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[WIND POWER GENERATION FOR A GENERIC HOUSEHOLD]

Table of Contents

Introduction

Background

Today the society has higher and higher demands on environmentally friendly and renewable energy sources. Right now, there are talks on the government level about adding reactors to the existing nuclear program in Sweden. Even though there are environmentally friendly and clean energy sources available, they still cannot compete with nuclear power.

Wind power is a clean energy source which popularity has increased and today, big wind power parks are being built in on strategic places, mainly in the southern parts of Sweden. These wind power plants are tall, noisy and need a lot free space. Our group is going to look in to the possibilities to build a small, quiet and efficient wind driven power source for a household. This should be mounted on the roof of an average house.

Demands and problems

Specified demands:

- Optimizing the effect
- Reliability
- Good interface with the Swedish power grid
- Storm safety and firm design
- The investment should be able to pay itself of in a period of 20 years
- An automated system

Possible problems:

- Solid design
  - Storms
  - Vibrations
- Amount of power generated
- Geographically bound
- Too high noise levels
- Economics
  - The cost to produce is too high
  - The cost to transmit energy to the grid is too high
  - the payoff is too low

Limitations

The group chose to focus on the development of a concept ignoring the aesthetics, the building permissions and laws. The laws concerning safety should be considered and applied. Moreover the optimal geographical location from a wind prospective should be investigated. The wind speed at the chosen location will be used for the dimensioning of the system. A typical house will be chosen to determine the dimensions and the material parameters of the system.

Goals and purpose

Our goal is to try to design a wind power generation system mounted on the roof which provides high standards on all aspects and make sure it is economically viable. We will investigate the price of the system and its pay-back time. The system should have the highest efficiency possible from both the production and consumption sides. The system should be as quiet as possible and only generate moderate amounts of vibrations.

Expected results and presentation of the project

The results are going to be presented in a report and an oral presentation. Our group expects to present a concept solution and be able to show energy generation in different locations I Sweden.

Method

1. Identify customer needs
2. Target specifications
3. Concept generation
   - Brainstorming
   - XYZ-method
4. Choice of a concept
   - Product profile
5. Development of the concept
   - see appendix 2 WBS
6. Final report
7. Presentation

Planning

Gantt-Schedule

See appendix 1 for Gant-schedule. Red dots are marked as milestones planned for the different subgroups (see below).

Organization and PBS/WBS

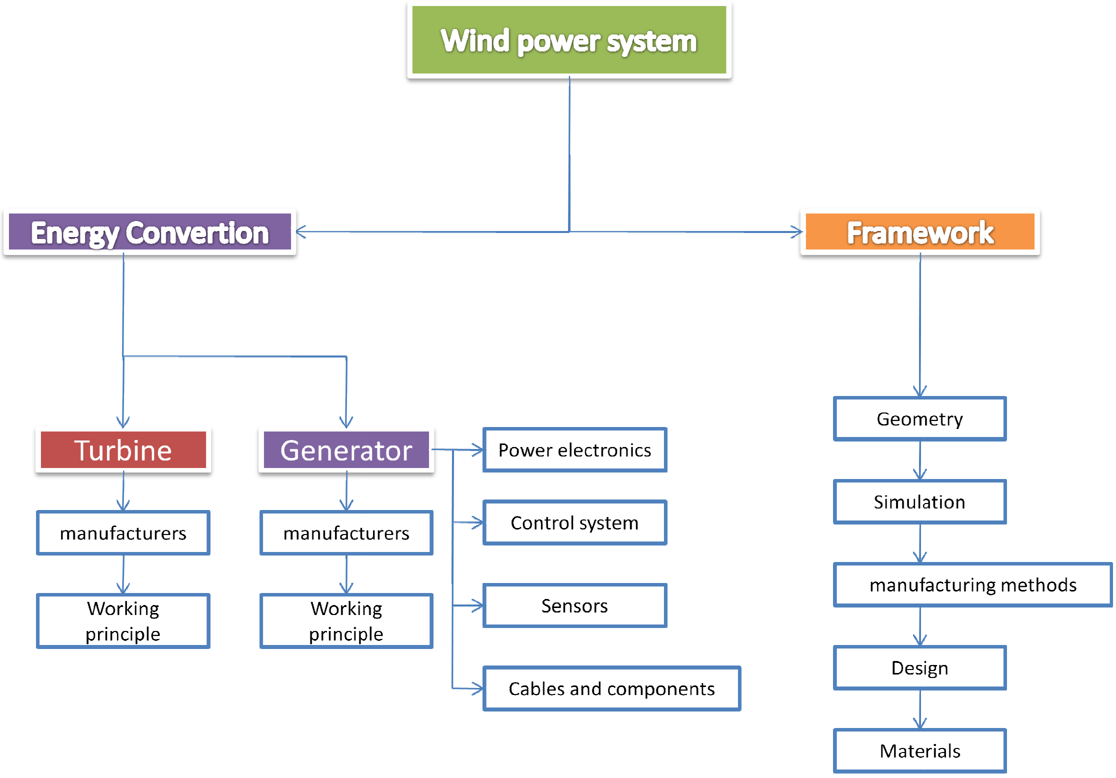
The project is divided in two subcategories (PBS). These are:

