaw-wing' design to ensure responsive yawing and to reduce weight
- Maintenance-free, low friction bearing in both main shaft and yaw assemblies
- Extremely quiet injection moulded blades with 'Whisper' geometry and aerofoil design
- Long-life yaw pivot slip-rings and wipers
- Easy tower-top installation
- Simple design for low cost and durability
- Fully marinised using stainless steel fixings and anodised aluminium components
- Low mass to help reduce exerted forces and ensure easy installation.

The *LE-450* has been designed for both land-based and marine environments. Thanks to its unique design, the *LE-450* will minimise corrosion in both normal and salt water operating conditions.

Applications include:

- Telecommunications
- Security cameras
- Sailboats, yachts
- Remote homes / caravans
- Street lighting and road signage
- Complementary installation with photovoltaic modules for home power
- Farm utilities (electric fencing, irrigation, etc.)
- Wind-electric water pumping
- Cathodic protection
- Monitoring sites
- The Developing World.

## **Safety Precautions**

Safety must always be your primary concern during the assembly, installation and operation of your *LE-450* turbine. Always be aware of the risks involved with mechanical and electrical installation work. If in doubt about any issue regarding your turbine, please seek further assistance before proceeding. Installation of the *LE-450* turbine should only be undertaken by suitably competent and qualified personnel.

### **Mechanical Safety Hazards**

- The main rotor is the most obvious and serious mechanical safety risk. When the turbine is operating at its rated performance, the blades will be very difficult to see, due to the speed of rotation. Never approach the turbine whilst it is operating. Always shut down the turbine by activating the stop switch. **Ensure that the turbine is installed in a suitable position where nobody can approach or interfere with the path of the rotor blades.**
- Working with tools of any kind can be dangerous. Your *LE-450* turbine requires some basic mechanical assembly with rudimentary hand tools. If you are in any doubt about how to use these tools correctly, please seek advice from a suitably experienced person.
- Your *LE-450* turbine will inevitably be installed upon a tower or other support mount. This may mean working at height. Always ensure that all personnel in the immediate vicinity are aware of any lifting / hoisting operations that will be occurring. Check there are no loose components or tools likely to fall and cause injury during the lifting operation. Where possible, all assembly work should be completed at ground level. In the case of roof mount brackets, a suitable fitter should carry out the installation with the appropriate equipment for working at height.
- Ensure that the batteries are disconnected during the installation procedure.
- Twist the turbine output cables together (to create a short circuit) during the mechanical installation process. This will prevent the turbine from 'spinning up' during the installation.
- Never install the turbine upside down or in any orientation other than that depicted on the installation instructions.
- Install your turbine during a calm day.
- When performing routine inspection or maintenance, always stop the turbine by activating the stop switch.

### **Electrical Safety Hazards**

- The *LE-450* generates rectified DC voltage. Even at these low voltages there are inherent risks. Caution should always be used when connecting the *LE-450* to the electrical system.
- Be sure that you have followed the cable-sizing chart to ensure that the correct size of transmission cable has been selected. If a cable of insufficient cross-sectional area is used, heat may build up in the cables causing a potential fire hazard. A properly sized fuse or circuit breaker should be used in the cables connected to the battery. This will stop the risk of short circuit currents. Using cables of insufficient cross-sectional area may also reduce the power transmission efficiency of the turbine.
- Battery systems can deliver a serious amount of current. A short circuit in the battery circuit can lead to hundreds of amps flowing through the battery cables. This will cause a heat build-up and ultimately an electrical fire. Batteries can explode when shorted. Always use insulated electrical tools when working on the battery's electrical connections.
- Batteries are very heavy. Do not attempt to move batteries by yourself. Always use manual handling tools and an assistant.
- Always keep lead-acid batteries the correct way up. Do not allow the acidic electrolyte to spill or come into contact with your skin or face. Always follow the manufacturer's safety instructions when handling lead-acid batteries.
- Never run the *LE-450* 'off-load' with the output cables not connected to anything.

***Please use common sense when installing and operating your turbine!***

## Specifications

Turbine Name: *LE-450*  
 Part Number: GA-LETU-016  
 Nominal Voltage: 12V / 24V / 48V DC or Grid-tie optimised  
 Rotor Diameter: 1000 mm  
 Rated Wind Velocity: 8 m/s  
 Rated Output: 105 Watts  
 Max Output: 450 Watts  
 Start-up Wind Velocity: 2 m/s  
 Total weight: 8.5 Kg  
 Tower mount: 48.3 mm / 50 mm Outer Diameter Tube  
 Chassis Construction: Aluminium  
 Rotor Blades (5-off): Glass Reinforced Nylon



Fig-1: Overall View

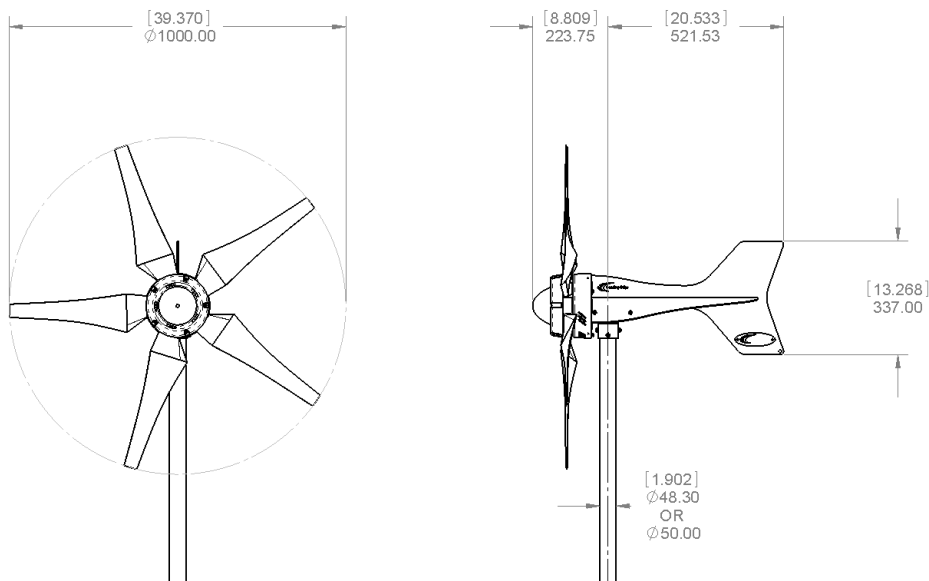


Fig-2: Operating Envelope

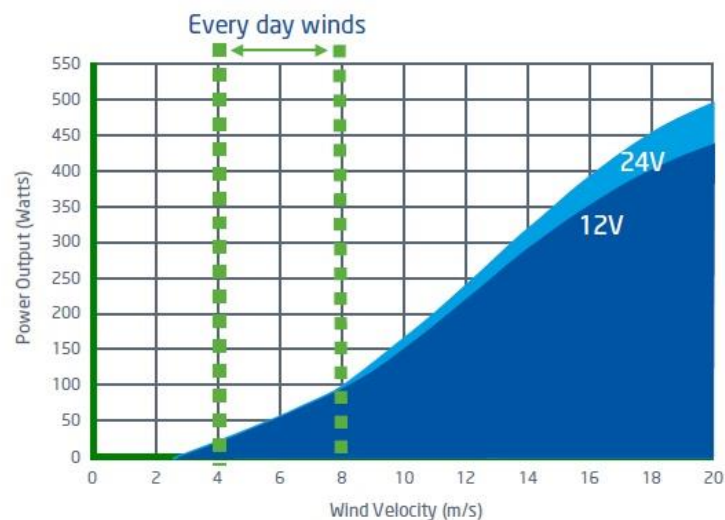
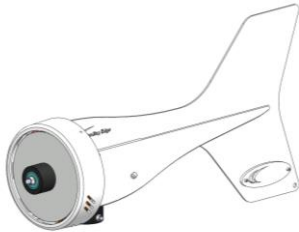


Fig-3: Energy Conversion

## Package Contents

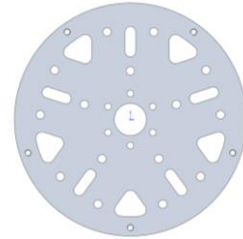
Your *LE-450* turbine will arrive containing the components shown below. If any of the items are missing or damaged, please contact your dealer immediately.



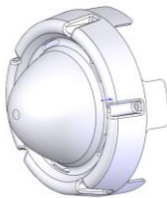
LE-450 Chassis: Qty 1



Rotor Blade: Qty 5



Hub Plate: Qty 1



Nose Cone: Qty 1



User Manual: Qty 1

17 x M6 Nylock Nuts
34 x M6 Plain Washers
15 x M6 x 16 Cap Heads
11 x M5 Plain Washers
6 x M5 x 20 Hex Heads
5 x M5 x 12 Cap Heads
2 x M6 x 70 Cap Heads

Fixings Bag: Qty 1

## Tools Required For Assembly

You will require the following tools to assemble your *LE-450* turbine:

- 10 mm spanner & 10 mm ratchet (one of each required)
- 8 mm spanner or ratchet
- A set of Metric Standard Hexagon Keys
- Electrical screw drivers
- Power drill
- 6.5 mm diameter twist drill bit, suitable for drilling through steel
- Digital multi-meter capable of measuring DC Volts
- Tape measure or steel rule
- Thread locking compound e.g. Loctite.
- Protective Gloves

## Mechanical Assembly Procedure

- 1) **Unpacking** - Inspect the contents of the box and ensure that all items are present and undamaged. If any of the components are missing or damaged, please contact your dealer immediately.
- 2) **Check Magnet Rotor & Continuity** - Ensure that the main shaft is free turning and does not scrape or rub as it rotates - see Fig 4. You may feel a slight resistance from the bearings at this stage. The bearing units used in the magnet rotor assembly are factory lubricated and sealed for life. It will take approximately 100 hours of normal operation for the seals to 'bed-in' and the lubrication to be distributed correctly around the bearing raceways and ball cages. During this period you may notice a reduced performance caused by the additional friction of the bearing seals. In operating temperatures of  $-10$  degrees Centigrade or lower, this 'bedding-in' period will be extended by a further 50 hours of normal operation. Connect a digital multi-meter to the positive (red) and negative (black) output leads extending from the yaw pivot. With the multi-meter set to detect DC Volts (0-20V approx), a voltage should be displayed when the magnet rotor is spun. This voltage will vary with the speed of rotation. If the magnet rotor rubs, or no voltage is detected whilst turning the magnet rotor, please contact your dealer immediately.

**Warning:** The magnet rotor within your *LE-450* turbine is constructed using neodymium iron boron rare earth magnets. These are extremely powerful magnets and can cause injury if not handled with respect. Take care when working with tools made of ferrous materials (such as spanners and screwdrivers) close to the *LE-450* alternator. The magnetic forces between ferrous materials and the magnet rotor within the alternator may be very strong. This may cause a sudden snapping action that can pinch or trap your fingers or skin.

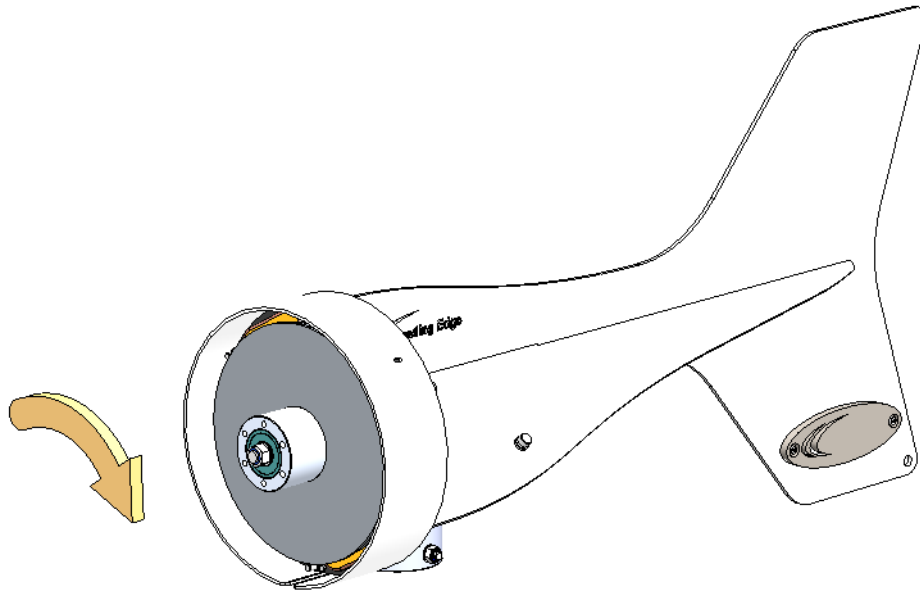


Fig-4: Checking magnet rotor rotation and coil-disc continuity



- 3) **Rotor Blade Assembly** - Take the five rotor blades and rotor hub plate. Be careful when handling the blades, they may have sharp edges. Use a 10 mm socket & hexagon key and three M6 x 16 mm Cap Heads to attach each blade to the hub plate - see Fig-5. Ensure that the cap head end of the screw is on the inside of the blades (thus allowing the washers and nuts to locate on rotor hub plate side). The blades should all be fixed to the hub plate on the same side, with the blades in the same orientation. It is important that a washer is used underneath the anti-vibration nuts. Three set-screws, three washers and three anti-vibration nuts should be used on each blade. Tighten the fixings until the blades are safely secured. Do not over-tighten the nuts as this may damage the blades and fixings.

