Version 1.1
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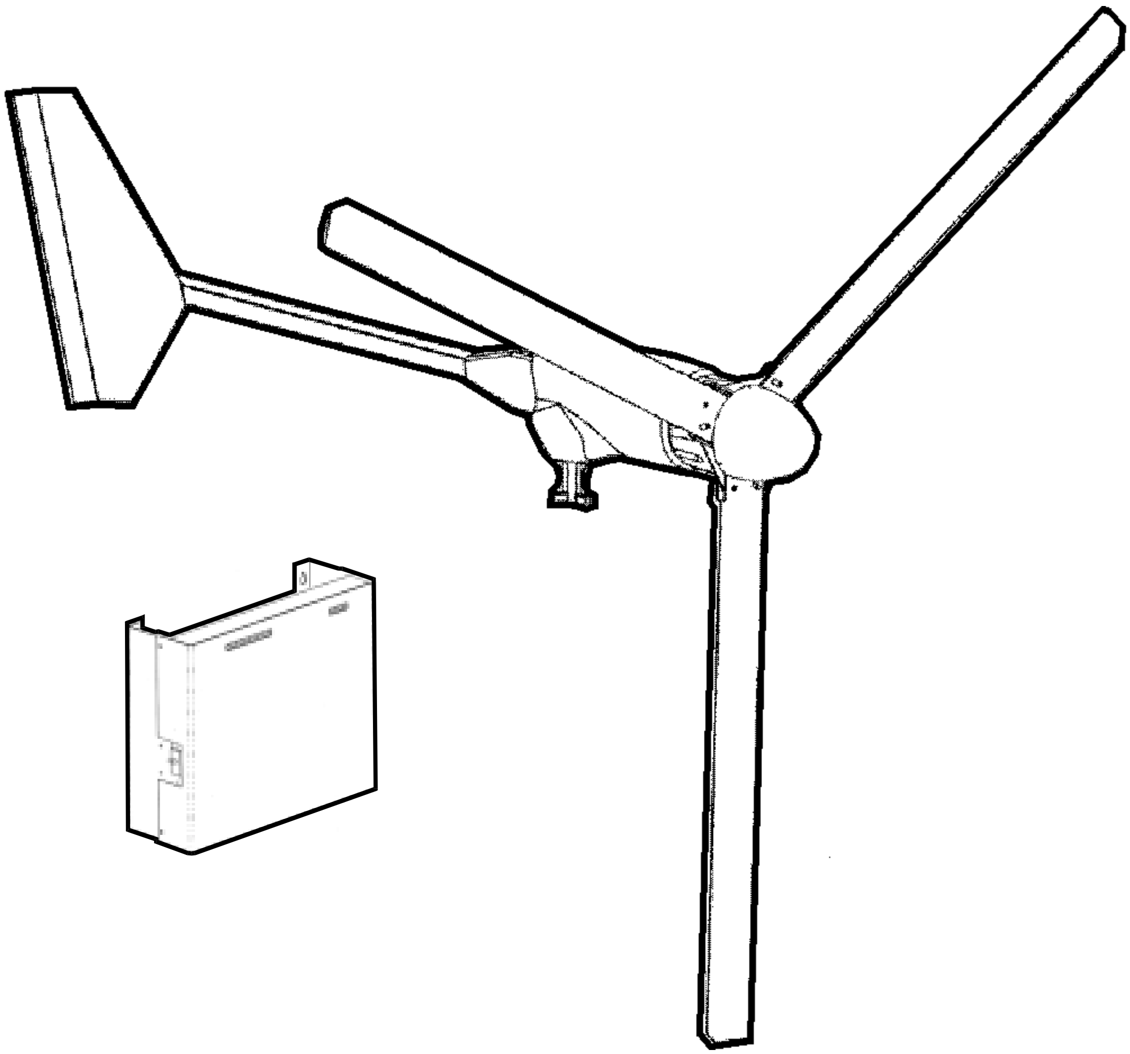
BWC 77XL.1

24 VDC Battery Charging System

Owners Manual

MANUALE D'INSTALLAZIONE

XL.1 Wind Turbine
PowerCenter Controller



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BWC XL.1 Wind Turbine
24V Battery Charging System
OWNERS MANUAL

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1. Overview

The BWC XL.1-24 wind turbine system is a state-of-the-art small generator designed to charge batteries and supply electrical loads in a 24 VDC DC-bus based remote power system. When used in conjunction with a suitable sine wave DC-AC inverter and a 24 VDC battery bank the XL.1-24 can also be connected to the power grid.

The XL.1-24 turbine consists of a 2.5 meter (8.2 ft.), 37-kilogram (82 lb) wind turbine rated at 1,000 watts and a multi-function turbine and system controller, the PowerCenter.

The XL.1-24 wind turbine features superior low-wind-speed performance, very high system efficiency, and low noise. The PowerCenter features a solar regulator, a dump load capability, an automated equalization function, and special circuitry to boost the low wind speed performance of the XL.1 wind turbine.

The BWC XL.1-24 is offered with the optional guyed tubular Tilt.Tower, which comes in heights from 9 m (30 ft.) to 32 m (104 ft.). The Tilt.Tower is shown in Figure 1. For installation procedures on this tower please refer to the "BWC XL.1 Tilt.Tower Installation Manual". This manual is available on-line at http://www.igetcol.it ,

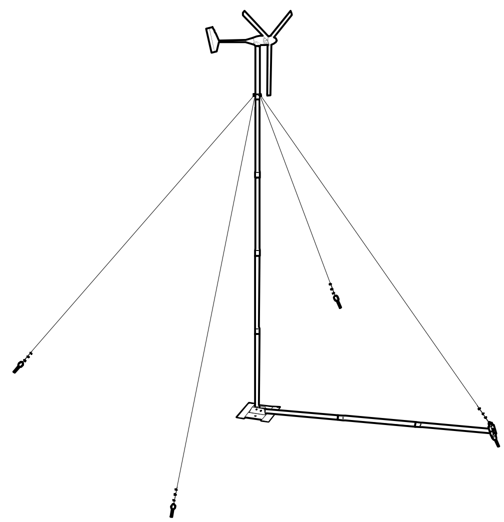

Figure 1, XL.1 with 9 m Tilt.Tower

2. Cautions and Warnings

This manual contains important information on the installation of your BWC XL.1 wind turbine and PowerCenter controller. We strongly recommend that you read and follow the instructions contained in this manual.

At several points in the manual items of special interest or significant impact are highlighted by one of the following notices.

Warning

Hazards or unsafe practices that could cause personal injury or death.

Caution
Hazards or unsafe practices that could cause product damage.

Note
Significant points of interest

3. Identification

Each BWC XL.1-24 wind turbine has a serial number decal located on the support structure inside the nacelle. Since this label is only accessible by removing the nacelle it has been noted on the Warranty Registration form. We recommend writing it here as well.

BWC XL.1-24 Serial No.: ___________________

Each PowerCenter has a serial number decal affixed to its side casing. This number has been noted on the Warranty Registration form. We recommend writing it here as well.

BWC PC.1-24 Serial No.: ___________________

4. System Description

XL.1 Wind Turbine Components

The major components of the XL.1 wind turbine are shown in Figure 2.

A. Blades / Rotor System

The rotor system consists of three fiberglass blades. Acting like aircraft wings, the blades convert the energy of the wind into rotational forces that can drive a generator. The airfoil on the XL.1 is the new SH3045 developed specifically for the XL.1 by Bergey Windpower. The fiberglass blades are exceptionally strong because they are densely packed with glass reinforcing fibers that run the full length of the blade. The rotor has three blades because three blades will run much smoother than rotors with two blades.