Energy conversion: One or two persons look into which alternatives are on the market for off-the-shelf wind turbines. Also manufactures, prizes, what kind of loads they are submitted to, level of noise, other problems and limitations for a roof mounted wind turbine shall be investigated.

One or two persons are responsible for the generator, the control system for the generator and turbine, the reliability and atomization of the design. These two groups will work together but have their own internal tasks within their respective subgroup. There are possibilities for persons in these groups to work in both subgroups.

For frame and mounting two persons will investigate the stresses on the roof and design a frame to mount the turbine. They will also calculate how big the load on the roof can be without any frame, to see if one actually needs a frame or not. They should present the final design which matches the chosen specifications.

One person is chosen as a coordinator. This person will handle the communication between the subgroups.

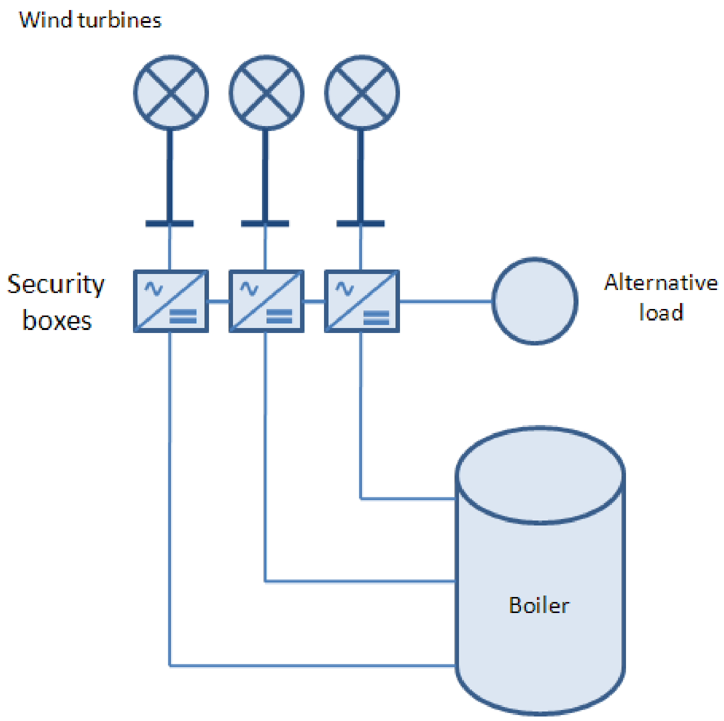

Wind power system
Energy Convertion
Framework
Turbine
Generator
Power electronics
manufacturers
Control system
manufacturers
Working principle
Sensors
Working principle
Cables and components
Geometry
Simulation
manufacturing methods
Design
Materials