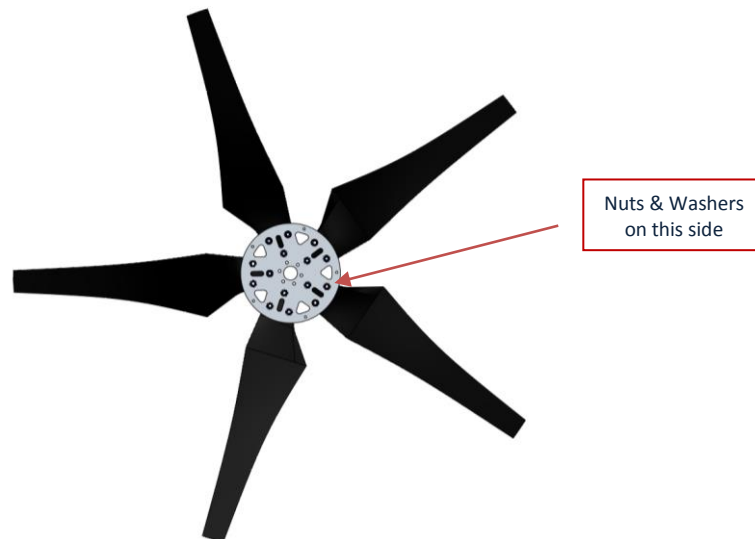


Fig-5: Attaching the 5 rotor blades to the hub plate

- 4) **Check the Tip Spacing** - Although the turbine blades are fitted with location 'keyways', it is important to check the tip spacing. Lay the assembled rotor blade on a flat surface. Using a tape measure or long steel rule, ensure that the spacing between each tip is equal to within a tolerance of  $\pm 1.5$  mm. Adjust the blades as required. Output performance may suffer if the blades are inaccurately set - see Fig-6.

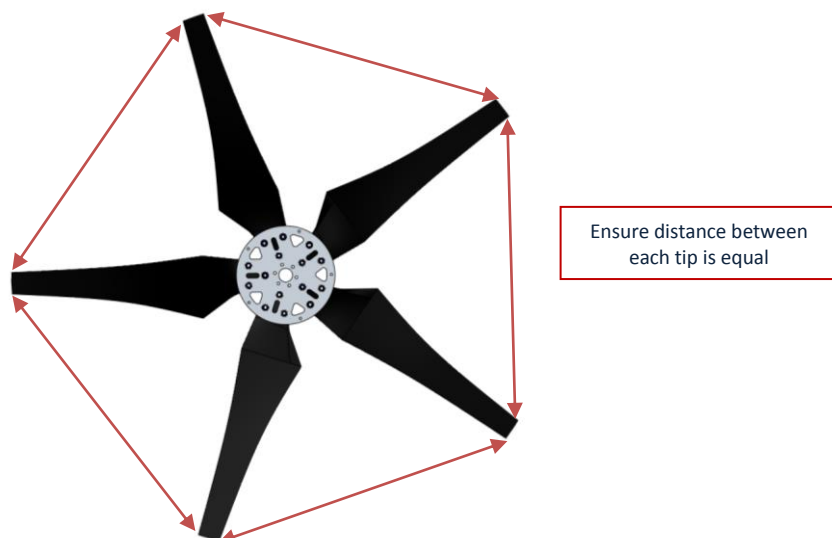


Fig-6: Checking tip spacing

- 5) **Fit the Rotor Blade Assembly** - The assembled rotor blades can now be fitted to the LE-450 chassis. This is done by offering the rotor hub plate against the drive shaft protruding from the front of the chassis. M5 x 20 mm Hex Head screws should then be used to fix the rotor hub in position using the six tapped holes in the drive shaft. Ensure that all screws are securely tightened and that the rotor blades are fitted with the flat side of the blade facing forwards. Thread-locking compound should be used on the screw threads.

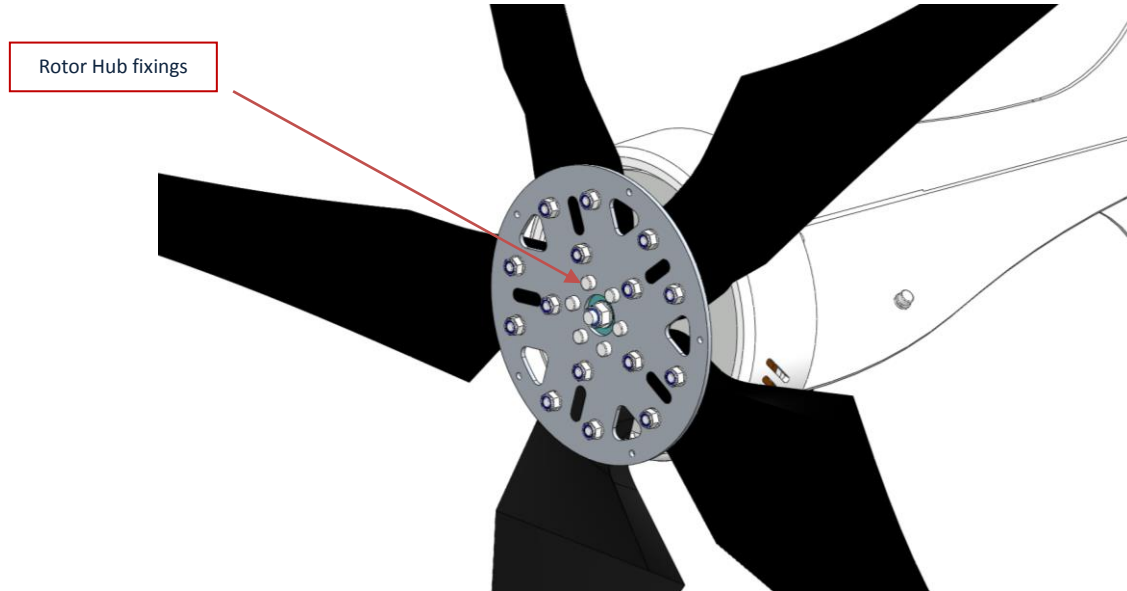


Fig-7: Fitting the rotor blades to the chassis

- 6) **Check the Blade Rotation** - Once the blades have been fitted and secured to the chassis, ensure that they rotate freely. Take this opportunity to check that all of the blade and hub fixings are secure - see Fig-8.

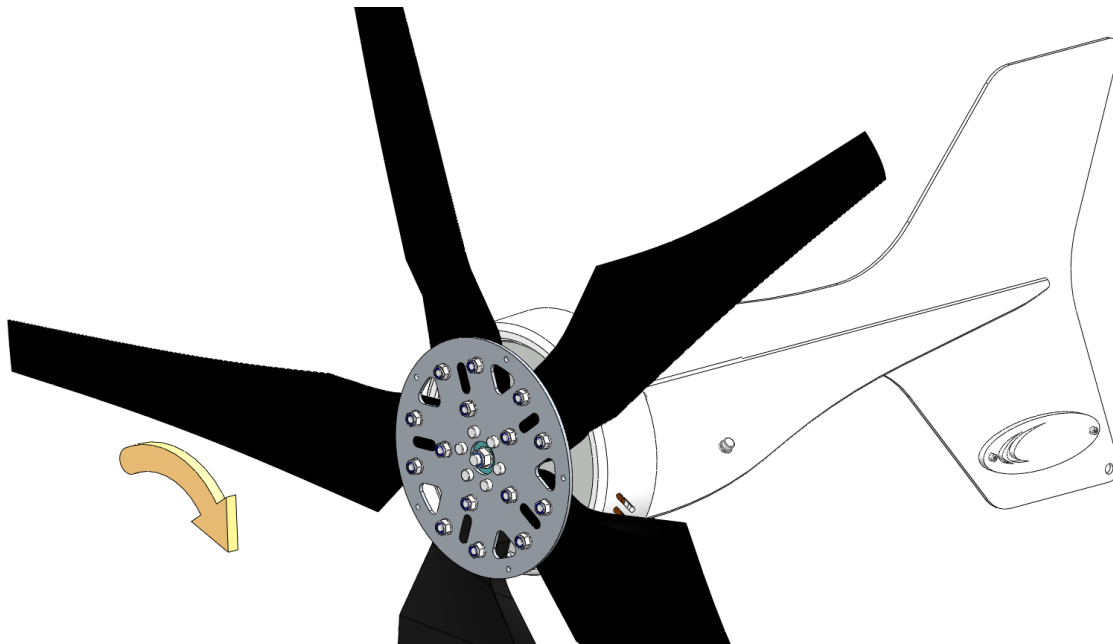


Fig-8: Check blade rotation

- 7) **Fit the Nose Cone** - The nose cone can now be fitted to the rotor. This is done by aligning the five mounting holes of the nose cone with those on the rotor hub plate. Use five M5 x 12 Cap Heads and five M5 washers to secure the nose cone in position - see Fig-9.

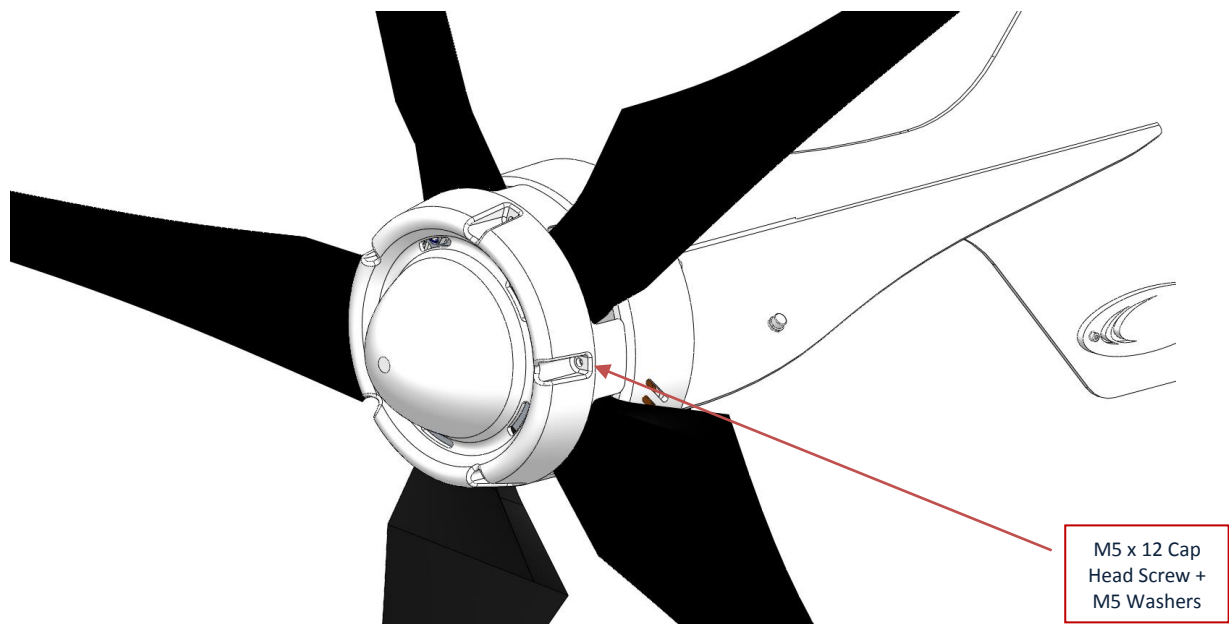


Fig-9: Attach the nose cone

- 8) **Prepare the Turbine Mount** - If you have purchased a *LE-450* mount bracket or tower from a *Leading Edge Turbines'* dealer, then please refer to the separate installation instructions supplied with the product. If you have sourced your own tower / mount bracket, 6.5 mm diameter holes will need to be drilled in order to secure the turbine. These holes should be drilled 10 mm & 25 mm from the top of the tower / mount bracket and should be perpendicular to the surface and skewed by 90 degrees. The holes should penetrate both sides and cross the centre line of the tubular section - see Fig-10.

