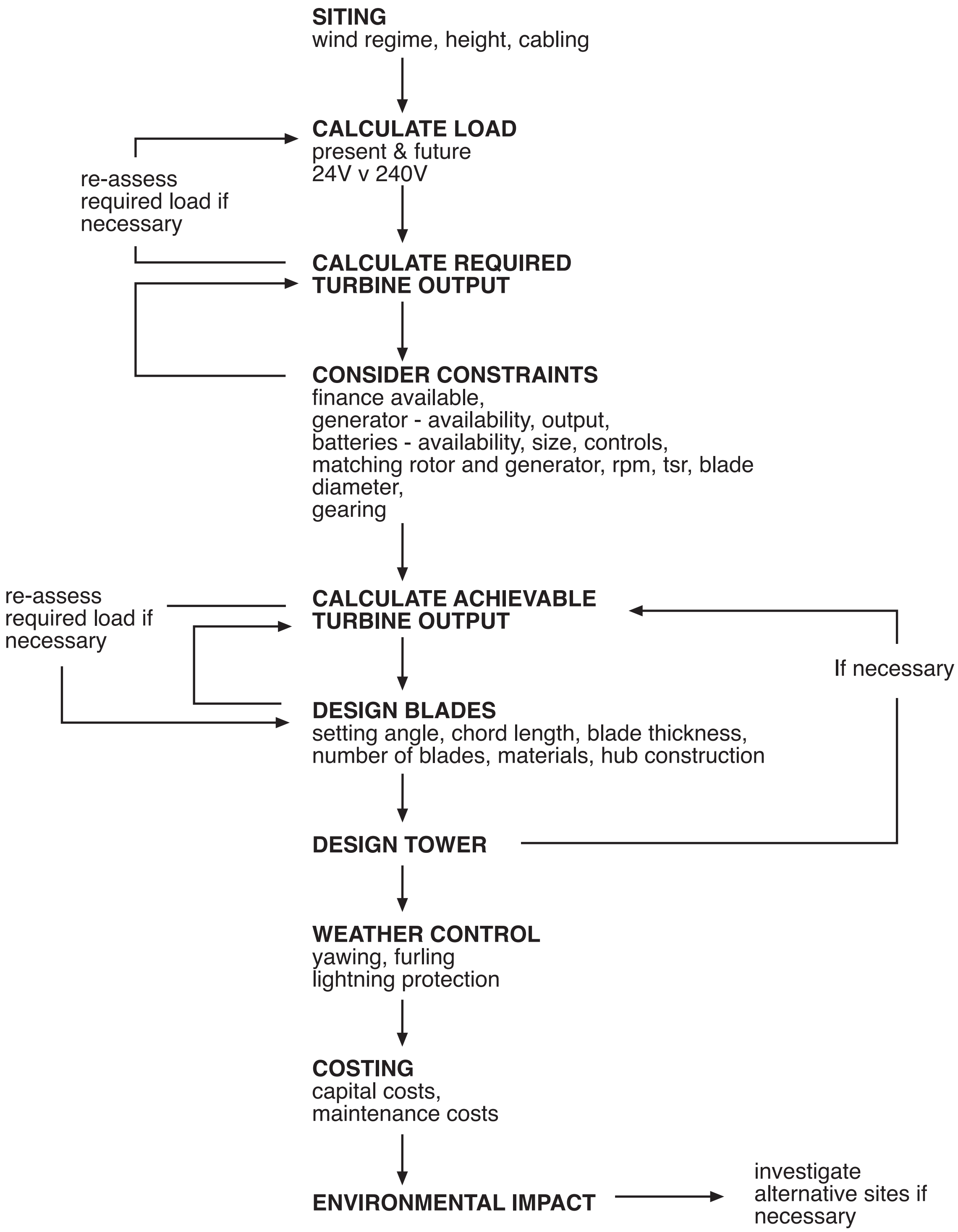
DESIGN AND MAKE A WIND TURBINE

CONTENTS

WIND TURBINE DESIGN PROCESS



TEP WIND TURBINES - CASE STUDY

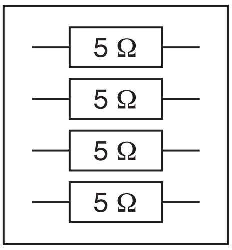
WRITHLINGTON SCHOOL - 'A' LEVEL PHYSICS STUDENTS DESIGNING AND BUILDING GENERATORS FOR SCHOOL FARM

DESIGN BRIEF
Students were asked to design wind turbines as part of 'A' level Physics Assessed practical work to provide energy for the school farm.