WBS

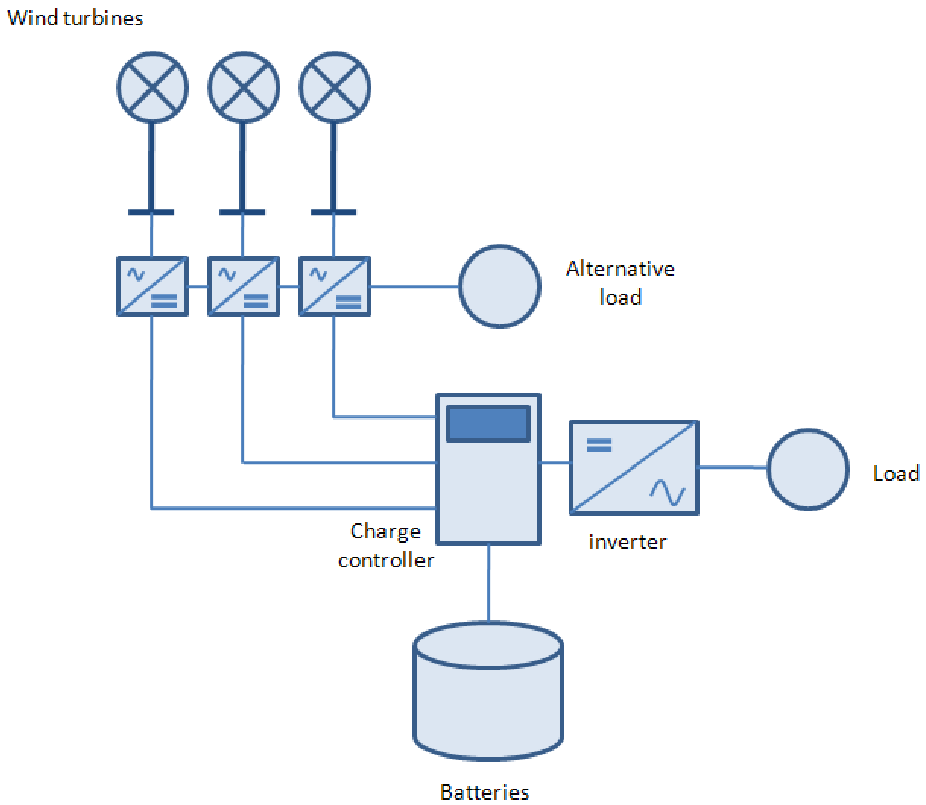
Proposals for system architecture

After a brainstorm the group ended up with three possible solutions on how to maximize the use of the generated energy.

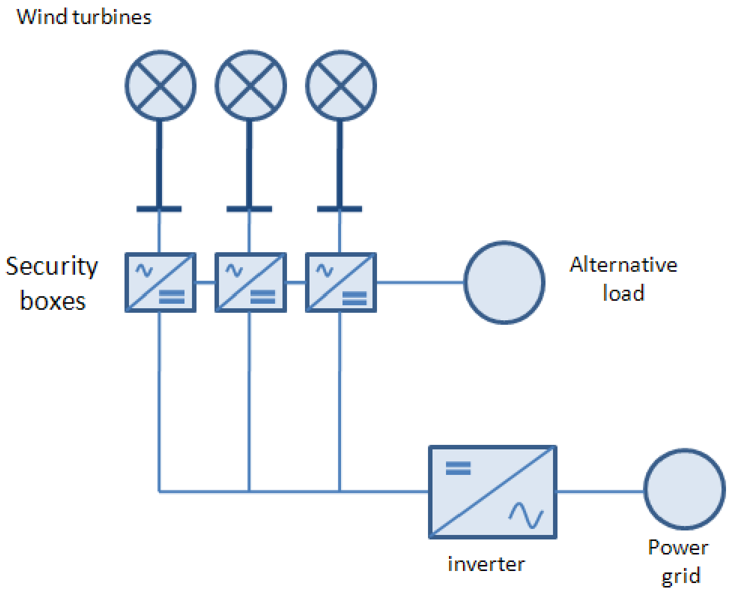
One solution was presented for a household: **using warm water to heat the house** and for everyday use. Using a basic generator and a simple control system allows you to concentrate on heating the main water reserve. The control system only regulates the temperature of the water. The advantages are that no converters or expensive power electronics are required and therefore the system becomes relatively cheap. One disadvantage is that during warm periods of the year you can't utilize the system to its full potential.



Charge batteries and use the extra energy to heat water. The generated current from a small wind driven generator is not of a very good quality. Therefore a converter is used to converts the alternating current into direct current. It is then converted again to alternating, 50 Hz current. This electricity can then be used to drive the household appliances. A control system is used to monitor the charging of the batteries and automatically switch between charging batteries and heating the water (if the house has a system like that). The advantages with this system are that all of the generated energy is consumed and the household is protected against power failures in the public power grid. This does however require a lot of power electronics and batteries to store electricity are needed.



Feeding all of the generated energy to the public power grid requires a AC to DC converter. The requirements on the quality of the current to the power grid is high, therefore a DC to AC converter of high quality will also be needed. There seems to only be disadvantages with this design since the license fee for selling electricity in Sweden are high. The income will be lower than the fee and the price together.