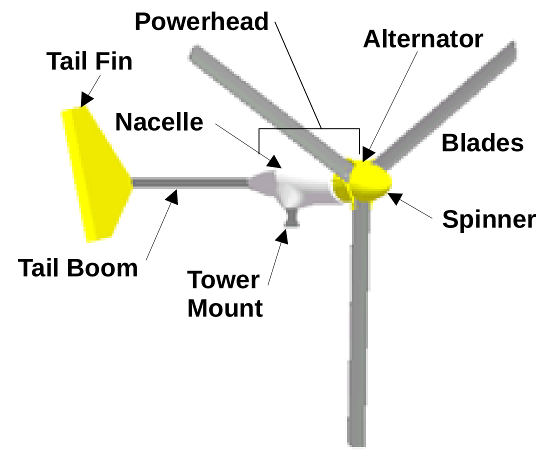

Figure 2, Major Components of the XL.1 Wind Turbine

B. Alternator

The alternator converts the rotational energy of the rotor into electricity. The alternator utilizes permanent magnets and has an inverted configuration in that the outside housing (magnet can) rotates, while the internal windings and central shaft are stationary. The alternator was specially designed for the XL.1 and produces power at low speeds, eliminating the need for a speed-increasing gearbox.

The output from the alternator is three-phase alternating current (AC), but it is rectified to direct current inside the nacelle. Since it uses permanent magnets, the alternator is generating voltage whenever the rotor is turning.

Warning
The output wiring of the BWC XL.1-24 presents a low voltage shock hazard whenever the rotor is turning. Caution must be exercised at all times to avoid electrical shock.

C. Nacelle

The nacelle is the fiberglass housing around the main body of the machine. It contains the main structural "backbone" of the turbine (called the mainframe), the rectifier, the slip-ring assembly, the yaw bearings, and the tower mount. The yaw bearings allow the wind turbine to freely pivot around the top of the tower so that the rotor will face into the wind.

The slip-ring assembly is the electrical connection between the moving (as it orients with the wind direction) wind turbine and the fixed tower wiring. The slip-rings and yaw bearings are located just above the tower mount. The tower mount attaches the XL.1 turbine to the top of the tower.

D. Tail Assembly and AutoFurl® Operation

The tail assembly, composed of a tail boom and the tail fin, keeps the powerhead (and, therefore, the rotor) aligned into the wind at wind speeds below approximately 12.5 m/s (28 mph). At about 12.5 m/s the AutoFurl® action turns the rotor away from the wind to limit its speed. The tail appears to fold, but in reality the tail stays stationary as the powerhead turns sideways to the wind. The rotor does not, however, furl completely sideways. This allows the turbine to continue to produce power in high winds. When the high winds subside the AutoFurl® system automatically restores the turbine to the normal straight position.

E. PowerCenter

The PowerCenter, shown in Figure 3, serves as the central connection point for the electrical components in the system and it provides a number of necessary and valuable control functions. Not all of the available functions will be used in all installations. The PowerCenter also provides status lights for the system and a handy light-bar "fuel gage" for the battery bank.

Note
The XL.1 wind turbine will not perform properly, particularly at low wind speeds, without the PowerCenter controller. The Power Boost circuitry in the PowerCenter is needed to provide acceptable performance in wind speeds below approximately 7.5 m/s (17 mph).

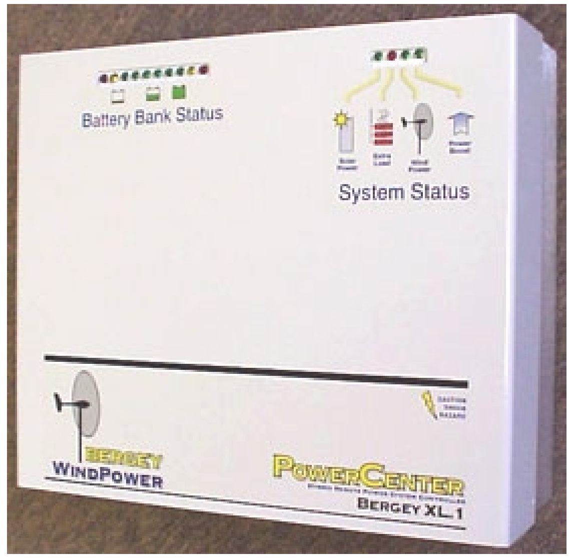

Figure 3, PowerCenter for the BWC XL.1

5. SYSTEM OPERATION

A. Normal Operation

The rotor of the BWC XL.1 should begin to rotate when the wind speed reaches approximately 3 m/s (7 mph). Battery charging should commence shortly after the rotor spins up to speed. Once turning, the rotor will continue to turn in lower wind speeds, down to approximately 2.5 m/s (6 mph).

Note
All operational wind speeds given assume steady winds, sea-level altitude and moderate temperatures. Hot weather, high altitude, turbulence, and gusting winds will reduce system performance.

The rotor speed will increase with increasing wind speed and the system will provide a higher output. This output increases rapidly because the energy available in the wind varies as the third power (cube) of the wind speed. For example, if the wind speed doubles from 5 m/s (11.2 mph) to 10 m/s (22.4 m/s), the energy in the wind increases by a factor of eight ($2^3 = 2 \times 2 \times 2 = 8$). One result of this relationship is that there is very little energy available in light winds. For the average site, winds in the range of 5.5 – 9 m/s (12 – 20 mph) will provide most of the system's annual energy production.

B. High Winds - AutoFurl

During periods of high wind speeds the AutoFurl system will automatically protect the wind turbine. When furled, the power output of the turbine will be significantly reduced. In winds between 13 m/s (29 mph) and 18 m/s (40 mph) it is normal for the turbine to repeatedly furl, unfurl and then furl again. In winds above 18 m/s (40 mph) the turbine should remain continuously furled.

AutoFurl is a simple and elegant method of providing high wind speed protection. The AutoFurl system is based on aerodynamic forces on the rotor, gravity, and the carefully engineered geometry of the wind turbine. As shown in Figure 4, the aerodynamic forces acting on the blades cause a thrust force pushing back on the rotor. This force increases with increasing wind speeds.

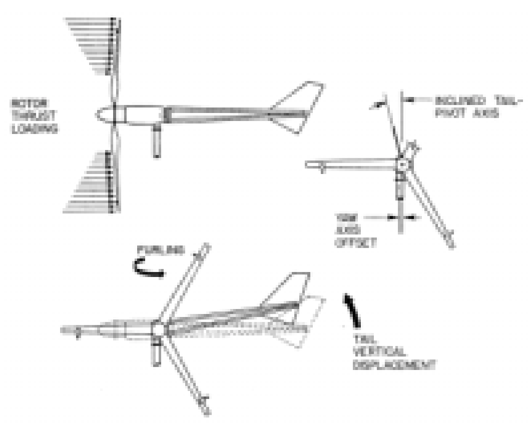

Figure 4, AutoFurl

The thrust force acts through the centerline of the rotor, which is offset from the centerline of the tower pivot axis (yaw axis). Therefore, the thrust force on the rotor is always trying to push the rotor over to the side, away from the wind.

But the rotor is kept facing into the wind at speeds up to ~ 12.5 m/s (28 mph) by the wind turbine's tail assembly. The tail, in turn, is kept straight by its own weight because its pivot at the back of the nacelle is inclined. So the weight of the tail holds it against a rubber bumper and the tail holds the rotor into the wind.

The geometries in the systems are carefully balanced so that at ~ 12.5 m/s (28 mph) the rotor force acting on the yaw-offset is large enough to overcome the preset force holding the tail straight. At this point the rotor will start turning away from the wind or furling. The tail stays aligned with the wind direction. The speed of furling depends on the severity of the wind gusts and whether the wind turbine stays furled depends on the wind speed.

As the wind turbine furls the geometry of the tail pivot causes the tail to lift slightly. When the high winds subside the weight of the tail assembly returns the whole turbine to the straight position.

The AutoFurl system is completely passive so it is very reliable and since there are no wear points, like in a mechanical brake system, it is very robust. AutoFurl was used in the very first wind system produced by Bergey Windpower in 1980 and in every unit produced since. AutoFurl is an important element of our success.

There is one situation in the field, however, that we have found can disrupt the operation of AutoFurl. If the wind turbine is installed on a sharp hill or next to a cliff so that the wind can come up through the rotor on an incline (e.g., from below; as opposed to horizontally) we know that this will affect furling and can produce higher peak outputs. We strongly recommend avoiding this situation.