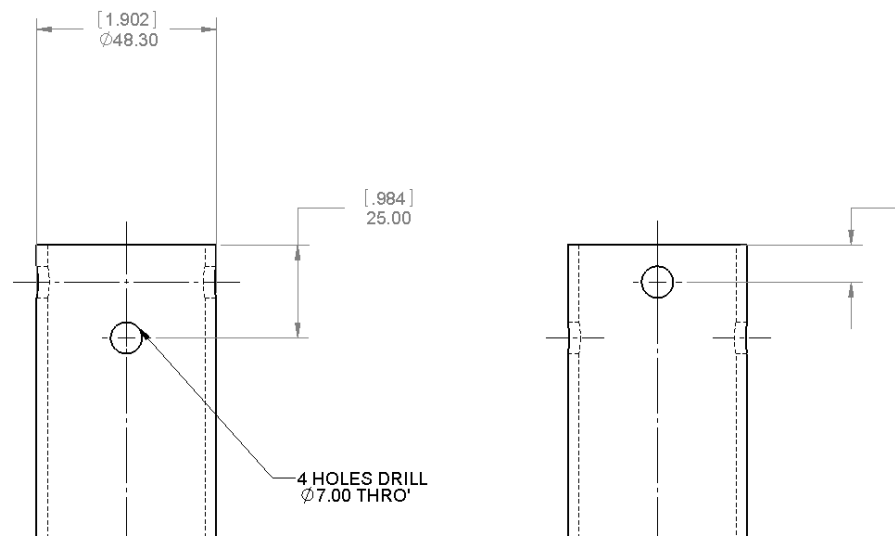


Fig-10: Drill through top of tower / mount bracket

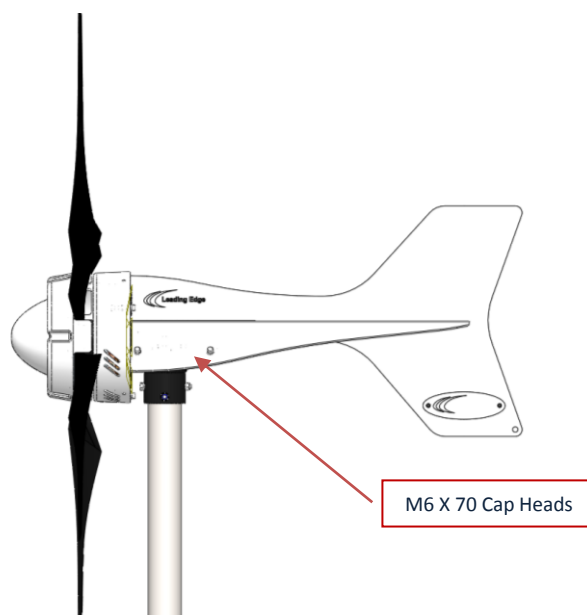
- 9) **Install the Transmission Cables** - When your tower or mount bracket is ready to receive its turbine, the next stage is to run the cables from the top of the tower to where the electrical controller and batteries / grid-tie inverter will be located. Follow the table below to select the correct wire size (cross-sectional area). This will vary depending on your nominal battery voltage and the distance that the cables will be run. Careful selection of the cable size is required. It will not only affect the safety of the system, but also the overall efficiency. A cable of insufficient cable size will cause a voltage drop, wasting the power that has been generated. The cable sizes listed below have been selected with efficiency and cost in mind, as it is unlikely that your turbine will be running at full capacity 100% of the time. If in doubt, consult your local electrical supplier. The cable should be installed in accordance with local electrical regulations and guidelines. If in doubt, use a local electrical contractor to complete the cable installation.

**Warning: If a cable of insufficient cross-sectional area is used, heat will build up in the cables causing a potential fire hazard. Cable capacities quoted below are based upon 'Tri-Rated' cables (BS6231).**

<b>LE-450 Nominal Output Voltage</b>	<b>Transmission Distance</b>		
	<b>10 Metres (30 Feet)</b>	<b>30 Metres (90 Feet)</b>	<b>100 Metres (300 Feet)</b>
<b>12 Volts</b>	6 mm <sup>2</sup>	10 mm <sup>2</sup>	Not Recommended
<b>24 Volts</b>	1.5 mm <sup>2</sup>	6 mm <sup>2</sup>	16 mm <sup>2</sup>
<b>48 Volts</b>	1.5 mm <sup>2</sup>	2.5 mm <sup>2</sup>	4 mm <sup>2</sup>

- 10) **Mount the LE-450 Turbine onto the Support Structure** - Ensure that the previously installed power transmission cables are not yet connected to any batteries and are 'shorted' together. This will prevent the turbine from operating during the installation process. Once this has been done, connect the turbine output cables to the transmission cables using a suitable terminal block with a minimum rating of 40 Amps. Offer the turbine up to the support structure and push the turbine body onto the tower. Ensure that no cables are snagged. Use the M6 x 70 Cap Heads along with two washers and an anti-vibration nut to secure the turbine using the holes previously drilled and the hole in the yaw pivot - see Fig-11. Ensure that M6 set-screws are securely fastened. Depending on the exact dimension of the tower, it may be necessary to use the supplied shim plate to ensure that the turbine is a snug fit upon the tower.

Use Yaw Shim if mounting to a 48.3mm Dia Pole



## Electrical Installation

Please refer to Figs 12 - 14 for appropriate generic wiring diagrams. In a battery charging renewable energy system there may be different ways of wiring small wind turbines, photovoltaic panels, charge controllers and batteries together. This type of system will often expand 'organically', but the following guidelines should be followed:

- **Follow the appropriate electrical code** - The electrical wiring of your LE-450 turbine and associated electrical systems must be done in accordance with national and local electrical codes and regulations.
- **Do not connect the turbine or batteries during the installation** - Ensure that the turbine is not running or connected to the batteries during the installation or wiring process. Connect the output cables of the turbine together to prevent the rotor from starting up.
- **Galvanic corrosion of electrical joints** - Try to avoid connections between dissimilar metals. For example, connecting copper and aluminium together will result in galvanic corrosion of the connection. This will increase the electrical resistance of the connection (wasting energy), and reduce the mechanical integrity of the joint. Where possible, use a fluxed solder to make electrical joints.
- **Protect the cables** - The power transmission cables must be protected from mechanical damage and fatigue. Run the cables through an approved conduit / trunking.
- **Cable strain relief** - Prevent mechanical strain on the transmission cables running down the tower from the turbine. Clip the cables to the inside of the tower. Failure to do this will result in excessive mechanical strain on the cable joints within the slip-ring assembly and may cause a failure. Cable ties or cable glands are a good way to prevent mechanical strain on the cables.
- **'Earth' the system** - The turbine tower should have its own separate earth point. The negative terminal of the battery bank should also be earthed. This provides protection against the build-up of static and lightning strikes. The tower should be earthed separately with its own ground rod if there is a long transmission distance between the tower and batteries. An appropriate surge arrestor could also be used to help prevent damage to the battery charging system during a lightning strike. Ensure that the earth cables are of the same rating as the positive and negative cables.
- **Cable Selection** - The cable size table should be used to select the minimum sized cable for a given transmission distance. Voltage drop in the cable will be improved if a larger cable is used. We recommend using 'Tri-Rated' cable as it should comply with the wiring codes for your area.
- **Fuses** - The turbine and charging circuit should be protected with a suitably rated 'slow-blow' DC fuse or DC circuit breaker. Please refer to the table below for the minimum fuse rating. Because a wind turbine is very unlikely to produce a current surge an in-line fuse is only really protecting against short circuit. The fuse or breaker should be positioned between the turbine and batteries (on the positive cable). If a stop switch is used (recommended) the fuse should be positioned between the switch and the batteries.

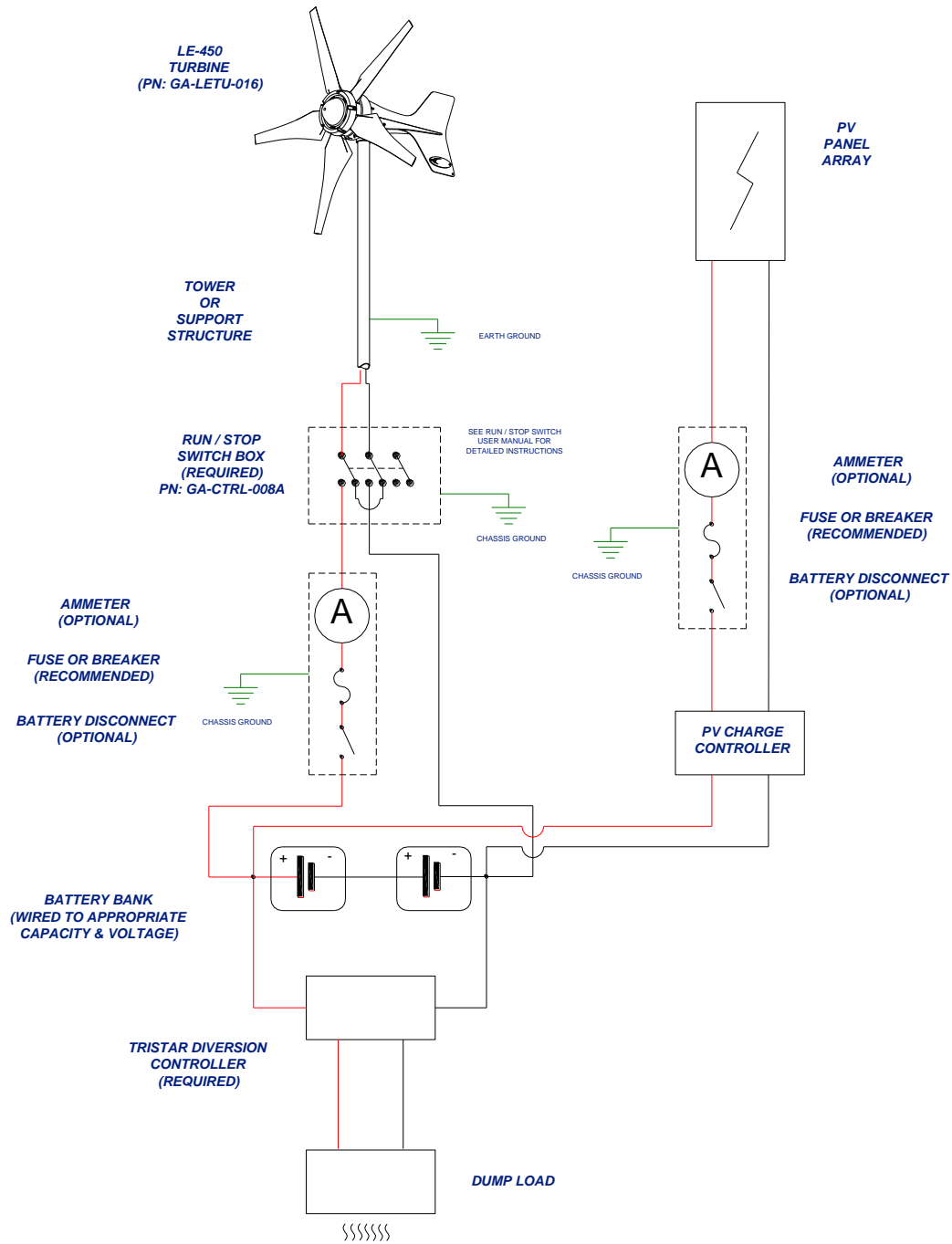
<b>LE-450 Nominal Output Voltage</b>	<b>DC Fuse / DC Circuit Breaker Rating</b>
<b>12V</b>	50 Amp
<b>24V</b>	30 Amp
<b>48V</b>	15 Amp

- **Run / Stop Switch** - A simple switch arrangement can provide a safe and easy way of stopping the turbine for maintenance. *Leading Edge Turbines* can supply a switch which is best for this purpose. As the switch is thrown, the batteries are disconnected and the turbine is 'shorted' reducing the blades to a slow rotation. Refer to the generic wiring diagrams.

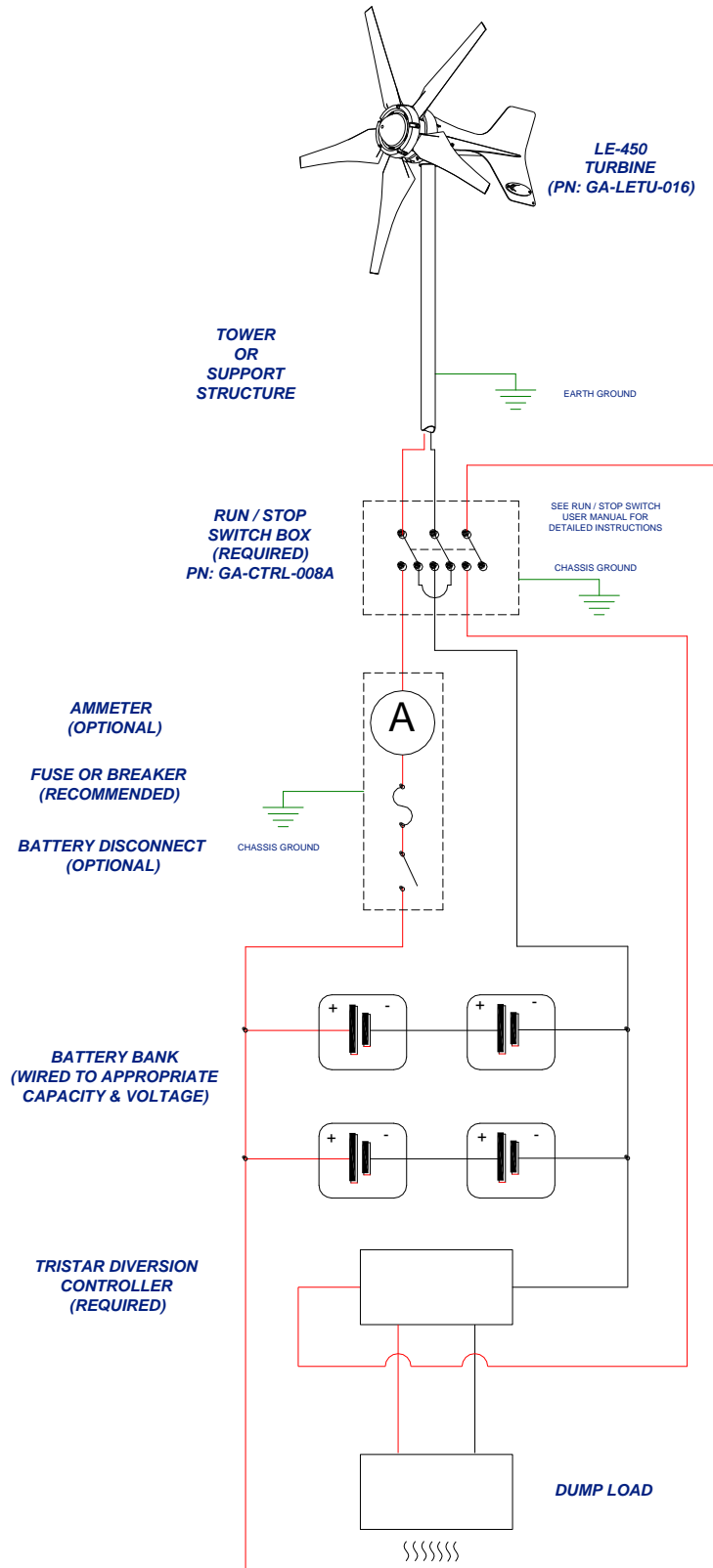
***If the cables you are using don't easily fit into the run / stop switch terminals, the cable can be reduced to 4mm<sup>2</sup> or 2.5mm<sup>2</sup> before entering the run / stop switch. The cable can then be increased again to its previous size after the switch and this will have a negligible effect on volt drop.***

