Wind Turbine Rectifier Design Guide

Date created: 28th May 2008

Version: 1.0

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Sibol ng Agham at Teknolohiya
(Wellspring of Science and Technology)

Contents

Introduction

This is a guide to the design and construction for a rectifier for a small wind turbine.

This guide was produced for SIBAT, an NGO based in the Philippines, who are implementing a 1kW (1.8m blade) small wind turbine for use in remote areas of the Philippines. The basic turbine design is from Hugh Piggott and is described in detail in his ‘How to build a wind turbine: the axial flux windmill plans’ guide, available from http://www.scoraigwind.com/.

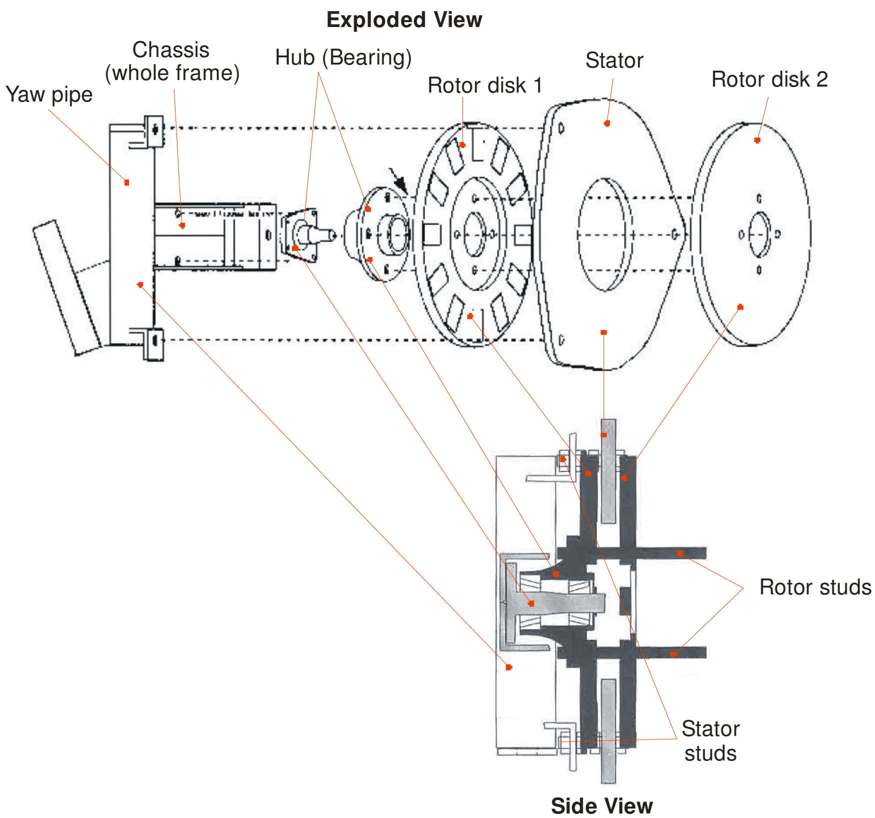
Note: Electricity can be very dangerous. Please consult a qualified electrical engineer before implementing any systems.

Note: *This is not a definitive document. Please email the author (matt@re-innovation.co.uk) if you have any comments and suggestions.*