DESIGN DETAILS
Materials: students were given little choice, as the main focus of their work was developing design investigations on given generators as this best fitted the requirements of Cambridge A level Physics for design experiments and the limited time available.

Generators - scrap 12 V car radiator fan motors. 2 donated by local car dealers and 6 purchased from local scrap yard (rated between 40 and 80w).

Test Equipment - high power resistance boxes using 50W, 5 Ω resistors from RS, were made up to allow testing of the generators.

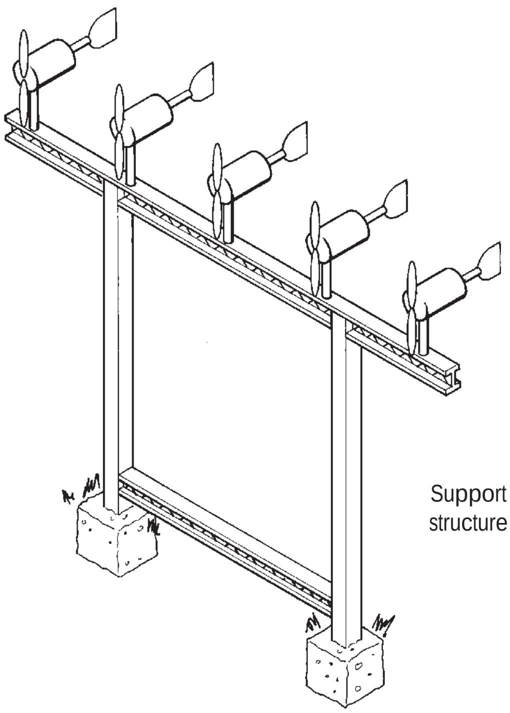


Gives 20 Ω to 1.25 Ω in combinations of series and parallel

Rotor blades - carved from Jelutong, an easily carved hardwood with a limited life expectancy but easily worked by non experts with spoke shaves and files.

Tail etc - from sheet ply

Support structure - The school farm is a 5 acre site with a mixture of animals, pigs, sheep, cattle, poultry, goats, rabbits. It is heavily used as a community resource by other schools and groups. There is therefore great potential for expanding the energy education features of the farm. As a result a clean lined structure (no guys) was important, and via a school parent we obtained scrap framing.



TIME SCALE
My approach for working within a tight curriculum was to make it clear that for a completed project the students would need to spend some of their own time on sections not suitable for inclusion in assessed practical work. The project generated enough enthusiasm for this to be successful.

The approximate timing is as follows:

Activity	In Class Time	Own Time
Generator investigations	6 x 75 mins	—
Carving rotor blades	1 x 75 mins	3 hours
Excavations	1 days work by Youth Awards Y10 pupils	
Erection of Structure	2 days with parent (contracts manager) + friend	
Concrete to Foundations	1 afternoon of own time for 3 members of 'A' level class	

Items to be completed (all in students own time)
1. Fixing tails, rotors, generators
2. Connection of electrical services (display only with this group)

FUTURE PLANS
Future work for other 'A' level groups will be to monitor the performance of wind turbines and compare these to theoretical values.

Design work for future groups will focus on using the power generated to provide a 12v lighting system for the farm and electric fencing for animals.

PROJECT ASSESSMENT
The greatest success of the project has been the enthusiasm and determination of the students who have recognised the complexity of the work but have had the confidence to proceed with a number of new concepts and difficult problems, and have responded to the challenge of real engineering design.

There has been a clear awareness within the school that the Physics department is involved in important projects and numbers for 'A' level Physics are up for next year.

With the project I have been disappointed that it is taking longer than I hoped and that I have had to give a lot of my time to support the project - scrap yard visits, work on the structure etc., - but the results are well worth it.

The students have obtained improved assessed practical marks and the school farm has an important resource.

STUDENT BRIEFING SHEET 1 - DESIGN PROBLEM

WIND ENERGY
It is widely accepted that global warming and acid rain are major environmental problems facing the world today. The main cause of these are carbon, sulphur and nitrogen emissions from oil-fired and coal-fired power stations. Most governments in the world accept that a reduction in this pollution must be made quickly. This is reflected in policies which state that a certain percentage of electricity must be produced by cleaner production methods.