Five areas shared by all the solutions and their respective weight are stated in table 1 below. Furthermore, the investment costs for the various designs are presented in appendix *3*.

Weight factor	Criteria	Water heating system	Tot	Stand alone	Tot	Grid connected	Tot
3	Investment cost	4	12	1	3	2	6
3	Savings made	3	9	5	15	1	3
2	Maintenance	5	10	3	6	4	8
1	Complexity	5	5	3	3	2	2
1	Compatibility	5	5	4	4	1	1
	Total		**41**		**31**		**20**

Table 1

The alternative that got the highest score was to use all the generated energy to heat the water. The group, however decided to explore both this solution and the one involving batteries. To only supply the power grid had, as stated above, no visible advantages and was discarded.

Wind turbine

Different types wind turbine systems

A vertical axis wind turbine (VAWT) has a vertical axis in contrast to the conventional horizontal turbines most commonly used today. The turbine usually has three blades rotating around its own axis, and therefore absorbs energy from any direction. Furthermore it is relatively quiet and does not vibrate that much compared to the horizontal. A drawback is that it does not self start.

A horizontal axis wind turbine (HAWT) is the one most commonly used system today for the big wind power parks. It is self starting and can generate a lot of energy. It always yaws up against the wind and therefore absorbs a maximal amount of energy. The drawbacks are that they are noisy and need to be large, for this project, to generate sufficient amounts of energy.

Savonius wind turbine is also a VAWT system. As with the three blade system it generates power from any wind direction and is used with advantage in areas with gusty winds. This system does not need an external source for startup. They can be designed in many different sizes but they generate relatively small amounts of energy.

Figure 1. From left: three blades VAWT, Savonius VAWT and conventional HAWT

Deciding on turbine system

To choose of type of turbine for the design the group has considered the ten areas stated on table 2 below. A system has been described by different areas that are given a weight factor. The ones that were considered most important were power generation, weight, noise and vibrations. In some areas the group couldn't find information and these areas where therefore considered equal.

weight factor	Area	Three Blade turbine (VAWT)	Tot	Savonius (VAWT)	Tot	Horizontal	Tot
3	Power generation	5	15	1	3	4	12
/	Cost	n/a		n/a		n/a	
2	Noise	4	8	5	10	1	2
2	Vibrations	5	10	5	10	2	4
1	Reliability	3	3	5	5	4	4
2	Weight	4	8	2	4	5	10
/	Wind range	n/a		n/a		n/a	
2	Size	2	4	5	10	2	4
/	Control	n/a		n/a		n/a	
1	Maintenance	5	5	5	5	5	5
	Total		**53**		**47**		**41**

Table 2

The system that got the most points was the three blade vertical axis wind turbine. Therefore the group chose to move forward with this system.

Maintenance

Most of the maintenance tasks will be similar for both alternatives (water heating and stand alone solutions). Indeed, the structure is the same. Since steel has been chosen for the frame, it needs some care to protect it from rust. An anti rust paint should therefore be applied to both protect the structure from rust, and for esthetics. At the same time, one might want to check the bearing on the turbine axis for obvious safety reasons. The connection boxes and cables exposed to the outside environment shall also be checked. The user should refer to the manufacturer to know how often this check should be done.

Batteries' care applies only to the second solution. The chosen batteries are designed especially for renewable energy sources. Some basic rules about safety apply, since the energy stored is quite high. Batteries have a lifetime reaching around 10years. Therefore, extra attention shall be paid 10 years after the installation of the system.

Mounting & Integration

Mounting

Since the turbines put a lot of stress on its base it cannot be mounted directly on the roof. The group therefore designed a solution for this purpose. According to the manufacturer the turbine will be exposed to a 3.6 kN equivalent horizontal force at a wind speed of 50 m/s. With this data the group ran a few simple simulations to see the deformations and stresses. The material chosen for the design is ordinary construction steel. The results of the simulations are available in appendix 4. According to the simulations, we will have the biggest deformations, 30 mm, at the top of the turbine axis. We decided that a supporting framework was unnecessary and therefore we designed a platform which will be attached and fixed to the roof. The platform will also be supported by a small steel construction that will help to absorb and spread out the strains trough out the roof. This design is available in appendix 5.