Wind turbine operation

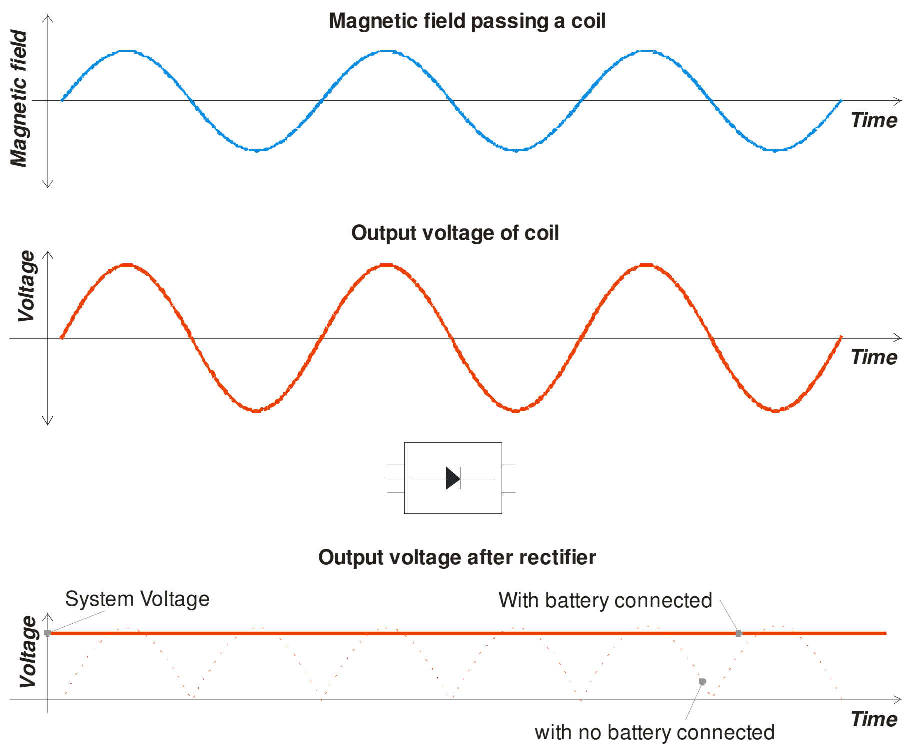
Basically, the blades capture the wind energy. The rotational motion of the blades is converted into electrical energy through the alternator (which is comprised of the rotor disk and stator). This is then ‘rectified’ and stored within a battery bank.

The alternator is comprised of:



The rotor disks contain very strong magnets. There are two rotor disks, one on each side of the stator. In-between the two rotor disks the magnetic field is very strong. The magnets in the rotor disks are mounted N-pole then S-pole so that the rotating magnetic field changes direction as the different magnets pass.

The stator is comprised of a number of coils of enamelled copper wire. (Please see 'WT Stator Construction Guide' for more details on the stator design). As the rotor disk magnets pass the stator coils, the changing magnetic field induces a voltage in the coil. As the magnetic field varies from one direction to the other, so does the induced voltage. This means the output from the stator coils is a sine wave with a frequency dependent upon the rotational speed of the blades.



In order to recharge a lead acid battery, the output from the stator must be 'rectified' from alternating (AC) to direct (DC).

Simplistically, the rectifier converts the alternating output voltage of the stator coil into the flat DC voltage required to recharge the battery.

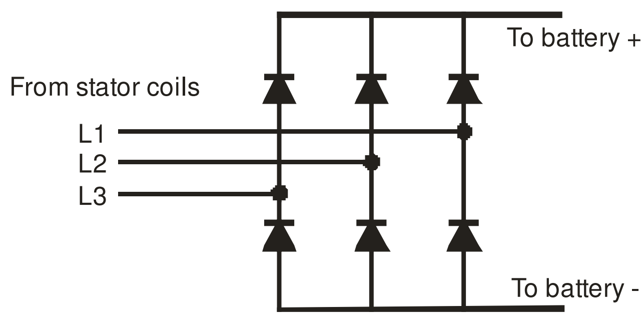
More technically, the rectifier allows current only to flow one way, hence the output waveform shown labelled 'with no battery connected'. When the battery is connected, power is transferred from the alternator to the battery only when the output voltage of the coil is higher than the system (which is the same as the battery bank) voltage. The battery bank smoothes the system voltage to a nearly constant DC level.

The rectifier is comprised of a number of diodes. A diode is a device which only allows current to flow one way through the device. The direction the current can flow is indicated by the direction of the 'arrow' on the electrical symbol.

The following design is for the 1kW wind turbine design, which has a three-phase (three wires) stator output. Please refer to 'How to build a wind turbine: the axial flux windmill plans' guide for details of the 500W rectifier design.