Caution

Do not install the XL.1 wind turbine near cliffs or precipices or on sharp hills such that the wind does not travel horizontally through the rotor.

C. Unloaded Operation

As the battery bank voltage rises the PowerCenter controller will try to regulate this voltage by switching off the solar charging and applying the optional Extra Load (or "dump load"). If these measures are not adequate then the PowerCenter will momentarily disconnect the XL.1 wind turbine, which allows the turbine to run unloaded. Under unloaded operation the rotor will spin faster and it will make more noise. In high winds the blades may also "flutter", causing a loud, low pitch growling sound.

The AutoFurl system works whether the turbine is loaded or unloaded. Applying extra loads during high wind periods can reduce the likelihood of blade flutter.

D. PowerCenter Controller

The basic electrical schematic for the BWC XL.1 is shown in Figure 5. The XL.1's alternator produces three-phase alternating current (AC) that varies in voltage and frequency with the rotor speed. The AC power is rectified to direct current (DC) power by a rectifier module inside the nacelle. Thus, the wire run from the wind turbine to the PowerCenter is DC.

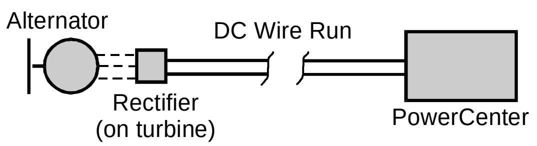

Figure 5, XL.1 Basic Electrical Schematic

The PowerCenter for the XL.1 has two sets of color-coded light-emitting-diodes (LED's) for System Status and Battery Bank Status.

System Status Lights:

Solar Power (green): Lights up when the optional solar panel(s) are charging the batteries.

Extra Load (red): Lights up when the optional auxiliary or dump load is activated due to high battery voltage.

Wind Power (green): Lights up when the XL.1 wind turbine is charging the batteries.

Power Boost (green): Lights up in low to moderate winds to indicate that the low wind speed performance optimizing boost circuitry is operating.

Battery Bank Status Lights:

Battery bank charge status is shown with ten colored LED's, which act like a fuel gage for the remote power system. This gage, however, is inexact and it is intended to provide only a general indication of the energy reserves available in the system. The following table shows the voltage indicated by the highest lit LED and its approximate relationship to the battery capacity available.

LED No. (from left side)	Indicated Battery Voltage Range	Approximate Battery Reserve
L1 (red)	Below 22 V	Below 5%
L2 (yellow)	22 – 23.5 V	5%
L3 (green)	23.5 – 24 V	15%
L4 (green)	24 – 24.5 V	30%
L5 (green)	24.5 – 25 V	60%
L6 (green)	25 – 27 V	90%
L7 (green)	27 – 28 V	100%
L8 (green)	28 – 29.5 V	100%
L9 (yellow)	29.5 – 30.5 V	100%
L10 (red)	Above 30.5 V	100%

Table 1, Battery Bank Status Indications

The LED's provide an indication of the instantaneous battery voltage. This voltage is affected by the state of battery charge and the instantaneous net current flow into or out of the battery. Therefore, during high charging/low load periods the gage will over-predict battery state of charge and during low charging/high load periods the gage will under-predict battery state of charge. Also, the smaller the battery bank the more rapidly the LED's will change in response to changing wind and electrical load conditions.

The PowerCenter is designed to work with flooded-cell or sealed, deep-cycle, lead-acid batteries. Do not use other types of batteries without first contacting Bergey Windpower Co.

Battery Equalization

The PowerCenter has an automatic one-hour battery equalization function that is initiated using the push button on the back side of the PowerCenter enclosure. Equalization is a maintenance function that brings the batteries up to a higher state of charge and causes them to out-gas (bubble) actively. It should be performed approximately once a month on a windy day.

To start the equalization process, press the button on the back side of the enclosure (see Figure 11).

Note

Equalization will allow the battery bank to reach 30 VDC, which may cause some inverters to shutdown due to "input over voltage".

Caution

Do not equalize sealed batteries. The out-gassing at high battery voltages will damage them.

Always check the electrolyte levels in each battery cell after equalization and add distilled water as necessary. Do not add battery acid. The loss of fluid is due to water being dissociated into hydrogen and oxygen. The sulfuric acid remains. The production of hydrogen gas during charging is the reason that battery enclosures should always be ventilated.

Operation of Controls and Factory Settings

The PowerCenter will switch the XL.1, the optional PV array, and the optional dump load on and off to prevent battery overcharge and maximize energy capture. These switching functions are determined by the battery bank voltage.

At battery voltages below 28 VDC, the wind and solar are connected and allowed to charge the batteries. If the battery voltage rises above 28 VDC the solar is switched off. At 29.5 VDC the Extra Load (dump load) circuit is turned on. At 30.5 VDC the wind turbine is turned off.

As the battery voltage decreases back down to 28 VDC the wind turbine is turned on and the Extra Load is turned off. At 27 VDC the solar is turned back on.

When the equalization function is activated all voltage set-points are raised by approximately 2 VDC.

6. Turbine Installation

Appendix 1 is an Installation Planning Guide. It provides recommendations on tower heights and locations, electrical components, and wiring.

Tower Mounting: The XL.1 wind turbine is attached to its tower by a three-sided, six fastener casting, shown in Figure 6, that is designed to fit inside a tube with an inner diameter of 85 mm (3.35 in). If you are using the BWC Tilt.Tower then the XL.1 will bolt directly in place. If you are mounting the XL.1 to a different type of tower then you will need to ensure that the tower meets the requirements for XL.1 towers (see Appendix) and that it has a proper adapter fitting for attaching the XL.1 tower mount casting (also defined in the Appendix)

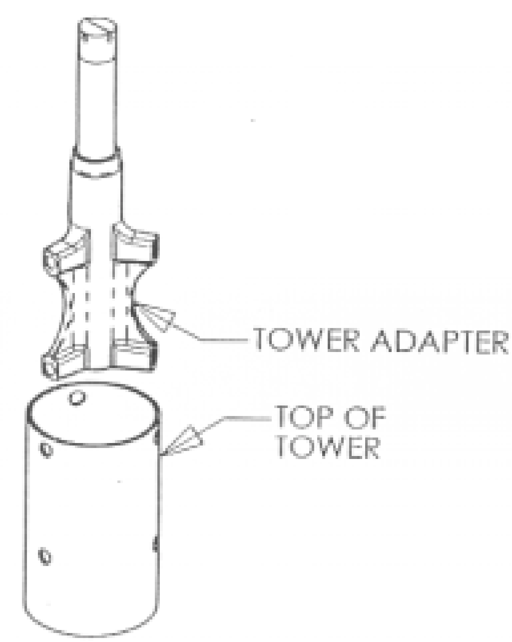

Figure 6, Tower Mounting for the XL.1

Once you have the proper mounting arrangement you can proceed with assembly of the wind turbine. The fasteners on the XL.1 are all metric.

Tilt-up Type Towers: If you have a tilting tower, such as the BWC Tilt.Tower, the following procedure is recommended:

Tools Required:

- 17 mm box end wrench
- 17 mm socket and ~ 300 mm (12") ratchet drive
- 8 mm socket or wrench
- pliers
- crimpers for wiring terminals (U-shaped crimp preferred over straight crimp)
- thread locking compound (like Loctite 242)
- tape measure, 12 ft.

Procedure:

Step 1:
With the tower tilted down, place the powerhead of the wind turbine near the top end of the tower.

The tower wiring is connected to the XL.1 wind turbine at the slip-ring using two small screws and ring terminals crimped to the two conductors. Cut the outer insulation on the wire back about 60 mm (2.5 in). Strip the insulation off the outer 12 mm (1/2 in) of each conductor and crimp on the appropriate ring terminals (several sizes are provided to match possible wire sizes). Attach the two power conductors to the slip-ring assembly with the screws provided. The polarities of the connections are marked. If your conductors are color-coded we recommend making note of the colors connected to positive and negative leads.