Integration

To get a decent amount of energy out of the wind we have chosen to put three vertically mounted turbines on the roof. Each turbine has three blades; approximately two meters high and each turbine have a rotor diameter of two meters. This is not too big to mount on the roof of an average villa, which is approximately eight meters long. Every turbine has PM generator mounted on the turbine axis which have a rated output at 1.0 kW. The turbines are producing 2.4 kW at a wind speed of ten m/s. The average wind speed in Skåne and Småland is estimated to 3.5 m/s. That gives a total of$(2400\,W * 24\,h * 365\,days) * 0.3 = 6300\,kWh/year$. The factor of 0.3 is to take in to account that the average wind speed is almost one third of value used to calculate the efficiency of the generator. Therefore three generators are enough for the project design since a typical villa in Sweden consumes approximately 25000kWh/year. This also eliminates the risk for overproducing energy.

The need for sensors varies between the designs. For the first one where all the energy is fed into the water tank, you need a sensor to measure temperature in the water. For both designs, you need a sensor measuring the rotation speed of the turbine. This is a safety measure in case the generator or a wire fails and the turbine starts to rotate out of control. They also need a sensor measuring wind speed for optimal point tracking. The second design using batteries also needs a sensor measuring the charge level of these.

For the tank a simple thermometer can be used. A tachometer measures the rotation of the turbine axis. A simple wind meter can be a small meteorology station.

Since the turbines aren't self starting the generators have to be able to start the rotation. For this purpose an asynchronous generator is optimal since you can use it like a motor and they have very low maintenance needs.

Calculation of payoff time

In the following calculations, the costs for installation were disregarded. The product cost for the two different designs was calculated and are presented in appendix X .The discounted payoff method was then used to calculate the payback time for each alternative

$$. \sum_{i=0}^{T} \frac{C_i}{(1+p)^i} = 0$$

p = cost of investment
R = residual value of the of the investment at the end of the calculation
T = payback time
C = total yearly cash flow of year *I*

For year 0 C is equal to the investment cost and for the following years C is equal to the savings that were calculated accordingly

C = [amount of saved energy] *[price of one kWh at the investment time] *[(increase rate of energy price)$^{\text{year after investment}}$]

Alternative 1 – Just heating water:

Investment: 70 000 SEK
Cost of investment: 5%
Energy price: 1.01 SEK/kWh
Energy price increase: 3%

Household electricity before:	10 000kWh/year
Household electricity after:	10 000Wh/year
Electricity for heating before:	15 000kWh/year
Electricity for heating after:	8 700kWh/year

Payback time = 12.5 years

Alternative 2 – Stand alone:

Investment: 117 500 SEK
Cost of investment: 5%
Energy price: 1.01 SEK/kWh
Energy price increase: 3%

Household electricity before:	10 000kWh/year
Household electricity after:	5 700kWh/year
Electricity for heating before:	15 000kWh/year
Electricity for heating after:	13 000kWh/year'

Payback time = 23.5 years

CONCLUSION

Using the energy to heat only the water is a viable alternative since the energy output covers about one quarter of this energy need. However, during a part of the year you are not able to utilize your system and therefore "loosing" part of these 6300 kWh. Even considering this the pay off period for this design is within the demands of the project. This seems to be the easiest design to implement; it has the fewest components and the control system is very basic. However, compared to a heat pump, which pay itself of in around ten years, it is not as good.

The "stand alone" design is more flexible than the first one. It utilizes all produced energy throughout the whole year. The design is more complex and almost twice as expensive. It also requires you to have a facility for storing the batteries. The pay off period for this is just outside the desired time.

To use wind power to cover some of the energy costs of a household seems to be a viable solution. However, there are more interesting options already on the market because of the subsidies from the state. If wind power can benefit from these subsidies as well it would become a very interesting solution.