Producing electricity by using wind as a source is probably one of the cleanest methods. We in Britain have an abundance of wind, which is renewable and therefore will not run out, as will oil and coal.

It is assumed that you have assessed the wind power available on your school site. You are now going to design a wind turbine which can be erected on the site in order to meet an individual need.

Outside the school site there may be other possibilities. There are many dwellings in Britain which, even today, are not close enough to the National Grid to make connection an economic option. These must, if they require electricity, find a way of producing their own. A wind powered generator producing enough energy for a single dwelling can be a viable option.

DESIGN BRIEF

Design and make a wind powered generating system to meet an identified need for electricity within your school.

RESTRICTIONS

The finished system must be assembled on the school site.
You will be expected to contribute Design and Technology methodology.
You should take responsibility for the development of the project and organise your time so that the project is completed on time.

Risk Assessments
Your design will need to include risk assessments for any potentially hazardous operations. For example, providing safe procedures for erection of towers.

GETTING STARTED

Getting started is one of the problems with designing anything. Looking at solutions to the problem which others have devised is always a good way of starting. There are many sites in the British Isles which you can visit and often people who have a wind turbine are willing to show and discuss them. Your teacher will help here and may be able to organise a visit. There are videos on wind energy that might act as a useful starting point.

Analysing the problem which you are trying to solve should be done at the outset. This helps by breaking a complex problem into units which may be easier to solve individually, although at a later stage the task will have to be looked at as a whole.

You will need to draw up specifications for each separate part of the system, ensuring that they are all compatible, before you can move on to the detailed design of each. There are various interrelated factors about wind turbine design and location that you will have to consider. If you move too hastily towards final designs for any separate part of the whole system (e.g. the blades) you may find on further consideration, that you have to change the location, only to discover that your blade design will not match the wind regime at the new site.

You need to consider carefully, precisely what you need to know -

- What will a system need to include - what are the parts?
- What could the power be used for - where and how much?
- What budget is available?
- What size of machine and system will be needed?
- Where could the machine be erected?

At this initial stage you will need a number of possible options in as many areas as possible, to give you the flexibility to devise an overall system that will work.

BUDGET AVAILABLE

This has to be discussed with your teacher. Every school's situation is different. However, you will see that there are possibilities within this project for using and adapting 'scrap' or 'found' materials and items. You will find that it requires more skill to select useful items from scrap available than to order new items.

Task

- Research the background of wind turbines and their application
- Identify the budget you have available
- Develop an outline specification for the proposed wind turbine
- Produce an investigation plan detailing how the project will be tackled and highlighting the necessary design process

STUDENT BRIEFING SHEET 2 - SITING THE WIND TURBINE AND IDENTIFYING NEEDS

SITING

Choosing the correct site is very important and developers of windfarms spend a considerable amount of money monitoring and evaluating the suitability of sites. The school campus might not be the most suitable location for a wind turbine because of buildings and other obstructions. However, there will be positions on the school site which will be better than others. You should look carefully at all areas available to you, research what criteria you should consider and choose the most suitable position.

Strength and consistency of the wind will certainly not be the only points you have to consider. Environmental and personal considerations are important; e.g. the head may, or may not, be pleased to have a wind turbine placed on the lawn outside his or her window.

You can find the site on the school premises with the best wind regime, but is it actually the 'best' site to erect the wind turbine on? Various other factors come into play -

- Could the tower be fixed securely to the ground?
- Would it be secure from damage by pupils or intruders?
- What would the environmental impact be?
- Would the height cause a problem?
- Who would be able to see it?
- Would carrying the electricity to where it will be used be a problem - expense or disruption?
- What about assessing damage caused by parts falling from the turbine?

USE OF THE POWER

You are required to design a device that will produce some useful power, so you will have to investigate the potential uses on the school site and choose something from those that will match the power that you can produce and will be in a convenient location on the site. Detailed suggestions of how to do this follow below in the section 'Calculating the Load'.

It is assumed that you will be using the power to generate electricity. Generally, this is the most appropriate use for wind power in Britain. However, you might find that there was some appropriate use for wind powered mechanical work on your site.

WHAT VOLTAGE?

Unless you have access to vastly greater financial resources than the average school has, you will be working on a relatively small scale, generating electricity at 6, 12 or 24 volts DC. You will probably be storing it at the same voltage.