- **Charge Controllers** – We recommend Tristar controllers for hybrid wind/PV systems as this allows you to set the regulation voltage very accurately. The Tristar should be used in Diversion mode along with a suitable Dump load. Please see Appendix 1 for details on wiring and configuring the Tristar diversion controller.
- **'Hybrid' Systems** - The *LE-450* turbine can be used in parallel with PV panels. We recommend that the PV panels are wired independently with a separate charge controller specifically designed for use with them and connected in parallel with the battery bank - see Fig-13. The Tristar diversion charge controller can then be configured to regulate at a slightly higher voltage than the PV charge controller - This will prevent the charge control systems for interfering with each other.
- **Installation on Yachts with shore power & engine alternator power sources-** When installed on a sailboat, the *LE-450* may be required to work alongside shore power systems and engine alternators. In these cases, it is important to ensure that the Tristar charge controller does not unintentionally 'dump' power from the shore power or engine alternator. This can be prevented by ensuring that the regulation set points on the shore power system and engine alternator are set below the regulation points of the Tristar diversion charge controller. This means that power from the shore power system and / or engine alternator will never be unintentionally 'dumped' through the dump load. If it is not possible to set the regulation points of the shore power / engine alternator below that of the Tristar (or similar charge controller), then the system should be wired in accordance with Fig 14 on Page 16 and the stop switch should be activated when the engine alternator or shore power system are in use. This will disconnect the diversion charge controller during use of shore power / engine alternator and will prevent unintentional dumping of power from these sources.

**Please refer to the following wiring diagrams as a guide.**



**Fig-12: Typical 'Hybrid' wind/PV System wiring diagram**



**Fig-13: Typical 'Marine' system wiring diagram (Tristar disconnects when the stop switch is activated – useful when the LE-450 turbine & Tristar controller are to be used in conjunction with shore power and engine alternator power sources).**



## Turbine Operation

The LE-450 turbine is based on a simple design for ease of installation and reliable operation. You may notice the following behaviour during normal operation:

- **Cut-in** - The turbine will not begin to charge the batteries until the rotor is spinning at approximately 300 RPM. Whilst operating below this speed, the turbine will be 'off-load' and freewheeling. Once the turbine output voltage becomes equal to the nominal battery voltage (at around 300 RPM), the turbine will come 'on-load' and begin to deliver current to the batteries. During the off-load stages of rotation, the rotor blades rotate very freely. This allows the rotor to build up speed and allows aerodynamic lift to be generated by the blades.
- **Normal Operation** - Once the rotor is spinning at 300 RPM, current will be delivered to the batteries. As the rotor speed increases, so too will the current and voltage. Excessive wind speed may increase the battery voltage to a high level. Once this happens the diversion charge controller will recognise that the battery voltage is too high and begin 'dumping' power to the heater module.
- **Charge Regulation** - Once the charge controller has switched over to the dump load, the turbine will no longer be charging the batteries. Instead, the power from the turbine will be delivered to the dump load (usually a resistive heater element). The battery voltage will begin to drop to normal levels during the regulation period. Once the battery voltage is back within acceptable limits, the charge controller will switch the turbine output back to the batteries. Refer to the charge controller user manual for specific operational instructions.
- **Shut Down** - By activating the stop switch, the output from cables of the turbine are 'shorted' together. This effectively puts an infinite load on the generator causing the turbine to stall. When the stop switch is activated the turbine may still rotate slowly during high winds, but the rotor blades will not be able to build up any significant speed. It is not recommended that the stop switch is activated whilst the rotor is spinning at high speed. This sudden braking action will stress the blades and other components. Only activate the stop switch during a 'lull' when the rotor is not spinning excessively fast.

**Warning – Using the Run /Stop Switch in strong winds > 40 mph.**

*In certain strong wind conditions the rotor can overpower the electromagnetic braking, which allows high currents to be produced in the stator coils. If this situation occurs for prolonged periods, damage to the turbine can occur. Therefore the Run / Stop switch should only be used to slow the unit prior to manually / mechanically tethering the turbine in very high winds. Either restrain the blades or swing the turbine to 90 degrees away from the wind and tether it in this position. A hole for tethering is provided in the tail-fin of the LE-450 (see Fig 16).*

- **Operation of the LE-450 in High Winds** - Every effort has been taken to ensure that the LE-450 will withstand the forces exerted by strong winds. However the raw power in high winds is immense and the stresses placed upon the turbine are magnified by gusty and turbulent conditions. Where possible the turbine should be shut down and tethered in advance of particularly strong, consistent winds (60+ mph) and storm conditions. This will decrease the wear and tear on the machine and will help to avoid a failure. Protect the turbine from extreme winds as you would protect other items of your property. ***Refer to the Shut Down procedure above.***



*Fig-16: Tethering the rotor blades using the hole on the tail-fin  
(shown on an LE-300 Turbine)*

***Note: Never allow the turbine to run off-load with no connection to a battery bank or grid-tie inverter. Doing so will allow open circuit voltages to be generated by the turbine. These voltages may be dangerous and may damage the stator coils within the turbine.***

## **Maintenance**

Please follow the preventive maintenance programme listed below. This will ensure that the turbine operates reliably and safely with good efficiency.

**Always shut down the turbine before attempting to carry out maintenance.**

### **Post-Installation Checks (to be carried out one month after installation):**

- Check that the tower mount pins are secure and have not worked loose. Adjust if required.
- Ensure that the rotor hub is still securely fitted.
- Ensure that the rotor blades rotate freely.
- Monitor the output. Ensure that the turbine and charge controller are functioning correctly.

### **Annual Maintenance:**

- Inspect the tower / support structure.
- Remove the turbine from its installation to a suitable workbench.
- Remove the rotor blade assembly.
- Inspect the edges of the rotor blades for damage such as dents or chips. The blades will become unbalanced if they are damaged. This will cause vibration, noise and poor performance. If many dents have occurred along the edges of the blades, a new set of rotor blades should be fitted (part numbers available in the Spares section).
- Inspect the roots of the blades (attachment tabs) for signs of stress cracking or fatigue. A new set of rotor blades should be fitted if any cracks or fractures have occurred (part numbers available in the Spares section).
- Remove any build-up of dirt and debris from the rotor blades using a mild detergent and warm water.
- Check the blade hub fixings for tightness.
- Carefully remove the yaw mount bracket by unscrewing the four connection screws from the sides of the LE-450 chassis. Inspect the slip rings and wipers for obvious signs of wear. Replace the wipers if required (part numbers available in the Spares section). Reassemble the yaw pivot carefully (do not pinch any cables).
- Check that all electrical connections are sound and free from corrosion.
- Generally ensure that the turbine is in good working condition and is safe for continued use.

### **After five years of normal operation:**

- We recommend that the rotor bearings and rotor blades should be replaced after five years of continuous operation. This will ensure that the turbine's performance and safety is not compromised.

### **Other Considerations:**

- The equipment used in the charging system (batteries, charge controller, PV panels, invertors, etc.) should be maintained according to the instructions published by the relevant manufacturer.
- Where lead-acid batteries are used, it is especially important that they are maintained carefully. Failure to do so will result in the batteries being rendered useless within a short period of time.

## **Spares**

The following components may need to be replaced during the service life of your *LE-450* turbine. Please contact your nearest *Leading Edge Turbines'* Dealer, and quote the part numbers listed below.

<b>Rotor Blade (set of 5)</b>	DP-LETU-145 (X5)
<b>Magnet Rotor</b>	SA-LETU-031
<b>Stator (12V / 24V / 48V)</b>	SA-LETU-027
<b>Yaw pivot &amp; Slip ring module</b>	SA-LETU-016
<b>Yaw Shim</b>	DP-LETU-153
<b>Nose cone</b>	DP-LETU-338
<b>Drive bearing (set of 2)</b>	OS-090 (X2)
<b>Rotor bearings and housing</b>	DP-LETU-155
<b>Run / Stop Switch</b>	GA-CTRL-008A
<b>Tristar Diversion Controller</b>	GA-CTRL-002A
<b>500W Dump Load (12V / 24V / 48V)</b>	CA-CTRL-006

## Warranty

Your *LE-450 turbine* from Leading Edge Turbines (LET) carries a two-year warranty, as supported by a retailer's receipt. The warranty starts from the date of installation or ninety (90) days after shipment from the LET factory, whichever comes first.

LET will supply 'non-wearing' parts at no cost. For minor component failures, replacements may be sent directly to the customer / dealer for replacement by them. For more serious defects we may suggest a 'return-to-base' arrangement for replacement or repair.

In these cases, the purchaser will be responsible for taking the turbine off the tower/mast and paying the return carriage costs.

Where a turbine is to be replaced, it must be returned to LET before the replacement unit is despatched. Should the product prove to be irreparable, LET reserves the right to substitute an equivalent product, if available.

This warranty does not extend to servicing a faulty turbine on location.

In all cases LET will take reasonable action to ensure customer satisfaction. You should always receive a warm, courteous service in or out of your warranty period.

Your turbine must be installed and operated in accordance with the guide. Failure to do so will result in this warranty becoming null and void. Any unauthorised modifications to the turbine design will void the warranty and may compromise the safety of the machine.

### What is not covered by your warranty?

- Damage caused by unsatisfactory installation of the turbine, tower and/or control equipment.
- Damage caused by the neglect of periodic maintenance in the manner recommended in the installation manual.
- Damage caused by repair or maintenance performed using methods not specified by LET or by non-authorised dealers of LET products.
- Damage caused by the use of non-genuine parts, or from the use of liquid agents or lubricants in or on the turbine, tower or control equipment.
- Damage caused by operating the turbine in conditions outside of those specified in the Owner's Guide – including, but not limited to, allowing the turbine to run while disconnected from the batteries or not configuring the Tristar charge controller for diversion mode.
- Damage caused by modifications to the turbine, tower or control equipment not approved by LET.
- Damage caused to the turbine, tower and control equipment by improper storage or transport.
- Damage caused by lightning strikes, flooding, fire, etc.
- Damage due to extremely high winds and storm conditions (18m/s, 40mph) and locations off-shore.
- Damage caused by flying debris.
- Damage to batteries due to excessive deep discharge, short-circuiting, excessively high load, over charging, loss of electrolyte, or any condition outside of the manufacturer's specification for battery use.
- Damage occurring as a result of not operating the turbine at a safe distance from individuals or property.
- Damage caused by unsatisfactory tower / support structure design.

- Damage caused by incorrect connection to external electrical equipment, or failure to observe current regulations concerning connection to external electrical networks, equipment or any other devices.

If you should experience a problem with your turbine, your first 'port-of-call' should be the reseller or installer from whom you purchased the product. They should be able to resolve the problem quickly and efficiently. If you are unable to contact the original reseller, then please contact us directly.

Please quote the serial number of your turbine when dealing with warranty issues. The serial number can be found on the nameplate positioned on the underside of the chassis.

### ***Disclaimer***

- All specifications are subject to change without prior notice.
- The information given in this user manual is believed to be accurate and reliable. *Leading Edge Turbines* assumes no responsibility for omissions or inaccuracies.
- The user of this information and product assumes full responsibility and risk.
- The *LE-450* turbine is a source of electrical power. It must be installed in accordance with local building and electrical regulations. Consult your local planning (zoning) office for details.
- The *LE-450* turbine has moving parts that may cause injury due to poor installation and unsafe operation. *Leading Edge Turbines* assumes no responsibility for problems caused by unsafe or unsatisfactory installation or operation.