The slip ring assembly is not designed to support the weight of the down-tower wire. A strain relieving installation is required, as shown in Figure 7. Use the two nylon cable ties provided to secure the tower wiring to the tower adapter casting. After completing the connections, pull on the tower wire to make sure that it is secure before mounting the wind turbine on the tower.

Step 2:
Raise the tower about 1 meter (3 ft) off the ground to provide room to assemble the XL.1 turbine. We recommend fashioning a temporary support stand to hold the tower up during turbine assembly.

Step 3:
Mount the wind turbine tower adapter to the top of the tower using the six M10 x 1.5 bolts and six washers. We strongly recommend applying Loctite 242 (Thread Locking Compound) to the threads prior to installation to reduce the likelihood of loosening due to vibration. We recommend using a torque wrench to achieve the proper fastener torque on the tower mounting bolts. The recommended toque is 54 N.m (40 ft-lbs).

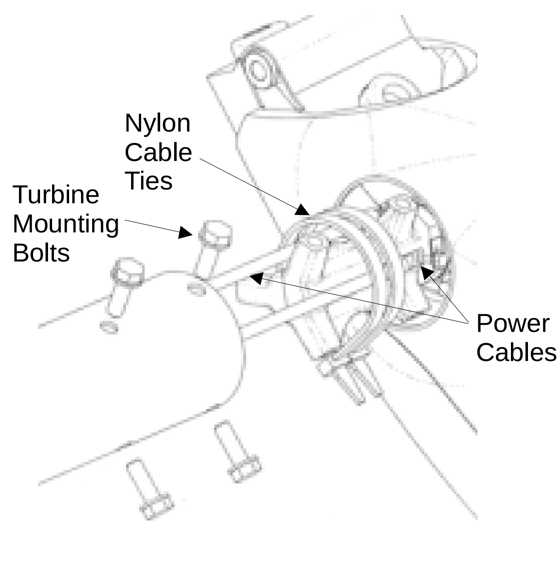

Figure 7, Turbine Mounting

Step 4:
Complete the wiring to the PowerCenter before adding the blades. This is recommended so that you can test the DC polarity of the wiring by spinning the alternator by hand. It is very important that the polarity [positive (+) and negative (-)] is correct when the turbine is connected to the PowerCenter. The best way to ensure this is to complete the wiring and then test the polarity with a Volt-Ohm-Meter.

Wiring recommendations are provided in Section 7 and in Appendix 1, section D. Turning the alternator by hand will provide enough voltage to make this check. Carefully mark the positive and negative electrical leads for later reference.

Step 5:
Turn the XL.1 powerhead upward so that the alternator is facing up. Attach the blades as shown in Figure 8 using the M10 hardware provided. We recommend bolting one blade up solidly and leaving the other two somewhat loose while you check the tip-to-tip blade distance. We recommend checking, and adjusting as necessary, the blade tip spacing to ensure that the blade tips are equally spaced. This step will help make the wind

turbine as smooth running as possible, which will maximize the operating life of the bearings and reduce vibration related noise. The blade tip-to-tip distances should not differ by more than 12 mm (1/2") for smooth operation.

We recommend using a torque wrench to achieve the proper fastener torque on the blade nuts. The recommended toque is 54 N.m (40 ft-lbs). Loctite is not necessary on the blade fasteners because the nylon locking nuts provide adequate locking.

Step 6:
Attach the spinner (nose cone) using the three M5 bolts and washers provided, as shown in Figure 8. We recommend applying Loctite to the bolt threads prior to assembly.

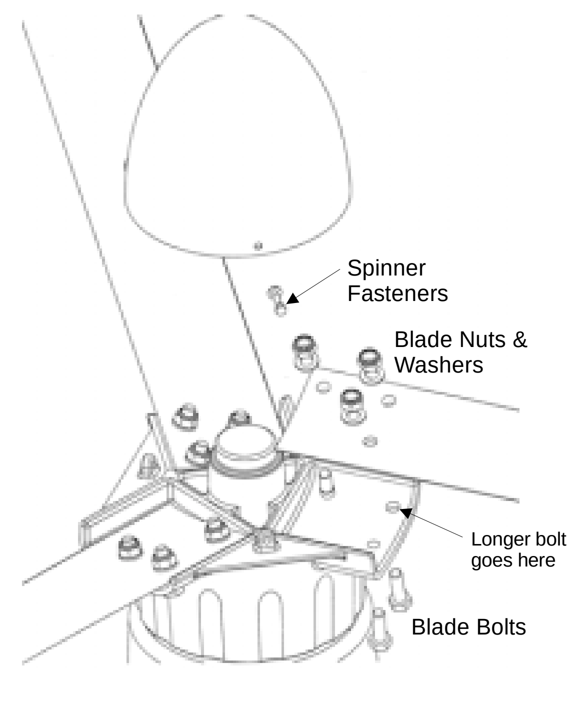

Figure 8, Blade and Spinner Fasteners

Step 7:
Bolt the tail fin to the tail boom using the eight M5 bolts and lock-washers provided, as shown in Figure 9. We recommend applying Loctite to the bolt threads prior to assembly.

Step 8:
Place the tail boom on the rear of the turbine powerhead and insert the 12 mm (1/2") tail pivot pin from the top. If the parts are aligned properly the pin should insert easily. Do not use a hammer to pound the pin in place, as this may cause scoring of the bronze bushings. Secure the tail pivot pin with two cotter pins, as shown in Figure 10. **Note:** Two M12 washers are provided to go on the Tail Pivot Pin between the cotter pins and the tail boom. <u>They are not shown in the drawing for Figure 10, but must be installed.</u> Failure to properly install and secure both cotter pins will lead to loss of the tail boom.

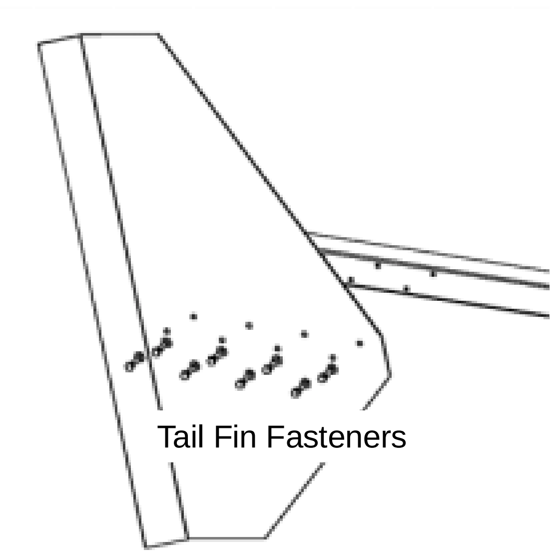

Figure 9, Tail Fin Attachment

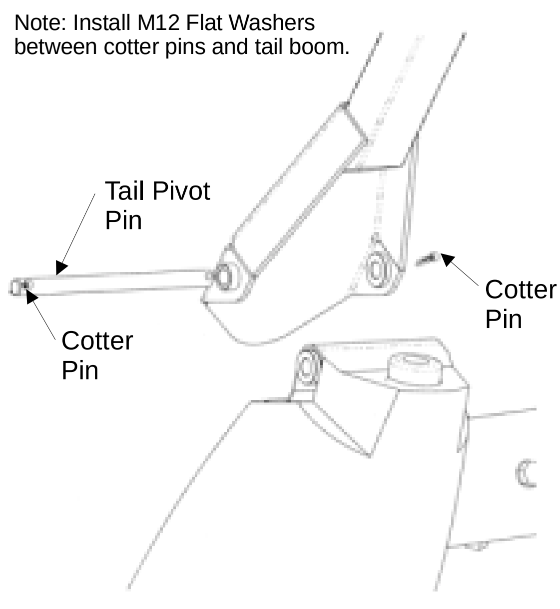

Figure 10, Tail Boom Attachment

Step 9:
Check the XL.1 wind turbine carefully to make sure that the installation is complete. We recommend the following checklist:

- ❑ Blade fasteners are secure and properly torqued
- ❑ Blade tips are evenly spaced
- ❑ Spinner is secure
- ❑ Tail fin is secure
- ❑ Tail pivot pin is locked in place with both cotter pins and washers.
- ❑ Tower adapter bolts are secure
- ❑ Wiring polarity is tested and marked

Step 10:
Dynamically brake the XL.1's alternator by connecting the positive (+) and negative (-) output leads together. The resulting short-circuit will keep the rotor from spinning during tower raising.