Then you have to decide at what voltage you will be using it. It is very likely that safety regulations will make it impossible for you to work on any system that involves 240V in any way, so you may be obliged to generate, store and use it at no more than 24V.

You will need to investigate what uses there are at present, or could be, for electricity at low voltages in the school. Systems might either be fixed or portable depending on the needs identified.

Size of Machine and System

How do you decide what size the windmill will be? This does not mean just the physical size but the power output. The two are obviously closely linked together.

Consider the factors that will affect the amount of electricity that can be generated -

the wind energy available on the site

the size of the blades

the design of the blades

the height of the tower

the generator that you use

manufacturing technologies available to you

money

the match between the rotor and the generator

energy storage possible

What you need to arrive at at this stage is some idea (which can be reassessed later) of the final size of your wind turbine.

You will find that some of these factors will be more flexible than others. Some will present serious constraints on your design and you will have to distinguish between those and the design problems which can relatively easily be resolved later.

For example, the detailed design of the blades is not likely to be a limiting constraint and you cannot arrive at a specification for them until you have designed the overall system, so there is no point in wasting your time on that at this stage.

However the following factors could place major constraints on your design -

- the generator
- the battery store
- the location and tower

Both the generator and battery are potentially expensive items. Your final design is likely therefore to be limited by what you can get hold of.

Found materials then should be seriously considered as an alternative to buying new. Potential sources might include scrap yards for car or van dynamos or alternators, and army surplus stores for second hand batteries. Deep cycle batteries should be chosen in preference to normal car batteries.

Tasks

- Identify the best site within your school grounds using the criteria outlined above
- Identify a range of applications for electricity that can be met using wind power
- Start considering the size of the wind turbine
- Begin sourcing the major elements of your system, the battery store and the generator

Risk Assessment

1. Visits to scrapyards should not be unsupervised as customers are frequently expected to work in unsafe places, i.e. stacks of cars.

2. All batteries contain hazardous chemicals. The chemicals involved should be identified and batteries handled appropriately.

STUDENT BRIEFING SHEET 3 - CALCULATING THE LOAD AND STORAGE

What you will be using the electricity for is a crucial factor. What will the load be and how will it vary?

CALCULATING LOAD

Having identified present and potential uses in the school, you now have to calculate what the overall load will be, what the demand is. What do you need to know in order to be able to do that?

PATTERN OF USE

What exactly do you need to know about the load? What sort of pattern of use do you need to be able to see?

There are various ways that you can use the data you collect. Will it be useful to see what the average use is per year, per month or perhaps per day? Do you need to know what the maximum load at one moment might be? Supposing the whole load came between 11 and 12 o'clock on Tuesday mornings?

Does it also matter how long such a peak load might last? How can you present the information so that you can see that there may be one particular appliance whose demands might create a problem?

SYSTEM EFFICIENCY

What would be a measure of overall efficiency?

- The amount of energy in the form of electricity available to run appliances as a proportion of the amount of energy in the wind?
- The amount of energy in the form of electricity available to run appliances as a proportion of what it would be realistically possible to get out of the wind?
- Some other criteria?

Consider the whole system and identify where energy losses will occur.

Stages where there could be losses -

- Efficiency of the rotor in taking energy out of the wind.
- Friction losses in bearings for rotor shaft.
- Losses in generator - heat.
- Losses in cables - heat.
- Losses in storage.
- What else?

Do not forget that the efficiency will vary with changes in wind speed. A loss of 100 watts in gearing, for example, which may be acceptable in high wind speeds, may reduce the efficiency to zero in lower windspeeds.

The efficiency of the system plays an important part in determining the required storage capacity.

STORAGE OF ENERGY

You have considered your energy requirements and your pattern of energy use. What sort of storage facility will you need, if any? How much energy are you going to want to store and how long for? What is the length of relatively windless periods that you will need to plan for in normal operation? (You will need to look again at your wind regime data).

Energy storage tends to be expensive. You will need to consider what will be worthwhile planning for, both in financial terms and in terms of the use of materials and other resources. You have various options -

- provide enough storage to satisfy your total demand at all times,
- provide minimal storage and use an alternative source of energy whenever necessary,
- do something in between (reasonable storage and occasional use of a back-up),
- provide as much storage as you can afford or get hold of.

Is there any possibility of doing without an energy store? What will happen when you have one of those exceptional very long windless periods which you may not be able to predict? What happens to the size of your store if you try to cater for that?