Designed & Manufactured in the UK by:  
Leading Edge Turbines Ltd  
Skyrrid Farm,  
Pontrilas,  
Hereford.  
HR2 0BW  
Tel: +44 (0)1981 241668  
[www.leturbines.com](http://www.leturbines.com)



Designed in accordance with  
EN BS 61400-2: Safety of Small Wind

## Appendix 1: Tristar 45 Diversion Charge Controller



## ***Introduction***

Please read this manual and the specific manual for the Tristar Charge Controller before attempting to assemble, install or operate your Tristar Charge Controller. This will assure optimum performance and safety.

The Tristar Charge Controller and Dump Load is a 3<sup>rd</sup> party solution designed to prevent 12, 24 or 48V batteries from overcharging.

The Tristar Charge Controller and dump load operates like an electrical overflow for your batteries. As the turbine charges the batteries, the State of Charge (SOC) and battery voltage will rise. As the batteries become fully charged and are no longer able to accept any further electrical energy, the battery voltage will rise. At this point, the Tristar controller begins to bleed power into the dump load. This energy is then dissipated as heat into the surrounding environment. More or less power is diverted to the dump load according to how much is being supplied to the battery from the turbine.

## ***Safety Precautions***

Safety must always be your primary concern during the assembly, installation and operation of your turbine and charge controller. Always be aware of the risks involved with mechanical and electrical installation work. If in doubt about any issue regarding your turbine system, please seek further assistance before proceeding.

### **Mechanical Safety Hazards:**

Whilst installing the charge controller or when performing routine inspection or maintenance, always stop the turbine by activating the stop switch.

### **Electrical Safety Hazards:**

The Tristar controller and dump load operates with low voltage DC. Even at these low voltages there are inherent risks. Caution should always be used when connecting a turbine or charge controller to the electrical system.

***Location*** – The Tristar controller and dump load should be mounted in an adequately ventilated area, which is not exposed to direct moisture or spray. The dump load elements become hot during normal operation and should not be covered or blocked.

***The Dump load should not be mounted on a flammable surface due to the high temperatures that can be achieved by the dump load.***

Ensure that you have followed the cable-sizing guidelines to ensure that the correct size of cable has been selected. If a cable of insufficient cross-sectional area is used at any point in the electrical system, heat will build up in the cables causing a potential fire hazard. A properly-sized fuse or circuit breaker should be used in the cables connected to the battery. This will stop the risk of short circuit currents.

Batteries used in renewable energy systems can deliver a serious amount of current. A short circuit in the battery circuit can lead to hundreds of Amps flowing through the battery cables. This will cause a heat build-up and ultimately an electrical fire. Batteries are also susceptible to explode when shorted. Always use insulated electrical tools when working on the battery's electrical connections.

Batteries are very heavy. Do not attempt to move batteries by yourself. Always use manual handling tools and an assistant.



Always keep lead-acid batteries the correct way up. Do not allow the acidic electrolyte to spill or come into contact with your skin. Always follow the manufacturer's safety instructions when handling lead-acid batteries.

Please use common sense when installing and operating your turbine and Charge Controller.

### Electrical Installation

Please refer to the overall electrical schematic in the turbine installation for appropriate generic wiring diagrams. In a battery charging renewable energy system, there may be different ways of wiring small wind turbines, photovoltaic panels, charge controllers and batteries together. This type of system will often expand 'organically', but the following guidelines from the Morningstar Tristar user manual should be followed:

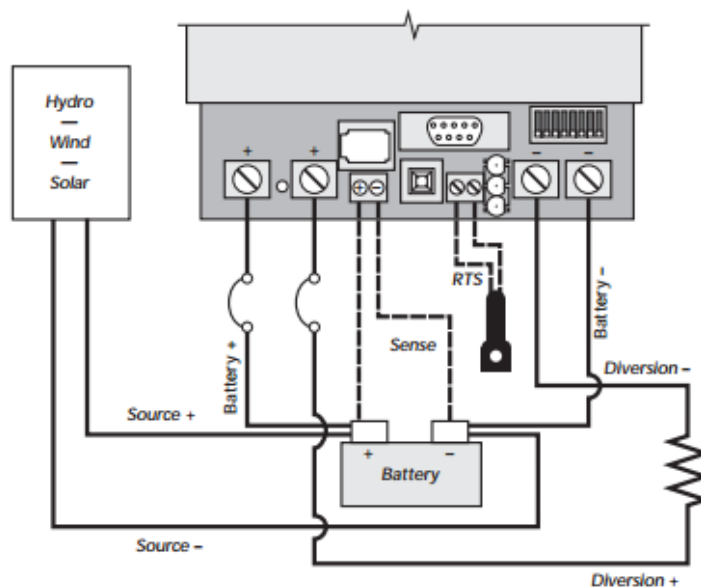


Figure 2.2c Installation Wiring for Diversion Charge Control

#### Step Diversion Charge Control

1. Remove the access cover
2. Mount the TriStar using the enclosed template.
3. Adjust the 8 switches in the DIP switch. Each switch must be in the correct position.
4. Attach the RTS if battery charging will be temperature compensated.
5. Connect battery voltage sense wires (recommended).
6. Connect the battery power wires to the TriStar. Then connect the diversion load wires.

#### Step Diversion Charge Control (continued)

7. Connect a computer to the TriStar if making adjustments with PC software.
8. Replace the cover.



NOTE: TriStar negative terminals are common negative.

Steps #4, #5, and #7 are optional.

## 2.3 Installation Steps

The TriStar controller must be installed properly and in accordance with the local and national electrical codes. It is also important that the installation be done safely, correctly and completely to realize all the benefits that the TriStar can provide for your solar system.

Refer to Sections 4.0 and 9.0 for information about the TriStar's standard battery charging programs and general charging needs for different battery types. Refer to Section 5.0 for load control information, and Section 6.0 for diversion.

Recommended tools:

- wire cutter
- torque wrench (to 50 in-lb)
- phillips screwdrivers
- slotted screw drivers
- wire stripper
- flashlight

Before starting the installation, review these safety notes:

- Do not exceed a battery voltage of 48V nominal (24 cells). Do not use a battery less than 12V (6 cells).
- Do not connect a solar input greater than a nominal 48V array for battery charging. Never exceed a Voc (open-circuit voltage) of 125V.
- Charge only 12, 24, or 48 volt lead-acid batteries when using the standard battery charging programs in the TriStar.
- Verify the nominal charging voltage is the same as the nominal battery voltage.
- Do not install a TriStar in a sealed compartment with batteries.
- Never open the TriStar access cover unless both the solar and battery power has been disconnected.
- Never allow the solar array to be connected to the TriStar with the battery disconnected. This can be a dangerous condition with high open-circuit solar voltages present at the terminals.

Follow the installation steps in order: #1 through #8

### Step 1 - Remove the Cover

Remove the 4 screws in the front cover. Lift the cover until the top edge clears the heat sink, and set it aside. If an LCD meter display is attached to the cover, disconnect the RJ-11 connector at the meter for access.



**CAUTION:** Do not remove the cover if power is present at any of the terminals. Verify that all power sources to the controller are disconnected.



**PRUDENCE :** N'enlevez pas le couvercle en cas de tension à une des bornes. Vérifiez que toutes les sources d'alimentation au contrôleur sont déconnectées.

### Step 2 - Mounting

Locate the TriStar on a wall protected from direct sun, high temperatures, and water. Do not install in a confined area where battery gasses can accumulate.



**NOTE:** When mounting the TriStar, make sure the air flow around the controller and heat sink is not obstructed. There should be open space above and below the heat sink, and at least 75 mm (3 inches) clearance around the heat sink to allow free air

flow for cooling.



**REMARQUE :** Lors du montage du TriStar, assurez-vous que l'écoulement d'air autour du contrôleur et du puits de chaleur n'est pas obstrué. Un espace doit se trouver au-dessus et en dessous du puits de chaleur et un dégagement de 75 mm (3 po) doit exister autour du puits de chaleur pour permettre l'écoulement de l'air à des fins de refroidissement.

Before starting the installation, place the TriStar on the wall where it will be mounted and determine where the wires will enter the controller (bottom, side, back). Remove the appropriate knockouts before mounting the controller. The knockouts are sized for 1 inch and 1.25 inch conduit.

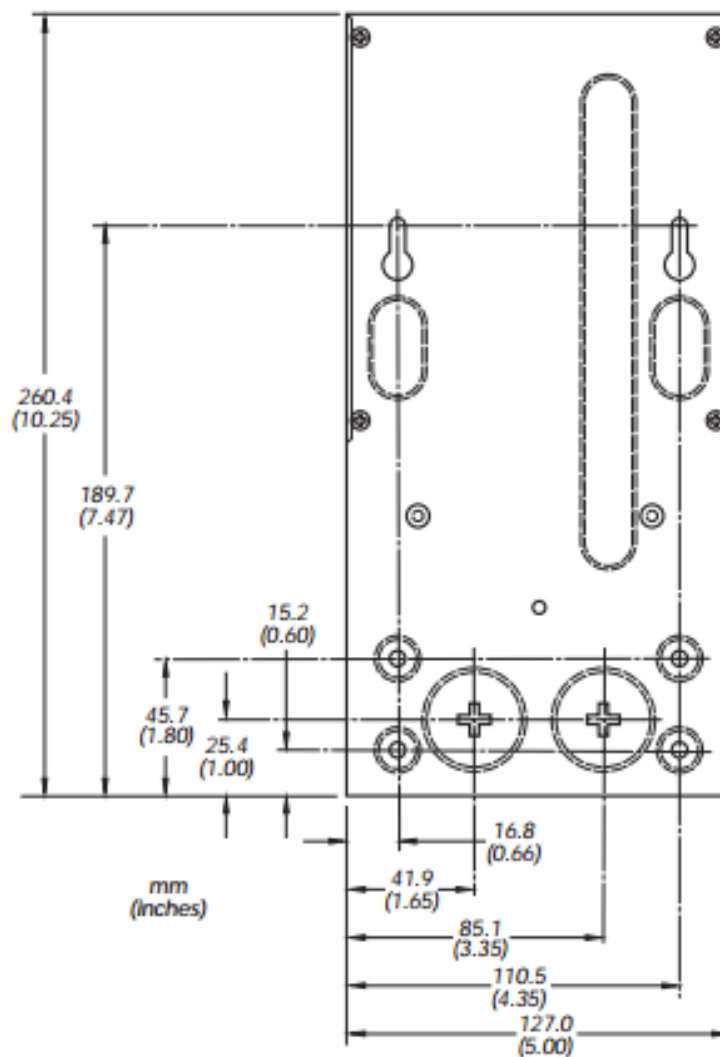


Figure 2.3 - Step 2 Mounting Dimensions

#### Step 2 - Mounting (continued)

Refer to Figure 2.3-2. Use the template provided in the shipping carton for locating the mounting holes and for stripping the wires. Use two of the #10 screws provided for the two keyhole slots. Leave the screw heads protruding enough to lock inside the keyhole slots (about 3.8 mm / 0.150 inch). Mount the controller and pull it down to lock the screws into the slots. Use the

remaining two screws to fasten the controller to the wall.

Provide for strain relief for the bottom knockouts if conduit will not be used.  
Avoid excessive pulling forces on the terminals from the wires.

### Step 3 - Adjust the DIP Switches

An 8-position DIP switch is used to set-up the controller for its intended use.  
All major functions can be set with the DIP switches. See Section 7.0 for additional custom settings using PC software.



**NOTE:** The DIP switches should be changed only when there is no power to the controller. Turn off disconnect switches and remove all power to the controller before changing a DIP switch. A fault will be indicated if a switch is changed while the controller is powered.

The Diversion Charge Control functions that can be adjusted with the DIP switches follow:

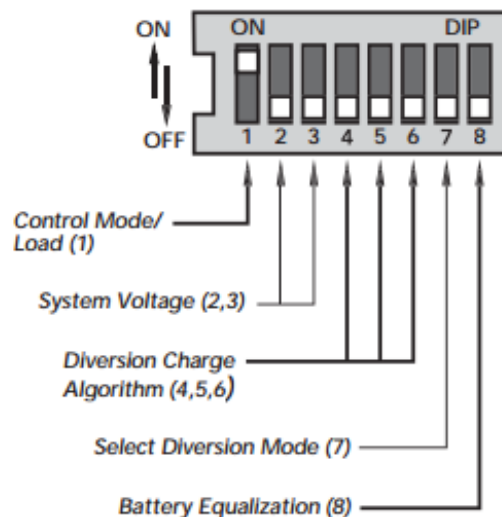


Figure 2.3 - Step 3 (Diversion) DIP Switch Functions

As shown in the diagram, all the positions are in the "OFF" position except switch number 1, which is in the "ON" position.



**NOTE:** The DIP switches should be changed only when there is no power to the controller. Turn off disconnect switches and remove all power to the controller before changing a DIP switch. A fault will be indicated if a switch is changed with the controller powered.



**REMARQUE :** Les commutateurs DIP ne doivent être changés que si le contrôleur est hors tension. Mettez les interrupteurs sur arrêt et mettez le contrôleur hors tension avant de changer un commutateur DIP. Une panne sera indiquée en cas de changement d'un commutateur quand le contrôleur est sous tension.



**CAUTION:** The TriStar is shipped with all the switches in the "OFF" position. Each switch position must be confirmed during installation. A wrong setting could cause damage to the battery or other system components.