The electrical schematic for the 1kW three-phase rectifier (called a 'three-phase bridge rectifier') is shown here:

Three Phase Bridge Rectifier



The main design features of the practical rectifier design are:

- *The current rating of each diode must be greater than the maximum current from the WT (I_{WT_max})*
- *The design must cope with the heat dissipated by the diodes*

  Each diode has a voltage drop of 0.7V (V_{diode}). This leads to power loss due to the current flowing through the diode (from the equation Power = Voltage x Current). There are two diodes in the current path (so the voltage drop is 2 x V_{diode}) and it is a three-phase system (so the current in each phase is reduced by a factor of root 3), but there are three diode pairs (so the power dissipated is the total of all three diode pairs (i.e. multiply by 3), hence the maximum power dissipated as heat is:

  $$P_{rectifier} = 3 \times \left(\frac{V_{diode} \times 2 \times \mathrm{I_{WTmax}}}{\sqrt{3}}\right)$$

  $$P_{rectifier} = 3 \times \left(\frac{1.4 \times \mathrm{I_{WTmax}}}{\sqrt{3}}\right)$$

  As an example, for a system voltage of 12V the maximum current is 1000W / 12V = 83A. This leads to a power loss within each diode pair of 67W, giving a maximum total heat dissipation in the rectifier of around 200W. To dissipate this heat, a heatsink is required and the unit is mounted at the top of the wind turbine tower.

- *Must be fully water proof*

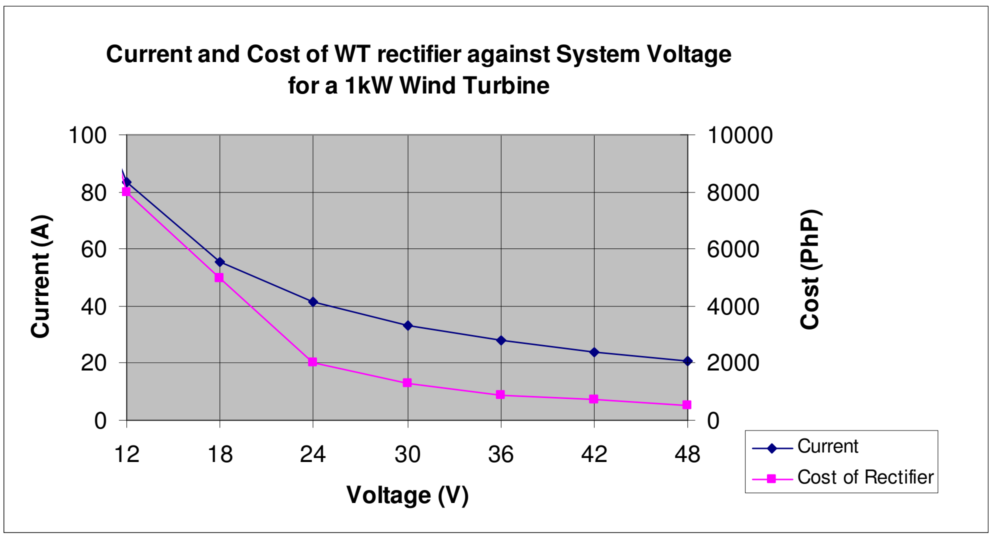
  As the rectifier is mounted at the top of the wind turbine tower.

Construction

Rectifier current rating

The first thing to choose is the current rating of the rectifier. It is assumed here that the system voltage has already been decided upon (see 'Wind Turbine Electrical System Design Guide' for more details). As mentioned in that guide, the rectifier will be less expensive with a higher system voltage, due to the higher currents at lower voltages.

The graph below shows current reduction as the system voltage is increased and the approximate cost of a wind turbine rectifier for a 1kW wind turbine. It can be seen that changing from 12V to 48V will reduce the current, and hence cable size and cost, by a factor of 4. The cost of the rectifier will be dramatically reduced by a factor of 16.