What are the energy loss implications of storage? (For details of battery suppliers, costs etc. see information sheet on batteries and Resources)

If it is absolutely vital that you can get the power when you want to use it and you cannot switch to a reliable back-up, then you will have to be very cautious about how big a load you try to satisfy.

WHAT HAPPENS WHEN THERE IS NO WIND AND THE STORE IS EMPTY?

This will happen. What you need to do about it depends on the nature of your load. It may be that it will not matter if it does not get power for an indefinite period of time. If it does matter then you will need some sort of back-up electricity supply, presumably the mains.

You will have to devise a way of doing this which does not involve breaking into or tampering with the mains supply in any way. For extremely good reasons there are safety regulations to stop you doing this. You may need a system that alerts you to the fact that you need to change to the mains.

A LOAD LED OR MAXIMUM SUPPLY LED SYSTEM

Now you have a choice of approaches.
One is to start with this target load, which is the demand for energy that you would like to fulfil, and calculate what size of wind turbine you will need to do this, bearing in mind the wind regime of the site and the efficiency of the system. Then you would need to investigate how practical it would be for you to build such a machine, taking into account the money available, the practical feasibility of manufacturing and erecting it and the other constrictions on siting, such as aesthetics, noise, security and safety. The costing needs to include batteries, control systems, tower, cabling etc.

The other approach is to start by calculating how large a machine you can practically build and erect on the site and then see how much of the target load that could supply.

The size of the machine might also be limited by the components you can get hold of. The questions then become 'what is the best way of utilising the available power and how many turbines will be needed for an identified load?'.

Tasks

- Calculate the potential loads and patterns of use created by the applications already identified.
- Calculate the turbine output required to meet these loads.
- Identify the application and load most appropriate to be met.
- Calculate the storage capacity required to meet this application and load.

STUDENT BRIEFING SHEET 4 - INVESTIGATING GENERATORS AND MOTORS

Get a collection of as many different types of motors and generators as you can, in sizes from very small (3V or less) motors up to 12V ones. Try turning them; just spinning them by hand to start off with. Note which are easy to turn and which difficult.

If possible, open them up and have a good look inside. Notice the number of poles, the position of the poles, the size and number of coils, whether it is the magnets or the coils which rotate, whether they are permanent or electromagnets and how big the airgap is between the coils and magnets. Are there any other features that distinguish one from another? If possible identify the current input (or output) that each is designed for.

POSSIBLE GENERATORS OR MOTORS TO USE

- You can buy a generator designed for a wind machine from LVM or World Power Technologies.
- Computer tape drive motors - old main frame type preferably.
- Servo motors.
- Car fan motors.
- Stepper motors may well be worth investigating.
- DIY generator construction.

Generators vary and have their own optimum speed of rotation. You will need to consider what you need in terms of a generator, and then what you can get hold of. Your design may well be limited by what is available.

You will have to consider -

- matching the rotor and generator.
- rpm (revs per minute = speed of rotation).
- tsr (tip speed ratio).
- blade diameter.
- gearing.

You could consider using gearing to match the speed of your rotor to that of the generator. The tip speed ratio (tsr) is a measure of how fast the blades turn in relation to the wind. It is how much faster the tip of the blade turns than the wind speed at the time, and it depends on the shape and number of the blades.

You will need to get a good grasp of these factors and how they affect each other and you will find information on all of them in the information sheets in this pack.

EXPERIMENTAL INVESTIGATIONS OF GENERATORS

Assuming you have selected a generator or motor as a potential generator for your wind turbine you need to carry out a series of bench tests to analyse its output characteristics to predict its likely performance in service and allow you to optimise your design.

The following five investigations will give you a detailed picture of your generators capabilities.

Risk Assessment

1. Rapidly rotating apparatus will need to be properly clamped.
2. When using a stroboscope, beware of 'frozen' generator motion.
3. Strobe frequencies of 8 - 15 Hz can induce fits in some epileptics.
4. If a driver motor is used to excite your generator, avoid possibilities of shock from the driver power supply.
5. Load resistors in INV 4 must be able to cope with the high power outputs from your generator to avoid overheating and fire hazard.

INVESTIGATION 1 - *DESIGN AN EXPERIMENT TO DETERMINE THE TORQUE REQUIRED TO START YOUR GENERATOR*

Your target is to develop techniques to measure as accurately as possible the small torques involved so the blade design can confidently allow for a start up in speed for your generator.

At least two techniques should be used to help you evaluate the reliability of your results.