**PRUDENCE :** Le TriStar est expédié avec tous les interrupteurs en position « ARRÊT ». La position de chaque interrupteur doit être confirmée pendant l'installation. Un mauvais réglage peut endommager la charge ou d'autres composants du système.

The DIP switch settings described below are Diversion Charge Control only.

The DIP switches are shipped in the OFF position. With switches 2-8 in the OFF



position, the following functions are present:

Switch	Function
1	Must be "ON" (load control)
2, 3	Auto voltage select
4, 5, 6	Lowest battery charging voltage
7	Must turn "ON" to select Diversion
8	Manual Equalization

To configure your TriStar for the diversion battery charging and control you require follow the DIP switch adjustments described below. To change a switch from OFF ON, slide the switch up toward the top of the controller. Make sure each switch is fully in the ON or OFF position.

#### DIP Switch Number 1 - Control Mode: Solar Battery Charging

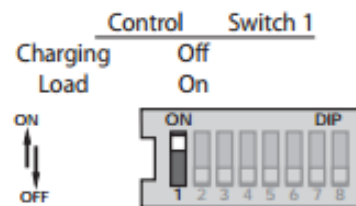


Figure 2.3 - Step 3 DIP Switch #1

For the Diversion Charge Control mode, move the DIP switch to the ON position as shown.

#### DIP Switches Number 2,3 - System Voltage:

Voltage	Switch 2	Switch 3
Auto	Off	Off
12	Off	On
24	On	Off
48	On	On

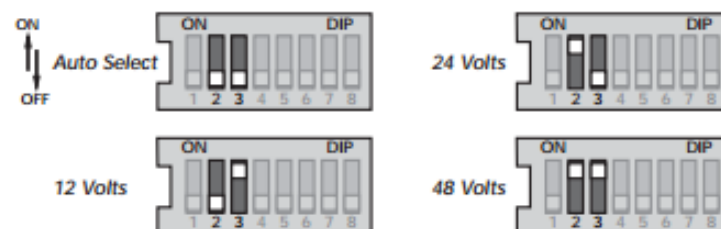


Figure 2.3 - Step 3 DIP Switches # 2,3

The auto voltage selection occurs when the battery is connected and the TriStar starts-up. There should be no loads on the battery that might cause a discharged battery to indicate a lower system voltage.

The DIP switch default voltages are for 12V, 24V or 48V lead-acid batteries. Although the "auto voltage" selection is very dependable, it is recommended to use the DIP switches to secure the correct system voltage.

### DIP Switches Number 4,5,6 - Diversion Charge Control:

Battery Type	PWM	Switch 4	Switch 5	Switch 6
1	13.8	Off	Off	Off
2	14.0	Off	Off	On
3	14.2	Off	On	Off
4	14.4	Off	On	On
5	14.6	On	Off	Off
6	14.8	On	Off	On
7	15.0	On	On	Off
8	Custom	On	On	On

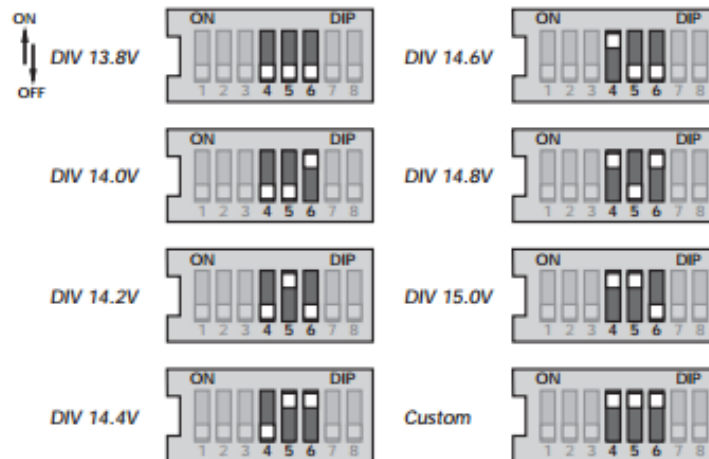


Figure 2.3 - Step 3 DIP Switches # 4,5,6

Select one of the 7 standard diversion charging algorithms, or select the "custom" DIP switch for special custom settings using the PC software.

Refer to Section 6.3 for information describing the 7 standard diversion charging algorithms. Refer to Section 9.0 of this manual for battery charging information.

### DIP Switch Number 7 - Select Diversion:

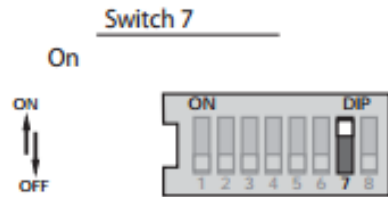


Figure 2.3 - Step 3 DIP Switch # 7

In the Diversion Charge Control mode, DIP switch #7 must be in the ON position.

### DIP Switch Number 8 - Battery Equalization:

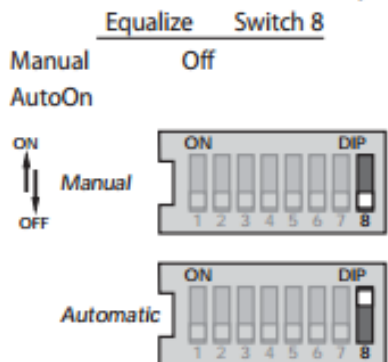


Figure 2.3 - Step 3 DIP Switch # 8

In the Auto Equalization mode (switch #8 On), battery equalization will automatically start and stop according to the battery program selected by the DIP switches 4,5,6 above. See Section 6.0 for detailed information about each standard diversion battery charging algorithm and equalization.

In the Manual Equalization mode (switch #8 Off), equalization will occur only when manually started with the pushbutton. Automatic starting of equalization is disabled. The equalization will automatically stop per the battery algorithm selection.

In both cases (auto and manual mode), the pushbutton can be used to start and stop battery equalization.



**NOTE:** Confirm all dip-switch settings before going to the next installation steps.



**REMARQUE :** Confirmez les réglages de tous les commutateurs dip avant de passer aux étapes suivantes d'installation.

The TriStar's third mode of operation is diversion load battery charge control. As the battery becomes fully charged, the TriStar will divert excess current from the battery to a dedicated diversion load. This diversion load must be large enough to absorb all the excess energy, but not too large to cause a controller overload condition.

## 6.1 Diversion Charge Control

In the diversion mode, the TriStar will use PWM charging regulation to divert excess current to an external load. As the battery becomes fully charged, the FET switches are closed for longer periods of time to direct more current to the diversion load.

As the battery charges, the diversion duty cycle will increase. When fully charged, all the source energy will flow into the diversion load if there are no other loads. The generating source is typically a wind or hydro generator. Some solar systems also use diversion to heat water rather than open the solar array and lose the energy.

The most important factor for successful diversion charge control is the correct sizing of the diversion load. If too large, the controller's protections may open the FET switches and stop diverting current from the battery. This condition can damage the battery.

If you are not confident and certain about the installation, a professional installation by your dealer is recommended.

## 6.2 Diversion Current Ratings

The maximum diversion load current capability for the two TriStar versions is 45 amps (TS-45) and 60 amps (TS-60). The diversion loads must be sized so that the peak load current cannot exceed these maximum ratings.

See section 6.4 below for selecting and sizing the diversion loads.

The total current for all combined charging sources (wind, hydro, solar) should be equal or less than two-thirds of the controller's current rating: 30A (TS-45) and 40A (TS-60). This limit will provide a required margin for high winds and high water flow rates as well as a margin for error in the rating and selection of the diversion load. This protects against an overload and a safety disconnect in the TriStar controller, which would leave the battery charging unregulated.



**CAUTION:** If the TriStar's rating is exceeded and the controller disconnects the diversion load, Morningstar will not be responsible for any damage resulting to the system battery or other system components. Refer to Morningstar's Limited Warranty in Section 10.0.



**PRUDENCE :** Si la capacité du TriStar est dépassée et que le contrôleur déconnecte la charge de diversion, Morningstar ne sera pas responsable de tout dommage résultant de la batterie du système ou d'autres composants du système. Reportez-vous à la Garantie limitée de Morningstar dans la Section 10.0.

## 6.3 Standard Diversion Battery Charging Programs

The TriStar provides 7 standard diversion charging algorithms (programs) that are selected with the DIP switches. An 8th algorithm can be used for custom setpoints using the PC software.



The table below summarizes the major parameters of the standard diversion battery charging algorithms. Note that all the voltages are for 12V systems (24V = 2X, 48V = 4X).

All values are 25°C (77°F).

	A.	B.	C.	D.	E.	F.	G.
DIP Switches (4-5-6)	PWM Absorp. Voltage	Float Voltage	Time Until Float (hours)	Equalization Voltage	Time in Equal. (hours)	Equalize Interval (days)	Max. Equalize Cycle (hours)
off-off-off	13.8	13.6	4	14.1	3	28	3
off-off-on	14.0	13.6	4	14.3	3	28	3
off-on-off	14.2	13.6	4	14.5	3	28	4
off-on-on	14.4	13.6	4	14.7	4	28	4
on-off-off	14.6	13.7	4	14.9	4	28	5
on-off-on	14.8	13.7	4	15.1	4	28	5
on-on-off	15.0	13.7	4	15.3	4	28	5
on-on-on	Custom		Custom		Custom		

Table 6.3 Standard Diversion Charging Programs

A. PWM Absorption Voltage - This is the PWM Absorption stage with constant voltage charging. The PWM absorption voltage is the maximum battery voltage that will be held constant.

B. Float Voltage - When the battery is fully charged, the charging voltage will be reduced to the float voltage for all diversion settings. The float voltage and transition values are adjustable with the PC software.

C. Time Until Float - This is the cumulative time in PWM before the battery voltage is reduced to the float voltage. If loads are present during the PWM absorption, the time to transition into float will be extended.

D. Equalization Voltage - During an equalization cycle, the charging voltage will be held constant at this voltage. Equalizations are manual, and can be selected for automatic (See Section 4.4.1).

E. Time in Equalization - Charging at the selected equalization voltage will continue for this number of hours.

F. Equalization Interval - Equalizations are typically done once a month. The cycles are 28 days so the equalization will begin on the same day of the week. Each new cycle will be reset as the equalization starts so that a 28 day period will be maintained.

G. Maximum Equalization Cycle - If the battery voltage cannot reach the equalization voltage, the equalization will terminate after this number of hours to avoid over gassing or heating the battery. If the battery requires more time in equalization, the manual pushbutton can be used to continue for one or more additional equalization cycles.

### 3.1 Battery Charging References

The diversion load battery charging is similar to conventional solar charging. Refer to the following sections in this manual for additional battery charging information.

- 4.1 Four stages of charging (applies to diversion)
- 4.3 Temperature Effects and Battery Voltage Sense
- 4.4 Equalization
- 4.5 Float

## 9.0 Battery Information

### 6.4 Selecting the Diversion Load

---

It is critical that the diversion load be sized correctly. If the load is too small, it cannot divert enough power from the source (wind, hydro, etc). The battery will continue charging and could be overcharged.

If the diversion load is too large, it will draw more current than the rating of the TriStar. The controller's overload protection may disconnect the diversion load, and this will result in all of the source current going to the battery.



**CAUTION:** The diversion load must be able to absorb the full power output of the source, but the load must never exceed the current rating of the TriStar controller. Otherwise, the battery can be overcharged and damaged.

---



**PRUDENCE :** La charge de diversion doit être capable d'absorber toute la puissance de sortie de la source, mais la charge ne doit jamais dépasser l'intensité nominale du contrôleur TriStar, pour ne pas surcharger et endommager la batterie.

---

#### 7.4.1 Suitable Loads for Diversion

Water heating elements are commonly used for diversion load systems. These heating elements are reliable and widely available. Heating elements are also easy to replace, and the ratings are stable.



**NOTE:** Do not use light bulbs, motors, or other electrical devices for diversion loads. These loads will fail or cause the TriStar to disconnect the load. Only heating elements should be used.

---



**REMARQUE :** N'utilisez pas d'ampoules, de moteurs ou d'autres appareils électriques pour les charges de diversion. Ces charges ne fonctionneront pas ou provoqueront une déconnexion de la charge par le TriStar. Seuls les éléments de chauffe doivent être utilisés.

---

Water heating elements are typically 120 volts. Elements rated for 12, 24 and 48 volts are also available, but more difficult to source. The derating for 120 volt heating elements is discussed in 6.4.3 below.

#### 6.4.2 Definition of Terms

**Maximum Source Current:**

This is the maximum current output of all the energy sources (hydro, wind, solar, etc.) added together. This current will be diverted through the TriStar to the diversion load.

**Maximum Battery Voltage:**

This maximum voltage is the PWM regulation voltage selected with the DIP switches, plus the increase with an equalization, plus the increase due to lower temperatures. The highest battery voltage is commonly 15, 30 and 60 volts for 12-, 24- and 48-volt systems.

**Peak Load Current:**

At the maximum battery voltage, this is the current the diversion load will

draw. This peak load current must not exceed the TriStar's rating.



NOTE: Because the battery can supply any size load, the peak load current is not limited by the source (hydro or wind rating). The diversion load's power rating is the critical specification for reliable battery charging.