Step 11:
Raise the tower following the procedures outlined by the tower supplier. Please make safety your top priority.

Non-tilting Towers: On a non-tilting tower, such as a fixed guyed tower or a self-supporting pole type tower, there are two general approaches that can be used: 1) assemble the tower and turbine together on the ground and then use a light-duty crane to set the tower in place, or 2) erect the tower and then lift the wind turbine to the top with either a light-duty crane or a gin-pole.

A gin-pole, in this case, is a tower assembly tool that attaches to the tower and provides an arm with a pulley so that parts can be hoisted above the top of the tower. Gin-poles are used by professional tower erectors and we do not recommend their use by non-professionals. We know of at least one homeowner who died approximately fifteen years ago while improperly using a gin-pole to install a small wind turbine (though not a Bergey turbine).

Where possible we recommend the first general procedure because it allows work to be done more safely, on the ground. In this case please follow the general procedure for turbine assembly provided in the preceding section. When raising the tower you must lift the tower, not the XL.1 wind turbine. The XL.1 cannot support the weight of the tower.

For customers installing a BWC XL.1 on an existing fixed tower we recommend that you use a crane to lower the tower so that you can attach the turbine on the ground. Alternatively, we recommend you use a bucket-truck, like the type used by utility linemen. Check with local sign companies because they often offer bucket-truck services at reasonable hourly rates. If neither of these approaches is possible then we recommend that you engage the services of professional wind turbine or tower erectors to install your wind turbine.

The procedures for hoisting the BWC XL.1 using a gin-pole are available from Bergey Windpower. Please contact Customer Service for assistance.

7. PowerCenter Installation

A. Electrical System

The general electrical configuration for BWC XL.1 and hybrid system installations is shown in Figure 11. In most cases the loads will be AC (alternating current) and they will be supplied through a DC-to-AC inverter.

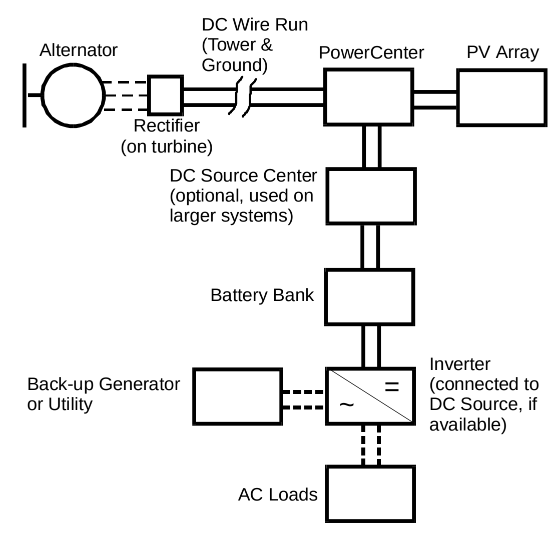

Figure 11, Typical XL.1 System Configuration

The PowerCenter has a limited current carrying capacity so we recommend that you use a DC Source Center whenever you have multiple XL.1 wind turbines. DC Source Centers are available from Bergey Windpower.

Additional Design Guidance:

1. If you have multiple XL.1 turbines and PowerCenters, do not connect more than one wind turbine to one PowerCenter.
2. Connect multiple PowerCenters to a DC Source Center via the PowerCenter's battery terminals.
3. Do not connect the PowerCenter to another controller that could disconnect the PowerCenter from the batteries. The PowerCenter should not be disconnected from the battery when there is input from the wind turbine.

B. Location

The PowerCenter must be installed indoors and should be located relatively close to the battery bank. Do not install the PowerCenter outdoors; it is not waterproof.

C. Mounting:

The PowerCenter needs to be mounted vertically to a wall, or other support structure, so that air can pass unobstructed through the passive cooling channel behind the enclosure. We recommend setting the height of the LED's at eye level if possible so that the system status lights will be easiest to read.

The enclosure dimensions and mounting layout for the PowerCenter are shown in Figure 12. The PowerCenter should be mounted with four M4 (0.157" dia.) screws. We recommend the following procedure:

Tools Required:

Pencil
Carpenters level
Drill with ~ 2 mm or 0.09" dia. drill bit
(4) M4, 1/8", or 5/32" screws
Screwdriver

Procedure:

Step 1:
Mark the mounting hole locations using the PowerCenter enclosure as the template. Use a carpenters level to check the levelness of the enclosure before marking the holes.

Step 2:
Drill small (~ 2.5 mm or 0.1 in diameter) pilot holes for the mounting screws.

Step 3:
Screw the top two mounting fasteners into the wall until ~ 6 mm (1/4") of the shank extends out from the wall.

Step 4:
Remove the PowerCenter cover and place the PowerCenter enclosure on the two upper mounting fasteners. Slide the enclosure down such that the fasteners are placed at the top of the inverted "T-slots".

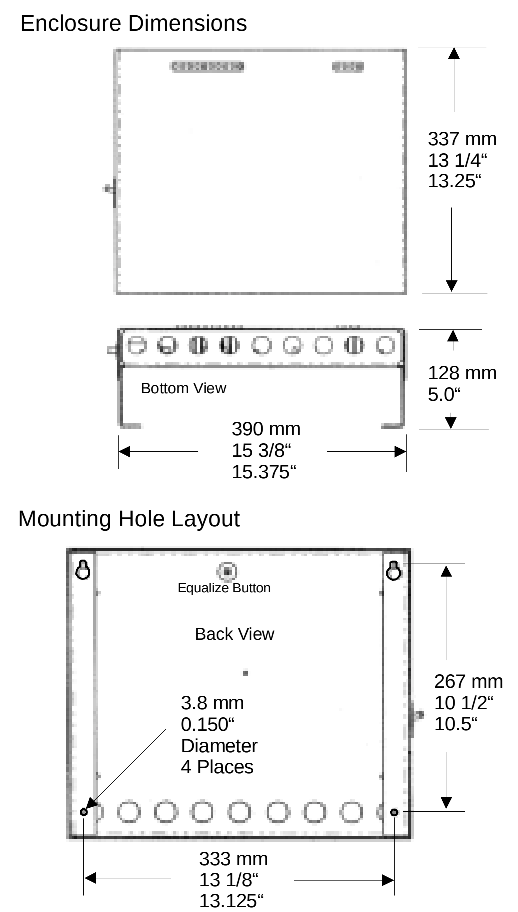

Figure 12, PowerCenter Mounting Dimensions

Step 5:
Install the bottom two mounting fasteners, and then tighten the top two fasteners.

C. Wiring

All wiring should conform to the National Electric Code or other governing local electrical code. The use of electrical conduit for wiring between components is highly recommended. If you have any connections with dissimilar metals (aluminum / copper) they should be coated with an anti-oxidation compound to prevent galvanic corrosion. All loads should be protected by fuses or circuit breakers to avoid hazards from accidental short circuits.

The wind turbine tower must be well grounded and a good quality lightning surge arrestor, connected to a good quality earth ground, should be installed on the wiring from the wind turbine. We recommend a Delta LA302DC arrestor installed into the third (from the left) rear entrance hole of the enclosure. This tucks the arrestor neatly behind the enclosure. The arrestor leads are connected to the wind turbine terminals.

We do not recommend grounding either the negative or positive DC bus on the PowerCenter. However, some inverter manufacturers recommend grounding and some electrical codes require it. If you do ground the PowerCenter, please conform to local practices for grounding either the positive or negative bus.

D. PowerCenter Connections

Cable Entrances: As shown in Figure 13, wiring can be connected to the PowerCenter from below or behind or in a combination of both. A total of eighteen 7/8” (~ M20) entrance holes are provided.