APPARATUS: motor/generator, small hand tools, rules, straws, masses, Plasticine, thread, 0-1N Newton meters, 1-10N Newton meters.

INVESTIGATION 2 - *DESIGN AN EXPERIMENT TO INVESTIGATE THE VOLTAGE, POWER AND SPEED CHARACTERISTICS OF YOUR GENERATOR RUN AS A MOTOR*

Your target is to develop methods to measure the output performance speed of your generator as a motor over a suitable range of inputs. You should attempt to devise a range of approaches to evaluate the accuracy of measurements taken and to build a good understanding of your generator.

APPARATUS: motor/generator, hand tools, G-clamps, rules, stroboscope.

INVESTIGATION 3 - *DESIGN EXPERIMENTS TO INVESTIGATE THE OUTPUT CHARACTERISTICS OF YOUR GENERATOR AT A SUITABLE RANGE OF SPEEDS*

You will need to design an arrangement to vary the speed of your generator and measure outputs (voltage ? power ?), relate this to generator theory and to likely generator speeds of your wind turbine in action.

APPARATUS: motor or generator, hand tools, G-clamps, stroboscope, various lab motors or other driving system, power supplies, CROs, ammeters, voltmeters, rheostats and resistance boxes.

INVESTIGATION 4 - *DESIGN AN EXPERIMENT TO INVESTIGATE THE VARIATION OF GENERATOR OUTPUTS WITH THE APPLIED LOAD.*

The output of any generator will vary with the load it is supplying.
Develop your ideas from investigation 3 to analyse suitable matching of your generator to practical loads.

APPARATUS: As Inv 3

INVESTIGATION 5 - *MATCHING GENERATOR AND ROTOR DESIGN TO SELECT AN OPTIMUM ROTOR DIAMETER*

Select an appropriate Tip Speed ratio and combine this with a suitable value of local wind speed to produce a range of generator speeds for different rotor diameters.
Compare the results obtained with experimental data and select an optimum rotor diameter to construct.

As an important check apply the following equation for starting torque and compare it with your results in INV1.

$$\text{Torque} = \frac{v^2 \times D^3}{10 \times TSR^2}$$

Tasks
Once you have

- identified an appropriate generator,
- identified its output characteristics,
- considered the need for gearing to match the generator with an appropriate rotor design,
- calculated the power output from a wind turbine using these characteristics,

you will need to reconsider the target load and evaluate the percentage that can be met considering the constraints of battery store availability, generator output and budget.

You might be able to only meet a percentage of the energy need identified, if so how will you provide back up supplies?

STUDENT BRIEFING SHEET 5 - GEARING, BLADES, AND NACELLE

GEARING

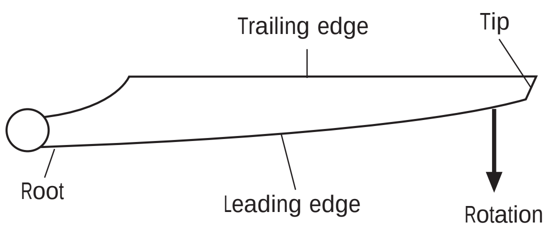
What are the advantages and disadvantages of using some sort of gearing?

Advantages -
speed up rpm to suit generator

Disadvantages -
friction losses
cost of another item
need for bearings to support shaft
need for weather protection for gearing system
another component to maintain.

What types of gearing could you use?
- belt and pulley
- toothed belt
- toothed gears.

BLADES



Factors you will need to consider include:
Size - length, width and thickness

Shape - not necessarily the same shape in section all the way along the length,

Setting angle - not necessarily the same along the whole length

Number

Material - what properties are you looking for and what materials will fit those requirements?

Attachment to hub - what kind of hub?

Ease of repair and maintenance

Safety

NACELLE

The nacelle is the housing that sits on the top of the tower and contains the generator, gearing, controls and bearings. It will need to:

- protect all these parts from bad weather, particularly rain,
- be able to rotate freely,
- not in itself produce undue interference to the wind,
- support the tail, generator, gearbox etc.,
- enable you to get easy access to the parts inside,
- not fly off, in whole or part, in high winds.

What materials would be suitable? (Bearing in mind robustness and ease of construction).
What sort of shape would be best?
How will you get access to the components inside?

If the rotor goes straight onto the generator shaft without any gearing, will you need a separate casing to protect anything?