For the three-phase 1kW system it is best to use a three-phase diode bridge rectifier. I think it is best to use a slightly over-rated component. The best options available from RS include:

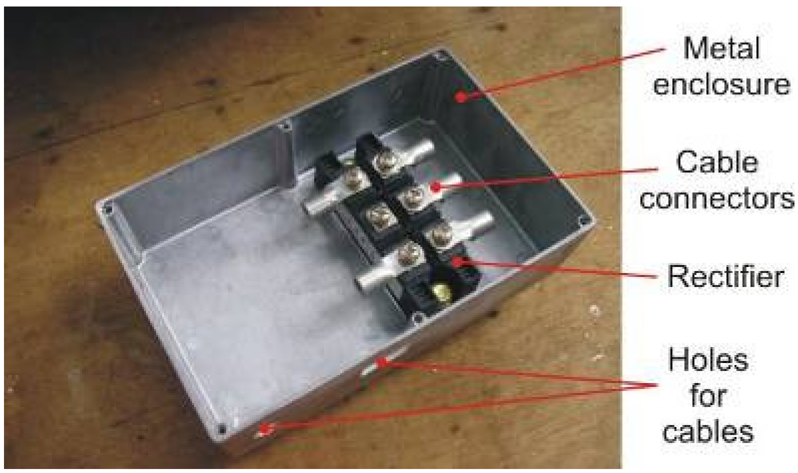
System Voltage	DC Current	3-Phase Current	Type	RS Code	Cost (PhP)
12V	83A	60A	70MT160K'B' 70A 3-Phase	395-3935	4801
24V	42A	30A	36MT40 35A 3-Phase	395-3238	868
48V	21A	15A	26MT60 25A 3-Phase	395-2897	646

Note: *These may be available at less expense from different suppliers. Also different types with similar ratings may also be available.*

Find suitable enclosure

Once the rectifier has been chosen a suitable enclosure must be found. This must be big enough to hold the rectifier along with enough space for the connectors and cables to the rectifier. The cables are quite thick therefore give a large space allowance for these cables. A metal enclosure must be used to allow transfer of heat from the rectifier to the heatsink through the metal box.

The enclosure should be water-proof, with a good seal. A rating of IP65 or above would be best.



Holes must be cut in the side for the three cables from the stator and for the two cables to the battery bank. Another hole is also required for mounting the unit onto the wind turbine chassis.

Stop and think about where the holes should go before drilling!

If possible use separate entry holes for each cable and water-proof cable glands (not shown on the enclosure above).

Cable glands available from RS components are shown to the left. Cost is approx. PhP150 each.

There are a number of suitable boxes available from RS, in the region of PhP600 to PhP2000, look at the ‘Enclosures/boxes’ section.

The enclosure shown in this guide was a cheaper, unsealed box. A seal was made using silicone sealant, but each time the enclosure is opened the silicone sealant must be replaced. This is still an option if costs are restricted, but ensure the unit is sealed very well each time it is opened.