Box Lugs: The PowerCenter is supplied with box lugs (not shown in Figures 12 and 13) that are used to connect electrical leads to the terminals on the PowerCenter circuit board. These lugs can accommodate wire sizes from 3.35 mm^2 to 7.1 mm^2 (8 AWG to 2 AWG).

Plastic Grommets and Plugs: The PowerCenter is supplied with a number of plastic grommets and plugs for the wire entrance holes at the bottom of the enclosure. Grommets should be used to protect incoming wires from the hard edge of the aluminum. They are not necessary if you are using conduit or special cable entrance fittings. Holes not used for wiring should be sealed using the plastic plugs. Even though 24 VDC is generally not considered a lethal voltage, most electrical codes will require that the unused entrance holes be sealed and we believe that this is prudent and the safest course of action.

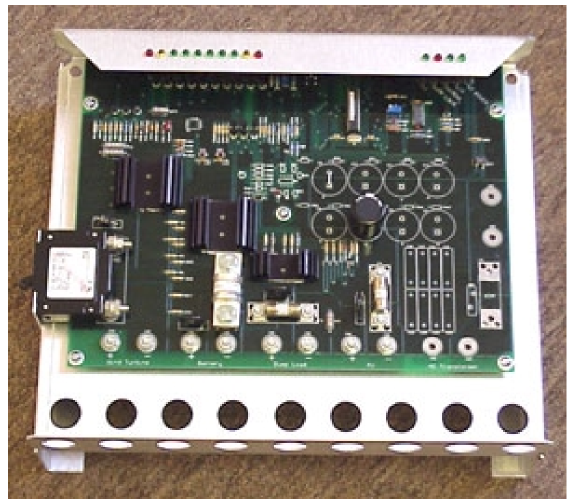

Figure 13, PowerCenter with Cover Removed

We recommend the following procedure for making the electrical connections:

Step 1:
Remove the cover to expose the circuit board and terminals. The terminals are on the circuit board, as shown in Figure 14.

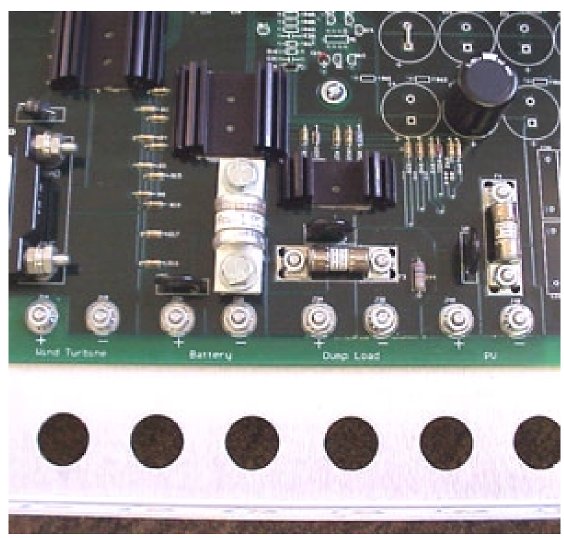

Figure 14, Terminals for Electrical Connections

Step 2:
Connect Dump Load leads. This is an optional resistance-heating load that will operate when the batteries are full. Polarity is not important in making this connection.

The specification for the dump is 1 Ohm or higher, with at least a 1,000 Watt capacity.

Step 3:
Connect Wind Turbine leads. The 60A circuit breaker on the side of the circuit board should be switched to "Off". Please ensure that the wind turbine wires are connected with the proper polarity. The system will not operate correctly and could be damaged if the polarity is reversed. The polarity can be checked with a Volt-Ohm-Meter, but it does require that the XL.1 alternator be rotated.

Step 4:
Connect Battery leads. Please ensure that the battery leads are connected with the proper polarity. The system will not operate correctly and could be damaged if the polarity is reversed. <u>Always check the polarity with a Volt-Ohm-Meter before making connections.</u>

The maximum current to the batteries will be ~ 60 amps with no PV and up to ~ 90 amps with the maximum allowed PV array size. Wiring to the batteries must be sized accordingly.

Step 5:
Connect PV leads. Please ensure that the PV leads are connected with the proper polarity. The system will not operate correctly and could be damaged if the polarity is reversed. <u>Always check the polarity with a Volt-Ohm-Meter before making connections.</u>

The maximum current capacity of the PV regulator circuit on the PowerCenter is 30 amps, or approximately 900 Watts.

Step 6:
Connect Inverter. If the system includes a DC to AC inverter, connect the inverter input leads to the battery terminals or DC source center, not to the PowerCenter. The PowerCenter circuit board is not designed to handle the high currents that are possible with inverters.

Step 7:
Connect Loads. If the system includes 24 VDC loads connect them to the battery terminals or DC source center.

Step 8:
Reinstall the cover. Switch the 60A circuit breaker to "On".

The XL.1 wind turbine system is now ready to operate.

8. Inspections and Maintenance

The BWC XL.1 installation should be inspected after 30 days and then again 180 days after installation. Following these two inspections the installation should be inspected every two years and after any particularly severe weather. In corrosive marine environments more frequent inspections are recommended. Inspections should be done on days when the wind is below 7 m/s (16 mph).

<u>Check List for Inspections</u>

1. Inspect each of the anchor points. Ensure that all hardware is secure and the guy wires are properly tensioned. Check to ensure that no strands are broken.

2. Short the alternator using the procedure given in the next subsection. Climb or lower the tower. Always use proper safety belts and lanyards when climbing.

3. Inspect the blades for:

    A. Condition of the leading edge, particularly out near the tip.
    B. Tip damage.

4. Remove the spinner. Check the torque on the blade nuts; the recommended value is 47 N.m (35 ft-lbs). Check the front bearing cover for seal integrity and grease loss. Reattach the spinner and check that it is secure.

5. Check the screws holding the nacelle rubber bumpers and tail fin in place.

6. Check the cotter pins and washers on the tail pivot pin.

7. Check the torque on the tower mounting bolts; the recommended value is 54 N.m (40 ft-lbs).

8. Check for cracks or loose hardware on the tail boom and fin.

9. While descending the tower or before raising it, inspect the following:

   A. Check that the tower wiring is properly secure.
   B. Check all tower fasteners.
   C. Look for any cracks in the tower structure.
   D. Check the condition of the guy wire attachments.

10. Check the connection on all ground rods and hardware.

11. Inspect the surge arrestor(s). Replace if there are signs of damage.

12. Remove the alternator shorting connection.

13. Listen to the sound of the machine as it speeds up. No mechanical sounds, such as a "clunking" or "banging," should be heard. Also watch for any new or significant vibration. Some "growling" from the alternator is normal. The turbine operation should be very smooth.

14. Inspect the wire run, particularly all electrical connections.

15. Check condition of all wiring connections into and out of the PowerCenter.

Warning

Only qualified personnel with proper safety equipment should climb the tower. Never climb the tower when the rotor is turning.

Preventive Maintenance

We recommend that the bearings be re-packed (re-greased) every 8-12 years. There are four tapered roller bearings, two for the alternator and two for the tower adapter. They are all the same size (Timken L44643/L44610). There are two bearing seals and we recommend that these be replaced when the bearings are re-packed.

The strength of the blades, particularly at the root (inner) end, may degrade over time due to flexure and UV degradation of the fiberglass material. The symptom of degradation is a reduction in blade stiffness fore-and-aft. The blades have to become very flexible in the fore-aft direction before there is any risk of tower strikes during severe weather. We recommend that you check blade stiffness about every 10 years and replace the blades if they become extremely flexible.