Tasks
- Provide a solution to the need for gearing.
- Design and construct the blades.
- Consider the need for a nacelle and its design if necessary.
- Construct the nacelle housing including generator and any gearing assemblies.

STUDENT BRIEFING SHEET 6 - HEIGHT, TOWER, CABLING AND YAWING

HEIGHT

Your wind turbine must be positioned away from the ground. What will determine the height? What difference will the height of the machine make to -

- power output
- visual impact
- planning restrictions
- cost of tower
- forces operating on tower?

The design must be safe. There will be stresses involved and vibrations from the rotor turning. It must be stressed that on a school site SAFETY must be considered of paramount importance and some loss of efficiency would be acceptable to ensure your safety and that of others.

TOWERS

You have several choices:

- build one yourselves,
- buy something specifically designed,
- use something ('found' or bought) that will do,
- have it guyed or freestanding.

What sort of stresses are there on the tower? Basically the wind is trying to push the windmill out of its path (i.e. over). Which is the prevailing wind direction and how prevailing is it? How likely are you to get very strong winds from other directions? Will the blades be stopped in high winds? If the blades are still rotating then the whole of the swept area will be wind resistant rather than just the area of the blades themselves. You could calculate what difference this would make for your design. What about gusts of wind?

You will need to do a calculation of moments about a point, the point being where the tower meets the ground (on the side away from the currently prevailing wind if it is a free standing tower). You will need to take into account the weight of the whole thing, the weight of the base (if there is one), and the width of the base. (Nb. For a structure to be stable, the resultant of all the forces acting on the structure must pass through the base of the structure.)

Then what about the safety factor? What would the advantages and disadvantages be of having a guyed tower? Where would you fix the guys? What sort of angle would they need to be at? i.e. how far out from the tower? How many would you need? What would happen if the blade tips hit the guy wires? What materials would be suitable for a tower? What materials would be suitable for guys?

The cables are going to have to go down via the tower, so you will have to consider what route they will take and what will happen at the top and bottom.

WIRING - CABLES

How much wiring are you going to need? What are the implications on wiring (and efficiency) of the siting of your windmill? What sort of losses will there be along the length of the cable? How will you make the cabling and the connections safe ? You will need to make it safe from:

- accidental damage,
- deliberate interference,
- animals,
- weather,
- water.

Does it present a risk to people? What will happen to the cable when the nacelle of the machine yaws? It could be that the effect of yawing will be progressive rotation in one direction. How are you going to get the cable from the machine to the battery store or to where the electricity will be used? The conventional large-scale answers are pylons or burying it.
The cable connection points present particular problems. They are a common failure point.

YAWING, TAILS AND FURLING

The windmill has got to be able to turn to face into the wind. This is called yawing.
There are two aspects to this. Up to a certain wind speed, the rotor needs to be positioned to take the best advantage of the prevailing wind. Above a certain wind speed, however, the machine needs to be protected from the wind.

In high winds the blades or the whole rotor may need to be turned partly out of the wind so they only catch part of the available power, to keep it generating not too far above its rated power output. Effects of very high winds -

more noise,

the generator might burn out (some types are more at risk than others),

the blades will wear away at an alarming rate,

the tailvane might drop off as a result of vibration fatigue,

blades may break and fly off.

Large commercial machines have an anemometer (often on the top of the nacelle) which measures the wind speed and electronic controls will turn the machine, adjust the blades and finally turn it off completely in very high winds. This sort of very sophisticated system is not normally used on small machines.

You will need to consider the different requirements of the yawing mechanism. Is there one type of mechanism that would fulfil the different needs at different wind speeds? Is it possible to incorporate a number of different solutions for the different requirements? Looking at the consequences of high wind speeds, is a different strategy altogether possible?

You could experiment with setting the rotor axis in positions other than centred immediately in front of the centre of the yaw bearing. What happens if you offset it? What happens if you allow the tail to hinge, to move out of alignment with the body of the nacelle?

What happens when this movement on a hinge takes place:

- *at different windspeeds,*
- *with different weights of tail,*
- *with different types and tension strengths of hinge mechanism,*
- *with different lengths of tail,*
- *with different shapes of tail?*

YAW BEARINGS

The yaw bearings allow the whole nacelle to turn according to the wind. What should the specifications for the yaw bearings be? They will need to:

- support the nacelle,
- allow as free movement as possible - low friction,
- be weatherproof (rain can rust bearings in a couple of years),
- be hard wearing,
- allow the cables to pass from the nacelle down the tower.