REMARQUE : La batterie pouvant fournir une charge de n'importe quelle dimension, le pic d'intensité de la charge n'est pas limité par la source (puissance hydro ou éolienne). La puissance nominale de la charge de diversion constitue la spécification critique pour une charge fiable de la batterie.

#### 6.4.3 Load Power Ratings

The power rating of the diversion load will depend on the voltage of the battery being charged. If the heating element is not rated for the same voltage as the diversion system, the power rating of the load must be adjusted to the diversion system's voltage.

The manufacturers typically rate the heating elements for power at a specified voltage. The peak load current at the load's rated voltage will be the power divided by the rated voltage ( $I = P / V$ ). For example:  
 $2000W / 120V = 16.7$  amps of current.

If the load is being used at a voltage less than the load's rated voltage, the power can be calculated by the ratio of the voltages squared. For example, a 120 volt 1000 watt heating element being used at 60 volts:

$$1000W \times (60/120)^2 = 250 \text{ watts}$$

The 1000W element will only dissipate 250W when being used at 60 volts.



NOTE: The loads (heating elements) can be used at the manufacturer's voltage rating, or at a lower voltage. Do not use the load at a higher voltage than the load's rating.



REMARQUE : Les charges (éléments de chauffe) peuvent être utilisées à la tension nominale du fabricant ou à une tension inférieure. N'utilisez pas la charge à une tension supérieure à la tension nominale.

#### 6.4.4 Maximum Diversion Load

The diversion load should never exceed the TriStar's current rating (45A or 60A). Note that the load is not limited by the source (wind, hydro), and will draw its rated current from the battery.

The following table specifies the absolute maximum diversion loads that can be used with each TriStar version. These loads (heating elements) are rated for the same voltage as the system voltage.



Nominal Voltage	TriStar-45	TriStar-60
48V	2700W at 60V	3600W at 60V
24V	1350W at 30V	1800W at 30V
12V	675W at 15V	900W at 15V

These maximum power ratings are translated to the equivalent at 120 volts in the following table. If using heating elements rated for 120 volts, the power ratings of all the elements can be simply added up and the sum compared with this table and no further math is required.

Nominal Voltage	TriStar-45	TriStar-60
48V	10,800W at 120V	14,400W at 120V
24V	21,600W at 120V	28,800W at 120V
12V	43,200W at 120V	57,600W at 120V

To illustrate the same point from the opposite perspective, a heating element rated for 120 volts will draw reduced load current as indicated by the following table. A standard 2,000 watt / 120 Vac heating element is used as the reference.

Voltage	Power	Current
120V	2000 W	16.7 A
60V (48V nominal)	500 W	8.3 A
30V (24V nominal)	125 W	4.2 A
15V (12V nominal)	31 W	2.1 A

Whether using dc rated loads (the first table) or 120V elements, the total diversion load current must not exceed the current rating of the TriStar.

#### 6.4.5 Minimum Diversion Load

The diversion load must be large enough to divert all the current produced by the source (wind, hydro, etc.). This value is the maximum battery voltage times the maximum source current.

For example, if a hydro source can generate up to 30 amps of current in a nominal 48 volt system (60V maximum), the minimum diversion load size =  $60V \times 30A = 1,800$  watts (for loads rated at 60 volts).

##### General Sizing Example

Consider a 24V system with a wind turbine that is rated to generate 35A of current. A TriStar-45 will not provide the 150% diversion load margin, and the TS-45 is only rated for 30A of source current. The TS-45 will not provide enough margin for wind gusts and overloads, so a TS-60 should be used.

The diversion load should be sized for 52.5A (150% of the source current) up to 60A (the rating of the TriStar-60). If 55A is selected for the diversion load, the load must be capable of diverting 55A at 30V (maximum battery voltage). If a 30V heating element is used, it would be rated for 1,650 watts (or from 1,575W to 1,800W per the load range noted above).

If a 2,000 watt / 120 volt heating element is used, 13 of these elements in parallel will be required for the diversion load (4.2 amps per element [Table in 6.4.4]  $\times$  13 = 54.6 amps).

The minimum diversion load would be the source output (35A) times the voltage (30V). This would require a 1,050 watt heating element rated at 30 volts. Or if a 2,000W heater element rated for 120 volts is used, 9 heater elements will be required to draw the required minimum diversion load at 30 volts.

## 6.5 NEC Requirements

To comply with NEC 690.72 (B), the following requirements will apply when the TriStar is being used as a diversion charge controller in a photovoltaic system.

### 6.5.1 Second Independent Means

If the TriStar is the only means of regulating the battery charging in a diversion charging mode, then a second independent means to prevent overcharging the battery must be added to the system. The second means can be another TriStar, or a different means of regulating the charging.

### 6.5.2 150 Percent Rating

The current rating of the diversion load must be at least 150% of the TriStar source current rating. Refer to Section 6.2 (Diversion Current Rating). The maximum allowable current ratings for both TriStar versions are summarized below:

	Max. Input Current	Max. Diversion Load Rating
TS-45	30 A	45 A
TS-60	40 A	60 A



**CAUTION:** The NEC requirement that the diversion load must be sized at least 150% of the controller rating does NOT mean the diversion load can exceed the maximum current rating of the TriStar. NEVER size a diversion load that can draw more than the 45 amps or 60 amps maximum rating of the TriStar controllers.



**PRUDENCE :** L'obligation de la CNE indiquant que la charge de diversion doit être 150 % plus grande que la puissance nominale du contrôleur NE signifie PAS que la charge de diversion peut dépasser l'intensité maximum du TriStar. Ne dimensionnez JAMAIS une charge de diversion qui peut appeler plus de 45 A ou l'intensité maximum de 60 A des contrôleurs TriStar.

## 6.6 Additional Information

Visit Morningstar's website ([www.morningstarcorp.com](http://www.morningstarcorp.com)) for additional diversion charge control information. The website provides expanded technical support for more complex diversion load systems.

## 8.0 Self-Testing / Diagnostics

The TriStar performs a continuous self-test to monitor controller and system operation. Detected problems are classified as either faults or alarms. Typically, faults are problems that stop the normal operation of the controller and require immediate attention. Alarms indicate an abnormal condition, but will not stop the controller's operation.

If a problem is detected, the TriStar will alert the user to an existing fault or alarm. In this situation, the LED indicators will flash a particular sequence. Section 3.3 references these sequences with their associated faults and alarms. Flashing LED sequences can indicate conditions ranging from a simple battery service reminder to an existing short circuit in the system. It is recommended that the user become familiar with the LED indications and their meanings.

If a TriStar meter option has been added, more detailed information concerning faults and alarms will be available. Menus provide text displays of the specific fault as well as indicating on the standard display screens when a problem exists. Consult the meter manual for further details.

### General Troubleshooting

TriStar is not powering up

- Confirm that all circuit breakers and switches in the system are closed
- Check all fuses
- Check for loose wiring connections and wiring continuity
- Verify that the battery voltage is not below 9Vdc (brownout: section 3.4)
- Verify that the battery power connection is not reversed polarity

Flashing/Sequencing LEDs

- Reference Section 3.3 for a list of LED indications and their corresponding faults/alarms

Self-Test Indication (R - Y - G sequencing)

- Self-testing will also detect various system wiring faults outside the TriStar
- Check for both TriStar faults and external system wiring problems

The RTS or Battery Sense is not working properly

- R/Y - G/Y sequencing LEDs indicates an RTS or Sense fault
- Check for a reverse polarity connection on the sense leads
- Verify that the RTS and Sense connections are wired to the correct terminals
- Check for shorts and continuity in the cables
- Verify that good electrical contact is made at the terminals
- Note that if the TriStar is restarted with an RTS or Sense fault present, it will not detect the RTS or Sense connection and the LED indication will stop

### Troubleshooting Diversion Control

- Diversion load is too small so PWM reaches 99%
- Diversion load is burned out so PWM reaches 99%
- Diversion load is too large so TriStar faults on overcurrent
- An overtemperature condition may have caused the load to be disconnected
- The RTS is not correcting for high or low temperatures
- Voltage drops between the TriStar and battery are too high

## ***Appendix 2: Run / Stop Switch User Manual***



Only operate in light winds



## ***Introduction***

Please read this manual thoroughly before attempting to assemble, install or operate your Universal Run / Stop Switch. This will assure optimum performance and safety.

The Universal Run / Stop Switch is designed to allow the user to dynamically brake an *LE-450* turbine at will. This is achieved by disconnecting the power output of the turbine from the relevant load and diverting it to a short circuit which then applies the dynamic braking effect on the permanent magnet alternator of the turbine. This will bring the turbine to a near stop for maintenance only.

The Universal Run / Stop Switch can be used with turbines of different manufacture as long as the relevant turbine has the following characteristics:

3-Phase Wild AC not exceeding 500 V & 16 A  
Wild DC not exceeding 150 V & 10 A  
Mechanically and electrically capable of dynamic braking

## ***Operation & Specification***

The Universal Run / Stop Switch should be operated during low speeds as repeated use at high speeds may cause damage if the turbine head (it was not designed to withstand repeated dynamic braking operations).

The switch has two positions:

Position 1: Turbine 'Stop' position. The turbine is dynamically braked and may be seen to rotate very slowly.

Position 2: Turbine 'Run' position. The turbine output is allowed to flow straight through the switch to the relevant output.

## ***Safety Precautions***

Safety must always be your primary concern during the assembly, installation and operation of your turbine and other associated equipment. Always be aware of the risks involved with mechanical and electrical installation work. If in doubt about any issue regarding your turbine system, please seek further assistance before proceeding.

**Mechanical Safety Hazards:**

Whilst installing the Universal Run / Stop Switch, ensure that the turbine is suitably restrained and not allowed to operate during the installation.

**Electrical Safety Hazards:**

The *LE-450* generates rectified DC voltage and the Universal Run / Stop Switch also operates at these voltages. Even at these low voltages there are inherent risks. Caution should always be used when connecting the *LE-450* or other equipment to the electrical system.

Ensure that you have followed the cable-sizing guidelines to ensure that the correct size of cable has been selected. If a cable of insufficient cross-sectional area is used at any point in the electrical system, heat will build up in the cables causing a potential fire hazard. A properly-sized fuse or circuit breaker should be used in the cables connected to the battery. This will stop the risk of short circuit currents.



Batteries used in renewable energy systems can deliver a serious amount of current. A short circuit in the battery circuit can lead to hundreds of Amps flowing through the battery cables. This will cause a heat build-up and ultimately an electrical fire. Batteries are also susceptible to exploding when shorted. Always use insulated electrical tools when working on the battery's electrical connections.

Batteries are very heavy. Do not attempt to move batteries by yourself. Always use manual handling tools and an assistant. Always keep lead-acid batteries the correct way up. Do not allow the acidic electrolyte to spill or come into contact with your skin. Always follow the manufacturer's safety instructions when handling lead-acid batteries. Ensure that the Universal Run / Stop switch is correctly wired as per these instructions and wiring schematics. Incorrect wiring may lead to a short circuit being placed across the batteries which can lead to fire or explosion.

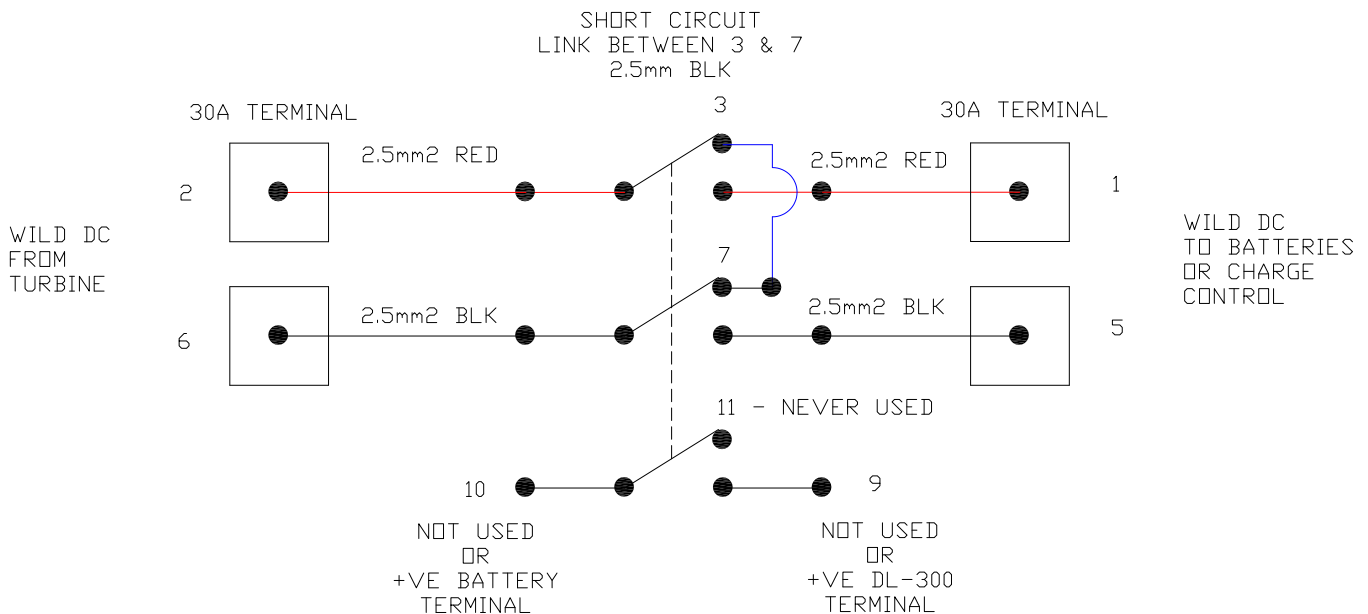
Please use common sense when installing and operating your turbine and associated equipment.