9. Trouble-Shooting Problems

The following guide can be used to pinpoint the cause of operational problems with the BWC XL.1 wind turbine and the PowerCenter controller. For problems or symptoms not found in the following listing, please contact the Service Department at Bergey Windpower Co. at:

Tel: +39 872 57123
Fax:+39 872 578735
e-mail: iget@igetcol.it

PROBLEM	CAUSE(S)	DIAGNOSIS	REMEDY
Battery voltage gets too high.	PowerCenter regulating voltage set too high or no dump load being used.	Excessive battery gassing. Use voltmeter to check battery cell voltages or hydrometer to check the specific gravity – compare to battery manufacturers recommendations.	Contact the BWC Service Department for the voltage regulation setpoint adjustment procedure.
Batteries do not reach full state of charge.	PowerCenter regulating voltage set too low.	Use hydrometer to check the specific gravity of the battery cells. Compare with battery manufacturer's recommendation.	Contact the BWC Service Department for the voltage regulation setpoint adjustment procedure.
	Loads are too large.	Remove largest load. If battery bank reaches higher state of charge, then the system is overloaded.	Consult with BWC about possible remedies.
Rotor turns, but the system doesn't charge the batteries.	Open circuit breaker.	Check circuit breaker on the side of the PowerCenter.	Switch to "On"
	Blow output fuse.	No lights on PowerCenter.	Replace 90A battery fuse on PowerCenter circuit board.
	Power transistor failure.	Turbine voltage is above 10 VDC and Turbine light is on, but no current is being delivered.	Return complete PowerCenter to BWC for repair.
	Turbine rectifier failure.	Check voltage from the turbine.	Replace rectifier assembly.

PROBLEM	CAUSE(S)	DIAGNOSIS	REMEDY
Rotor makes a loud "buzzing" sound during high winds.	Blade flutter, due to unloaded operation in high winds.	Battery is at high state of charge (L6 or higher LED's are lit). Turbine power LED goes out during wind gusts, indicating that the turbine is unloaded. Rotor buzzing may be amplified by tower.	Turn on additional loads. Add dump load, so turbine is not unloaded during charge regulation.
Rotor makes a high pitch "whistling" sound.	Blade tip damage.	Check condition of blade tips.	Repair damaged blade tips with automotive "body putty" (polyester)
Rotor is unbalanced, causing the turbine to move slightly back and forth as it spins.	Blade tips not evenly spaced.	Check tip-to-tip distances with a tape measure. They should be within 6.5 mm (¼").	Loosening one blade at a time, adjust the tip spacing to bring distances within specifications.
	Ice build-up on blades.	Visual inspection. Severe icing is very obvious.	Take no action. Do not stand under machine. The ice will be shed when there is sufficient sun and wind.
Wind is higher than 16 mph, but rotor will not turn.	Short in power leads.	Check connections first. Isolate power leads. Use VOM to check for short circuit.	Repair short circuit.
	Power transistor or MOV (varistor) failure.	Switch turbine circuit breaker "Off" on PowerCenter. Turbine should start.	Return complete PowerCenter to BWC for repair.
		Disconnect turbine and check with diode meter. Should read "IV" in one direction and "OL" in the other direction.	Replace rectifier.

PROBLEM	CAUSE(S)	DIAGNOSIS	REMEDY
PV is not on, even though sun is shining.	Voltage of battery is near regulation.	Turn on additional loads to pull down battery voltage. See if PV turns on.	Normal operation.
	PV hooked up back-wards.	Check polarity.	Reverse leads.
	PV fuse blown.	Check fuse with VOM.	Replace fuse.
Dump load does not work.	Fuse blown.	Check fuse with VOM.	Check resistance of dump load, should be no less than 1 ohm. Replace fuse.
	Voltage below regula-tion.	Check battery bank voltage with VOM. If it is below 28-29.5 VDC, the dump load should not be coming on.	Normal operation.

Appendices

Appendix 1

Installation Planning

The location and height of the tower for the BWC XL.1 wind system will be important factors in determining the overall performance of the system. Average wind speed is influenced by many things and may vary considerably within a relatively small region, particularly in complex terrain. Site and tower choice, however, are often limited by such factors as zoning restrictions, property size, proximity to neighbors, customer preferences, and wiring costs. All of these factors should be taken into consideration in choosing the best tower site and height.

A. Legal Restrictions and Good Neighbor Relations

One of the first steps in planning an installation is to determine the legal status of the proposed wind turbine installation in the community in which it will be installed. In most cities and some counties an installation will be subject to zoning laws and building codes. Some neighborhoods have protective covenants that limit the types of home improvements. In areas requiring permits the installation must be planned weeks to months in advance to allow time for applications to be processed and, if necessary, hearings to be held.

The quickest way to determine the local codes and requirements is to call or visit the office of the building inspector. Few cities have specific regulations dealing with wind turbines, but most will have height restrictions, building code requirements, and a formal process for obtaining a building permit. The most common problem encountered in the United States is a height restriction of 10.7 meters (35 feet), particularly in residentially zoned areas.

The 9 m (30 ft) Tilt.Tower meets the 35 ft restriction, but it does so at some loss in performance. If you need or want to go higher than the zoning height restriction you must apply for a variance. A variance is essentially permission to break a rule and it is granted following a public hearing before a Planning Board. Obtaining a variance is a major undertaking, costing $200-5,000 and taking several months, so it is important to establish whether it will be necessary as soon as possible.

Bergey Windpower Co. has experience in working with customers and BWC dealers in variance hearings and we offer advice and assistance to those who request it.

Generally, in order to obtain a building permit you will be required to submit a plot plan and fill out an application. A plot plan is a map, drawn to scale, of your property showing the boundaries, dwelling(s) and other structures, major topographic features, easements, and, most importantly, the location and height of the proposed wind turbine tower. Often you will be required to submit plans for the tower and information on the wind turbine. In some cases you will also be required to submit a structural analysis of the tower to show that it is in compliance with the building code. Sometimes a registered Professional Engineer (PE) must sign this analysis and occasionally the PE must be licensed in the State where the unit will be installed.

Bergey Windpower Co. has engineering analyses, PE-Certified, for most towers it offers and copies of these analyses are available to our customers. Noise data is occasionally required and will soon be available for the XL.1 from Bergey Windpower Co.

If your property size is several acres or more then the turbine will likely be so far from the nearest neighbor's house that they will not be bothered. It is, none the less, strongly recommended that you contact your nearest neighbors well in advance of any construction to let them know that you are installing a wind turbine. This is doubly good advise if your property size is less than several acres or you have to obtain a variance for a building permit. Good neighbor relations boil down to treating your neighbors the same way you would like to be treated and showing respect for their views. An example of what not to do is to put the turbine on your property line so that it is closer to a neighbors house than to your own and not give those neighbors any advance notice of your intentions.

<u>In general, we do not recommend that a BWC XL.1 be installed on property of less than one-half acre in size.</u> We say this because the impact of a wind turbine on the neighbors in such a "tight" area is significant and the potential for disputes is too great.

If you have questions about procedures, requirements, or tactics, please contact us. Since so few wind systems have been installed and communities are generally unfamiliar with them, you may face some obstacles in gaining permission to install a unit. We appreciate the pioneering spirit and resolve demonstrated by our customers and we stand ready to help out in any way that we can.

B. Towers

The smooth flow of the wind over the land is interrupted by obstructions and topographical variations. These interruptions bring about two important phenomena: **wind shear** and **turbulence**. Wind shear describes the fact that close to the ground the wind is slowed down by friction and the influence of obstacles. Thus, wind speed is low close to the ground and increases with increasing height above the ground. Wind shear is more pronounced over rough terrain and less pronounced over smooth terrain. Turbulence is essentially rough air caused by the wind passing over obstructions such as trees, buildings, or terrain features. Turbulent air reduces energy output and puts greater strain on the wind turbine.

The effects of both wind shear and turbulence diminish with height and can be largely overcome simply by putting the machine sufficiently high above the ground. Taller towers usually will provide better economics because the power in the wind increases as the cube of the wind velocity ($P = V^3$; e.g., a 26% increase in wind speed doubles the energy output). A small increase in average wind speed will result in a large increase in long-term energy output.

Table 2 shows the influence that tower height can have on annual energy output for the BWC XL.1 wind turbine under typical DOE Class 2 inland site conditions with a shear exponent of 0.20. Wind speed may increase more radically with tower height in hilly or wooded areas. In flat open areas, power production will increase less significantly with tower height.