Look around you to see how other appliances and devices overcome the problem. It may be difficult to look into the washing machine but there will be books in the library showing how machines work and all devices which involve movement will have thought of solutions to this problem.

Tasks

- Provide solutions to the need for a tower structure, how to accommodate the necessary cabling, how to control the yawing movement of the wind turbine, including the need for yaw bearings.
- Construct the tower structure.
- Attach the nacelle assembly.
- Erect the wind turbine.

Risk Assessment

1. Working at heights is hazardous and should be avoided or carefully supervised.
2. Lifting towers needs careful planning with regard to strength of ropes and the positioning of people. Hard hats should be worn.

Student Briefing Sheet 7 - Controls, Safety, Monitoring and Maintenance

Controls

What sort of controls are you likely to need on the wind turbine and its system?
You will need to think about the whole system and how it will function.
Controls might be needed both to prevent things from going wrong and to make them function as efficiently as possible.
What might go wrong? i.e. what possible dangers are there to people, property and the machine itself?
What might go wrong with the efficient running of the machine?

Make a list of all the different phases of operation of the wind turbine and the control that might be required at each phase.
Think about the behaviour of the system in various wind conditions and what different controls might be necessary to deal with those.

You might need to consider

- what prevents the batteries from motoring the generator?

- what happens if excessive power is generated?

What forms might controls take - mechanical or electronic? (Or hydraulic or pneumatic?)

Safety

What are the potential safety problems?
It would be useful to go through the whole system and list all the things that might go wrong and the dangers associated with them.
You have to have a suspicious mind and be a pessimist here. Consider all the possible ways that the system might be deliberately tampered with and all the accidental disasters that could happen. For things where the degree of probability is very small you will need to consider how awful the event would be.

It is probably necessary to check that the school or college's insurance policy will cover the effects of what you are doing, but do not let ample insurance cover encourage you to take risks. No amount of money is actually adequate compensation in cases of injury to people.

What about lightning?

Monitoring and Maintenance

You will need to work out a maintenance schedule for the machine and devise a system for ensuring that the maintenance takes place.

List all the parts of the system that will need monitoring and maintenance and note -
what monitoring they will need,
the frequency of the monitoring,
what sort of maintenance they will need,
the frequency of the maintenance

Task

- Identify all the necessary control systems required within the system and include their specification within your design
- Draw up a monitoring and maintenance programme for the finished product.

Student Briefing Sheet 8 - Economic and Environmental Costs

Estimating Financial Costs

There are two sets of costs. One is the initial cost of building the machine and installing it. The other is all the subsequent costs.
List all the different items in each of these.

When you come to consider the subsequent costs, there are a number of factors to take into account.
One is regular maintenance. How will this be done, who by and will their time have to be paid for? What will materials for regular maintenance cost?
What would the consequences be of not doing this sort of maintenance? You will need to consider this for every different item.

What about the lifetime of the various parts of the system? Large commercial wind turbines are expected to last 25 years before any major bits should need replacing. What about your machine?
How long do you expect the blades to last? And the batteries?

A different approach would be to decide how long you want the various parts to last and then design them to do that. What implications will this then have on your initial installation costs?

What factors do you consider are important when comparing energy sources. One of the ways in which you have to compare is in terms of the financial cost of different energy sources per unit of electricity produced. But what do you include in 'financial cost'? Obviously the here and now, money-handed-over costs, but what hidden financial costs are there?
One is what sort of future investment it is. You can compare a wind turbine, which you expect to last for 25 years with no fuel costs, with a gas-fired power station, when it is projected that all Britain's gas will have been used up by the year 2000 and you can only guess the fuel cost in 20 years time.

It would be useful to compile a list of all the factors you can think of. Bear in mind all the hidden costs of burning fossil fuels which we all pay for through our taxes and national insurance (damage to health, unemployment etc.).

Another approach is to consider other costs which may not be measurable in financial terms at all or have other costs as well as financial ones. Health is obviously one of the latter. There are huge personal and social costs to the individual and their family when illness or death is caused through an industrial process, as well as the financial and resources costs to the health service and social security system.

Environmental Impact

And what about the environmental costs? What are the main environmental benefits and impacts of the system you are developing? How might you consider the balance between impacts and benefits?

Tasks

- Consider the economics of your design.
- Produce an environmental impact assessment of the proposed development.