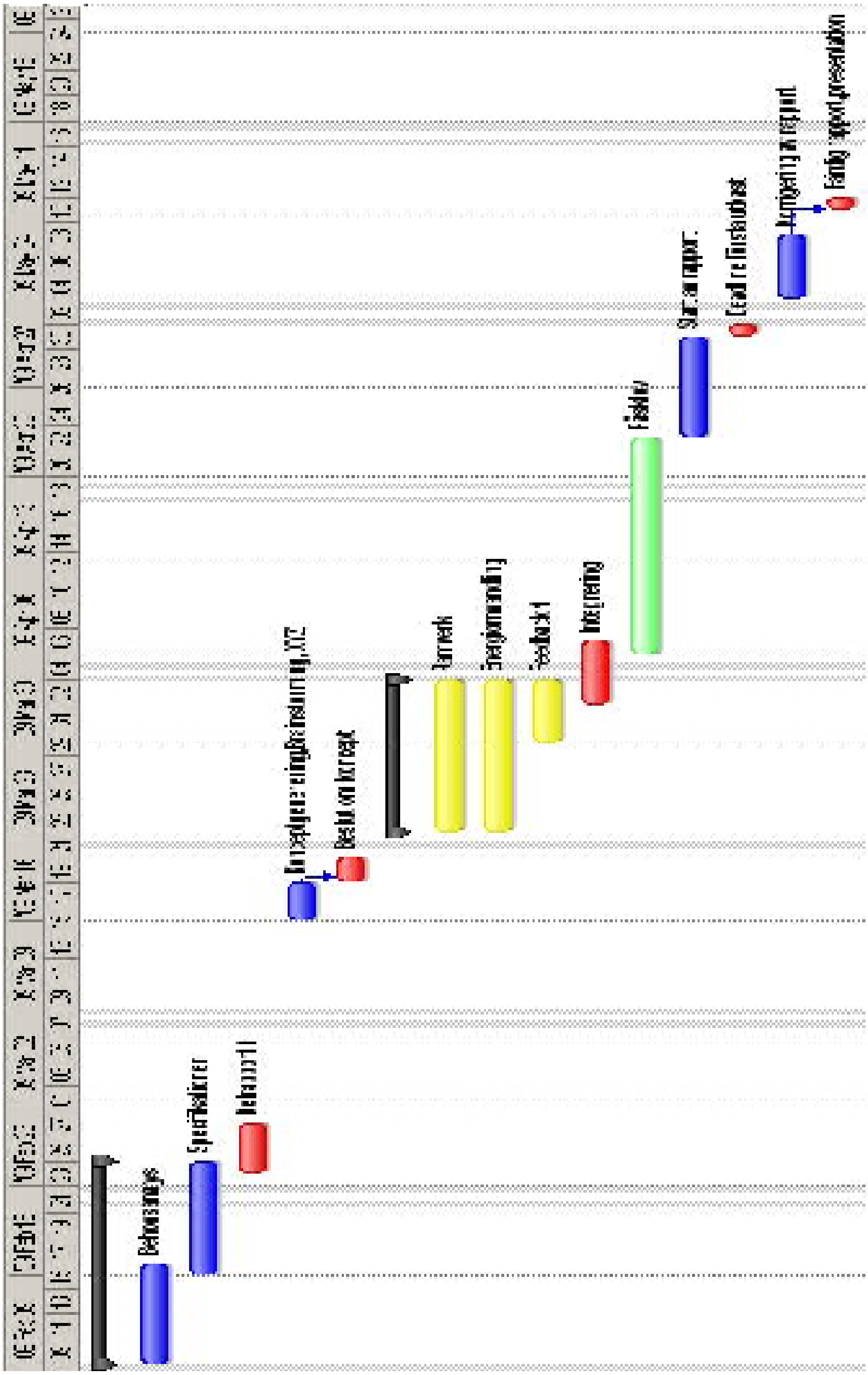
References:

www.ecokraft.se (Rotor VAWT > VAWT EcoWing >bottom of page)
www.energiberakning.se

Appendix 1: Gantt-Schedule

		Task Name	Duration	Start	Finish	Pred	Resource Names
1		⊟ **Planering**	**12 days**	**02-09**	**02-24**		
2		Behovsanalys	6 days	02-09	02-15		Behovsanalys
3		Specifikationer	7 days	02-15	02-24		Specifikationer
4		Delrapport 1	4 days	02-24	02-27		Delrapport 1
5		Konceptgenerering,Brainstorming, XYZ	3 days	03-13	03-13		Konceptgenerering,Brainstorming, XYZ
6		Beslut om koncept	2 days	03-19	03-20	5	Beslut om koncept
7		⊟ **Utveckling av koncept**	**10 days**	**03 23**	**04 03**		
8		Romverk	10 days	03-23	04-03		Romverk
9		Energiomvandling	10 days	03-23	04-03		Energiomvandling
10		Feedback 1	5 days	03-30	04-03		Feedback 1
11		Integrering	3 days	04-02	04-06		Integrering
12		Påsklov	13 days	04-06	04-22		Påsklov
13		Start av rapport	6 days	04-23	04-30		Start av rapport
14		Deadline första utkast	1 day	05-01	05-01		Deadline första utkast
15		Korrigering av rapport	5 days	05-04	05-08		Korrigering av rapport
16		Färdig rapport,presentation	1 day	05-11	05-11	15	Färdig rapport,presentation