The BWC XL.1 wind turbine must be placed on a tower that is tall enough to give the rotor proper exposure to the wind. Putting a wind turbine on a tower that is too short is like installing a solar system in the shade. <u>As a "rule-of-thumb" the BWC XL.1 should be 9 m (30 ft) above obstacles within 50 m (160 ft), particularly in the prevailing wind direction.</u> So, the minimum recommended tower height is 9 m (30 ft.).

Tower Height (meters)	Average Wind Speed (m/s)	Relative Energy Production
9 m	4.8	100%
13 m	5.2	121%
19 m	5.6	147%
25 m	5.9	165%
32 m	6.2	186%

Table 2: Variation in wind speed and expected relative energy output with tower height.

We do not recommend mounting the BWC XL.1 to a home and we suggest caution if installing one on a larger, more substantial, building. Our concerns are 1) the forces on the turbine and mounting system are substantial and homes are not designed structurally for them, 2) the air flow around and over a home or building is complex and can cause considerable turbulence, and 3) the wind turbine will cause vibrations that could be transmitted through the home's structure.

BWC offers a guyed-tubular tilt-up tower, the Tilt.Tower, for the XL.1 in heights form 9 m (30 ft) to 32 m (104 ft). The Tilt.Tower is cost-effective and is designed to be installable by non-experts. The installation of these towers is covered in the BWC XL.1 Tilt.Tower Installation Manual. BWC is working to expand the range of tower options, including self-supporting towers that do not require guy wires.

Customers can also supply their own towers. These towers have to meet certain criteria for strength and blade clearance (see Appendix), and a mounting adapter for the XL.1 wind turbine will need to be designed and fabricated. Customer supplied towers are not covered by the BWC warranty and any damage to the XL.1 wind turbine resulting from a customer supplied tower is excluded from the turbine warranty coverage.

C. Location

The size and layout of the installation site may limit the tower location, height, or type. More often than not, however, there are several potential sites. In choosing the best one, the following factors should be considered:

1. The proximity of the proposed site to dwellings.

As noted before, it is a good idea for you to consult with neighbors about the installation before proceeding. The rotor system and alternator do produce a certain amount of sound. This is a low-level whirring sound that usually can not be heard indoors. From a noise standpoint, the further the wind turbine is from a house the better. In general, we recommend that the turbine be installed at least 18 meters (60 feet) from the house. Most often the tower is installed 18 - 50 meters (60 - 160 feet) from the owner's house. Never choose a site that is closer to a neighbor's home than to your own.

2. The local elevation at the tower site.

Since system performance improves with increased wind turbine elevation it is sometimes best to site the tower on a hill or ridge to gain extra height. If, as is often the case however, the hill or ridge is a considerable distance (more that 100 meters or 330 ft.) from the house the additional wiring costs may more than offset the performance gain to be realized. It is often less expensive to avoid the hill and simply chose a taller tower installed closer to the house.

3. The length of the wire run.

While is possible to install wire runs (the wiring between the wind turbine and the wind turbine electronics) of several hundred meters (650 ft) or more, the costs for long wire runs, particularly if they are buried, can be prohibitive. The longer the wire run, the larger and more expensive the wire that is required to conduct the electricity with acceptable losses. As a general rule, wire runs over 100 meters (330 ft.) if buried or 200 meters (650 ft.) if installed overhead should be avoided because of their high costs. On the BWC XL.1 it is not possible to use transformers to increase the wire run voltage because the wire run is direct current (DC). Transformers only work with alternating current (AC).

4. General convenience.

Often the most compelling consideration for locating the wind turbine tower is the space where it will not interfere with vehicle traffic, fence lines, crops, gardens, septic system lateral lines, power poles, etc. Since the wind turbine installation is semi-permanent, your future plans for the property should also be taken into consideration. When using a Tilt.Tower you should consider the extra space needed for the tower when its is tilted down.

5. Safety

The BWC XL.1 should never be installed close to a power line. We recommend that the tower be at least 1 ½ times the height of the tower from any power line including any overhead service line bringing power to your home.

Warning

The wind turbine towers are typically made of metal, which readily conducts electricity. If any part of the wind turbine or tower makes contact with power lines there is a risk of electrocution.

We also recommend that any guy wire anchors be kept away from roads or paths used by vehicles.

D. Wiring

The basic electrical schematic for the BWC XL.1 battery charging system is shown in Figure 5.

The wind turbine alternator produces 3-phase AC, which is rectified into DC in the nacelle. A two (2)-conductor wire is needed between the wind turbine and the PowerCenter controller. The PowerCenter has a DC circuit breaker for the wind turbine input, so a fused-disconnect switch is not required at the base of the tower (as is recommended for the other BWC wind turbines).

We recommend that the tower wiring be with SO cord. The SO cord's neoprene jacket will provide good abrasion resistance. For ground runs we recommend THHN wire buried inside plastic conduit rated for electrical service. A suitable watertight junction box should be installed at the base of the tower to enclose the wire connections between the tower and underground wiring.

In some cases it will be possible to provide direct point-to-point wiring between the XL.1 wind turbine and the PowerCenter. For this purpose we recommend 2-conductor VNTC (Vinyl Nylon Tray Cable), which is suitable for outdoor and direct-burial applications. For rocky soils, or runs underneath roadways, we recommend that the underground wire run be installed in conduit. If a wiring junction is made at the base of the tower then a watertight junction box should be installed for the connections.

The recommended wire sizes for the 24 VDC XL.1 wind turbine are shown in Table 3. The listed distances include the height of the tower.

Maximum Current: 60 amps

Caution
Installing wire sizes larger than those recommended will increase the maximum current produced by the turbine.

Distance	Size (U.S.)	Size (metric)
23 m (75 ft)	#8 AWG	3.35 mm^2
46 m (150 ft)	#6 AWG	4.25 mm^2
69 m (225 ft)	#4 AWG	5 mm^2
91 m (300 ft)	#4 AWG	5 mm^2
114 m (375 ft)	#2 AWG	7.1 mm^2
130 m (450 ft)	#2 AWG	7.1 mm^2

Table 3: Recommended Wire Sizes for the XL.1

Note: These wire sizes have been engineered to provide optimum rotor loading for the BWC XL.1/24 wind turbine. Deviation from these recommendations can result in decreased performance from your machine and / or unnecessary additional wire-run costs. The use of a wire gage one size larger than the recommended size is acceptable and is recommended if aluminum wire is used.

Before assembling the wind turbine the tower wiring must be in place, though not necessarily permanently affixed. We recommend that you leave at least 30 cm (12 in) of free wire at the top of the tower for making the electrical connections to the wind turbine.

E. Other System Components

A complete remote power system will include other electrical components such as a solar array (optional), a battery bank (required), a dump load (optional), and an inverter (optional). These components are sometimes called the “balance of system” or BOS equipment.

The wind turbine and the other BOS equipment are electrically connected in a “DC-bus” architecture, as shown in Figure 6. The DC-bus architecture is robust and very flexible, allowing endless options for multiple and differing components. The unifying feature is that all of these components are electrically connected to the positive (+) and negative (-) DC bus, so they all experience the same DC voltage. The DC voltage of the system is largely determined by the state of charge of the battery bank and to a lesser, but still significant, extent by the charging or discharging rates (the rate at which DC current, or amps, is being created or consumed).

Charging components, such as wind turbines, solar arrays, and inverter/chargers (powered by a back-up generator or the power grid), can be added to a DC-bus system with separate charge regulators and these regulators can operate completely autonomously (e.g., they do not need to communicate with each other or be coordinated using a central system controller). The separate charge regulators, whether there is just one or if there are a dozen, will respond to the DC-bus voltage and control their generators charging current.

When putting together or adding to a DC-bus remote power system there are a few pitfalls to avoid if possible:

- Battery banks that are too small, so that battery voltage swings too much with high charging or discharging currents.
- Multiple charge regulators set to the same voltage, so that there is one big

step in charging current rather than several smaller ones.

- Setting high voltage regulation points too low so that the batteries don't get fully charged
- Setting the low voltage disconnect (typically part of the inverter) too high so that the battery bank capacity is underutilized