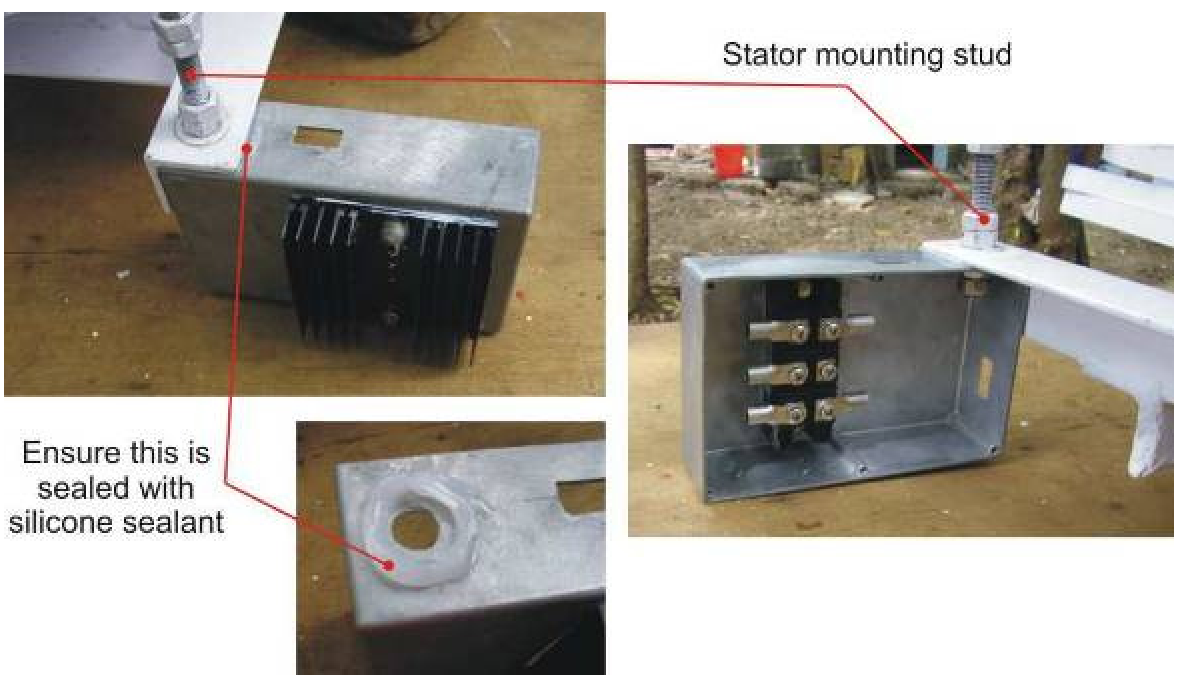
Find suitable heatsink

In order to help dissipate the heat generated by the rectifier an additional heatsink is also used. The fins on the heatsink allow heat to dissipate readily from the large surface area.

The heatsink is bolted on top of the rectifier, with the enclosure in-between. Silicone heat transfer compound must be used on the surfaces of the rectifier onto the enclosure and the heatsink onto the enclosure.

Mount onto turbine chassis

Next we need to find suitable attaching point to wind turbine chassis. The stator holding studs are suitable for this, but ensure that it will not be in the way of the blades or the tail, even when furled.



Connect stator and battery cables

Now we need to connect the stator cables. To do this, use good quality ring or spade connectors (choice depends upon type of rectifier terminals). The best practice is to crimp the cables and then solder them. This will give a good mechanical and electrical connection. Use heat shrink tubing or self-amalgamating rubber tape to insulate them.

Then place the chassis with the rectifier box attached onto the tower. When ready, connect the battery cables. Again use good quality ring or spade connectors. Ensure that the cables are correctly marked for positive and negative. Ensure all the connections are tight.

Now ensure that the cable entry points are well sealed. Tighten the cable glands (if used) or fill the gaps with a good quality silicone sealant suitable for external use.

The enclosure lid should be fitted. If this is not an IP65 sealed enclosure then this should be sealed well with silicone sealant.

The chassis should be able to easily spin on the yaw bearing. Ensure neither the cables nor the rectifier are in the way of the usual operation of the turbine (i.e. ensure the blades can spin easily and that the tail can furl).

Now to finish off the rest of the installation.....

Parts suppliers and costings

Item	Supplier	Quantity	Cost (PhP)
Rectifier	RS components (www.rswww.com)	1pc	600 - 5000
Enclosure	RS components (sealed) Alexan (cheaper, unsealed)	1pc	500 - 2000
Heatsink	Alexan	1pc	500
Cable glands	RS components	5pcs	0 - 750
Bolts/ Nuts/ Washers for rectifier	General hardware	4pcs	100
Heat transfer compound	Deeco/Alexan	Some	50
Silicone Sealant	Ace Hardware	1 tube	250
Cable connectors	Roks Electronics Center, G.Puyat Street, Quiapo	5pcs	200
Heatshrink tubing	Deeco/Alexan	1m	100
Electrical tape	Deeco/Alexan	1m	30
Self-amalgamating tape	Ace Hardware	1m	50
Total Cost	Guidance only – depends upon design		2380 to 9030