### Installation

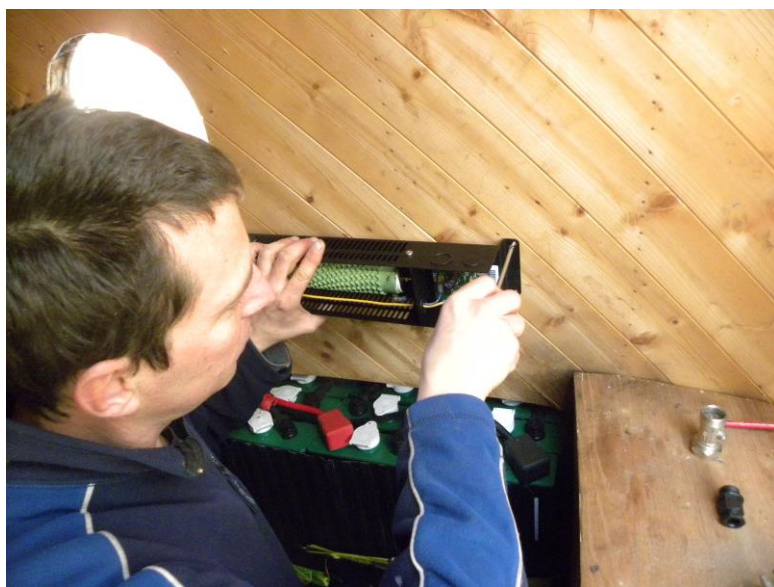
Please refer to electrical schematic for appropriate generic wiring diagrams. If the cables you are using don't easily fit into the run / stop switch terminals, the cable can be reduced to 4mm<sup>2</sup> or 2.5mm<sup>2</sup> before entering the run / stop switch. The cable can then be increased again to its previous size after the switch and this will have a negligible effect on volt drop.

The Universal Run / Stop Switch can either be mounted in the enclosure box (supplied), which in turn can be mounted on an internal panel, or the switch can be integrated into an existing panel. If the unit is to be integrated into an existing panel, a suitable cut-out, as detailed on the wiring diagram will need to be made.

**Switch Wiring for LE-450 Turbine – please ensure all 12 screw terminals of the switch are screwed closed before finally placing the top cover on the switch:**



### ***Appendix 3: System Trouble-Shooting***



## ***Introduction***

Small wind turbines are a complex mixture of mechanical, aerodynamic, electrical, electronic and civil engineering. Even with the most careful installation, it is possible that problems may occur during the installation or at some point during the life of the turbine.

The following headings are designed to help the installation engineer or turbine user to identify and resolve any issues with the system as a whole. Before referring to the trouble-shooting guide, ensure that the turbine has been correctly installed as per the instructions described earlier in this user manual.

## ***Common Problems pertaining to Installation***

### ***Issue:***

The turbine spins extremely quickly and noisily but doesn't deliver any electrical current to the batteries.

### ***Potential Causes:***

- The turbine may be running in an off-load state meaning that the circuit from the turbine to the batteries is not complete. In this situation, the turbine is free spinning and the turbine may be generating higher voltages than anticipated from the turbine output cables. Check that all of the connections from the turbine, through the run / stop switch to the batteries are correct. If a fuse or circuit breaker has been fitted to the turbine, ensure that this is correctly closing the circuit. Never leave the turbine running in an off-load state as it may cause damage to the turbine during high winds.
- The turbine may have developed an internal wiring fault which has resulted in a broken circuit. In this situation, the turbine is free spinning but no voltage will be measureable at the turbine output cables. If an internal fault is present, please contact your dealer or Leading Edge Turbines for further advice.

### ***Issue:***

The rotor hub plate fixings do not correctly grip the rotor hub plate which means that the rotor hub plate can rattle slightly.

### ***Potential Causes:***

- The rotor hub fixings have been positioned incorrectly in the drive bearing hub. Remove the fixings and replace them in the next hole over. This should allow the fixings to be completely tightened meaning that the rotor hub plate will be correctly installed.

### ***Issue:***

A slight oscillation can be observed in the turbine tail fin whilst the turbine is rotating at certain speeds.

### ***Potential Causes:***

- Due to the nature of small wind turbines, a small level of oscillation is acceptable as the turbine passes through certain speeds. This oscillation movement can be minimised by ensuring that the distance between each tip is within tolerance (please see step 4, page 8). Ensure, also, that the assembled rotor is correctly and concentrically fitted to the drive bearing housing.

**Issue:**

The turbine frequently comes to rest in the same horizontal position, regardless of which direction the wind is coming from.

**Potential Causes:**

- Turbines require that their towers are vertical. Although the *LE-450* is fitted with counterweights to compensate for the pitching and rolling of a yacht, it is still recommended in all applications that the turbine tower is set to be perfectly vertical. The *LE-450* is designed to be slightly tail heavy so that when it is fitted to a yacht that is heeling in the wind, the turbine will favour the windward side.

**Issue:**

The turbine never seems to reach its operating speed and does not give any or very little power output.

**Potential Causes:**

- You may have installed a 24V turbine on a 12V battery system. This means that the turbine will reach its cut-in RPM prematurely and this in turn will stall the blades. Ensure that you have the correct voltage turbine for your application.

**Issue:**

A slight oscillation can be observed in the turbine tail fin whilst the turbine is rotating at certain speeds.

**Potential Causes:**

- Due to the nature of small wind turbines, a small level of oscillation is acceptable as the turbine passes through certain speeds. This oscillation movement can be minimised by ensuring that the distance between each tip is within tolerance (please see step 4, page 8). Ensure, also, that the assembled rotor is correctly and concentrically fitted to the drive bearing housing.

**Issue:**

When fitted to a yacht, vibration is transmitted through to the hull of the vessel.

**Potential Causes:**

- Small wind turbines are electro-mechanical devices and as a result a small amount of 'hum' can be present during the operation of the *LE-450*. Depending on the type and method of mounting to a yacht, some of the natural hum of the turbine alternator can be transmitted to the hull of the vessel. In order to limit or avoid this vibration transmission, it is recommended that appropriate anti-vibration mountings and bushes are used upon the structure used to support the turbine.

### ***Common Problems pertaining to low turbine output***

#### ***Issue:***

- The turbine seems to be operating correctly, but the electrical output appears to be low. There are many reasons why the turbine may be demonstrating outputs that are lower than anticipated. These reasons can stem from turbulence, erroneous measurements through to battery type and condition.

#### ***Potential Causes:***

- Turbulence is the most common reason why turbines do not perform to their specification. Turbines require clean un-turbulent laminar air flows in order to operate at their peak performances. This means that turbines need to be carefully sited in order to avoid areas of turbulence - unfortunately this is not always possible and compromises need to be made. Please see Appendix 4 for information about siting your turbine for best performance. Turbulence created by trees, structures and general topography will all create eddy currents in the wind which will severely reduce the turbine's efficiency. Generally, the turbine should be positioned on a tower as high as possible above any local features of the topography.
- Ensure that the correct minimum and maximum cable sizes have been installed (see section 9, page 11 of this user manual). Using a cable that is too small may lead to volt-drop losses, especially on a 12V system. Alternatively, using a cable that is large than the recommended size may lead to the turbine becoming stalled or semi-stalled which will impair performance.
- During operation the turbine alternator will become warm and even hot, especially during high wind events. When this happens, the resistance in the alternator coils dramatically increases which causes the alternator efficiency to drop drastically. This effects the overall output of the turbine. Performance will drop after the turbine has heated up due to prolonged high end running.
- Different battery technologies have different rates at which they can absorb power from a wind turbine. The batteries will draw all of the power possible from a wind turbine until they reach their absorption limit. Generally, more battery capacity can be added to increase the rate at which they can absorb power. Battery age and condition will also affect the rate at which the batteries can absorb power - older batteries or those in a poor condition will not draw the same power levels from the turbine as newer batteries in good condition.
- Poor state of your batteries caused by sulphation. If your batteries routinely rest at less than 12.5V it is likely that your batteries are in poor condition and unable to draw full power from the turbine. When the turbine is operating at 100 watts, this will equate to 8.7 amps whilst the batteries are at 11.5 volts, but the same 100 watts only equates to 6.66 watts when the batteries are at 15 volts. When using a current measuring device such as an ammeter, the current reading must be qualified against the voltage reading in order to calculate an accurate power output.
- Measurement errors can easily occur whilst measuring both the wind and power output of the turbine. For example, in marine applications the wind speed measurement is often made at the top of the mast which will be approximately 10m + above the height of the wind turbine. The measured wind speeds at this height will be much higher than the wind speeds that the turbine experiences. This may lead to the assumption that the turbine is underperforming in any given wind speed. Furthermore, current shunts are often used in

low voltage DC systems due to the amount of currents flowing. Ensure that high quality shunts are employed for accurate current readings.

## Appendix 4: Turbine Site Selection

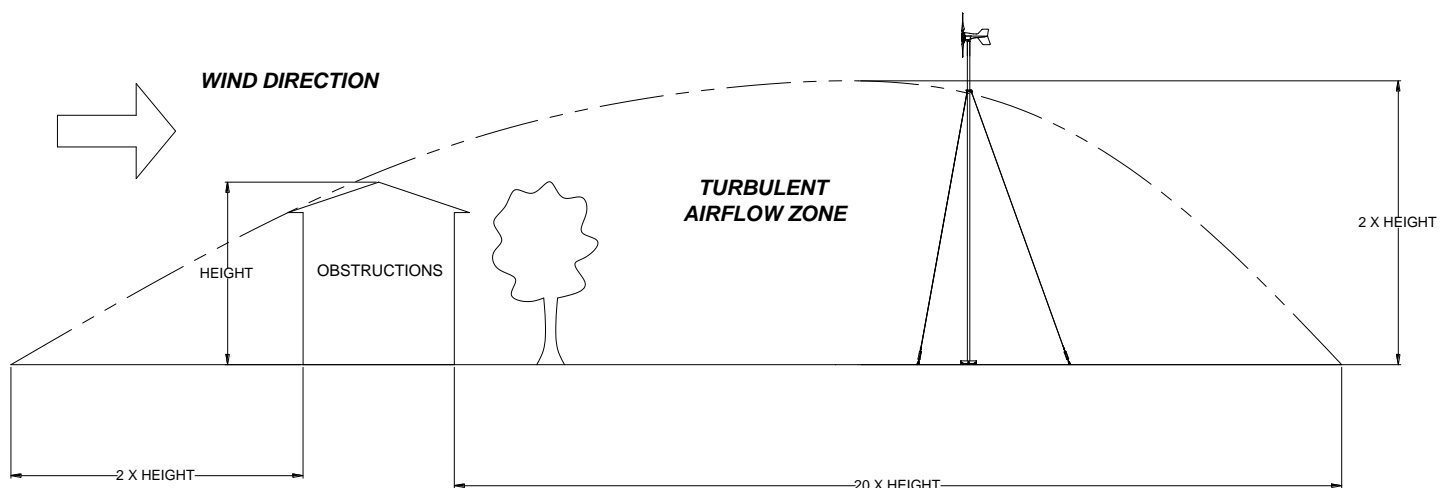
### Turbine Site Selection

The turbine location is a very important factor in the overall performance of your small wind turbine system. Good site selection will maximise the power that your turbine will be able to deliver. Installing a wind turbine in a bad position is similar to installing a solar panel system in the shade – it will not maximise the performance of your investment.

The total amount of energy available in the wind increases drastically with small increases in wind speed. Therefore it is very important that you site your turbine in the best possible location.

The proposed installation site for your wind turbine must have a good average wind speed of a minimum of 4.0m/s (9mph) and low wind turbulence. Wind turbulence is caused by obstructions to the wind such as trees and buildings. Excessive turbulence will hamper the performance of your turbine. Small wind turbines operate best in steady airflows. Free flowing airstreams are more consistent in direction and wind speed which results in more overall power being generated by the wind turbine system. Gusty conditions often result in a turbine 'hunting' the wind reducing the amount of overall power generated. Gusty and turbulent conditions also exert fluctuating forces upon the turbine that can reduce the reliability and lifespan of the system.

**Wind shadowing and barriers:** Wind barriers are simply obstacles that impede the flow of the wind (such as trees and buildings). A large 'wake' of turbulent airflow will occur for a long distance downwind of a barrier. It is not desirable to locate a turbine in this zone.



**Topography:** For areas of undulating ground, the turbine should be installed in the highest possible position avoiding wind barriers and turbulence. For areas that are generally flat, the turbine can be installed in any position. Remember that the LE-450 has a low voltage output, so it is important to keep the cable run to the batteries / inverter as short as possible.

**Surface roughness of the ground:** Long grass, crops or bushes will have the effect of slowing the wind down (even at the height of the tower). Try to install your turbine where the ground is smooth to increase the overall power production of the system.

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