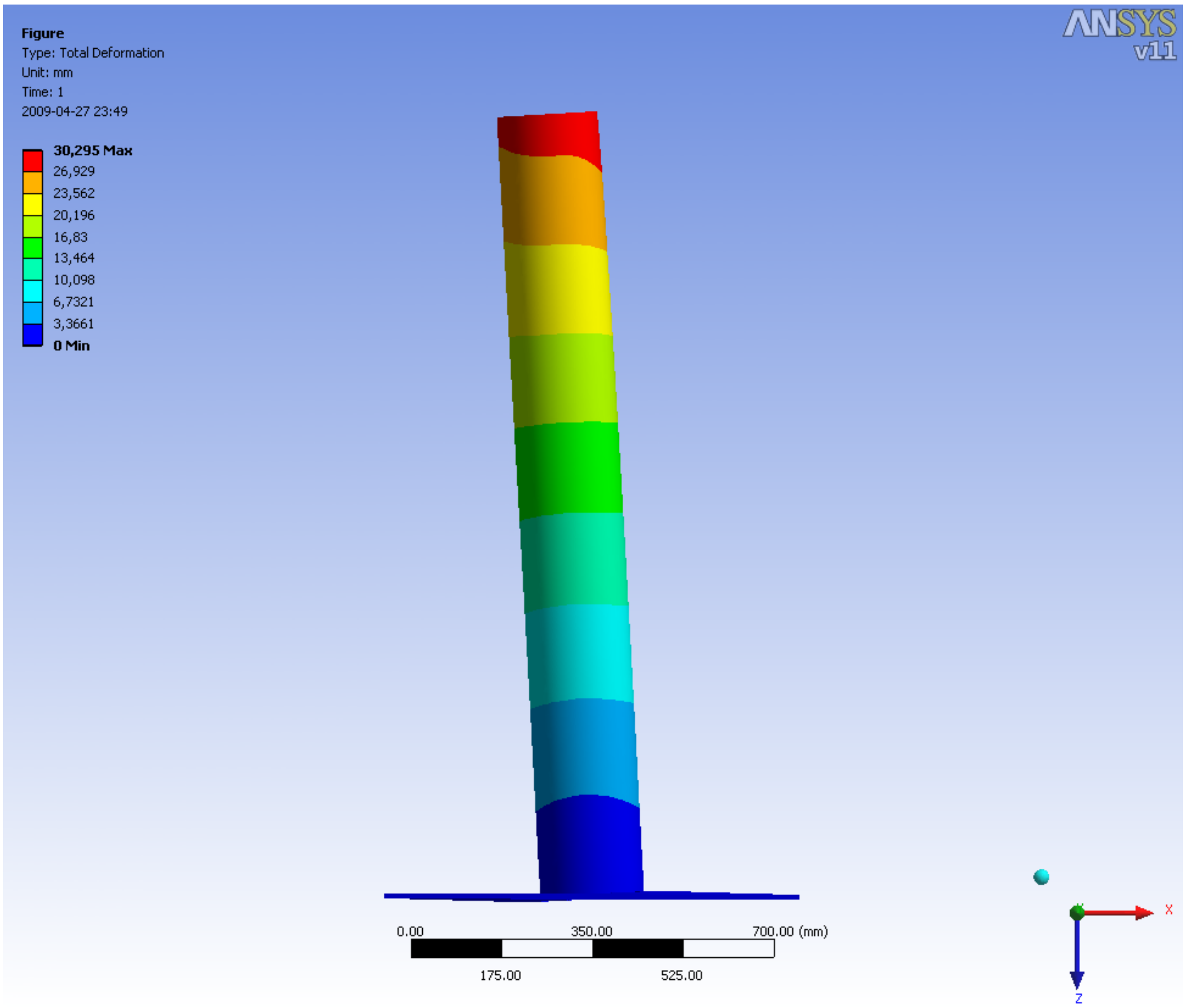
Appendix 2: Gantt-Schedule

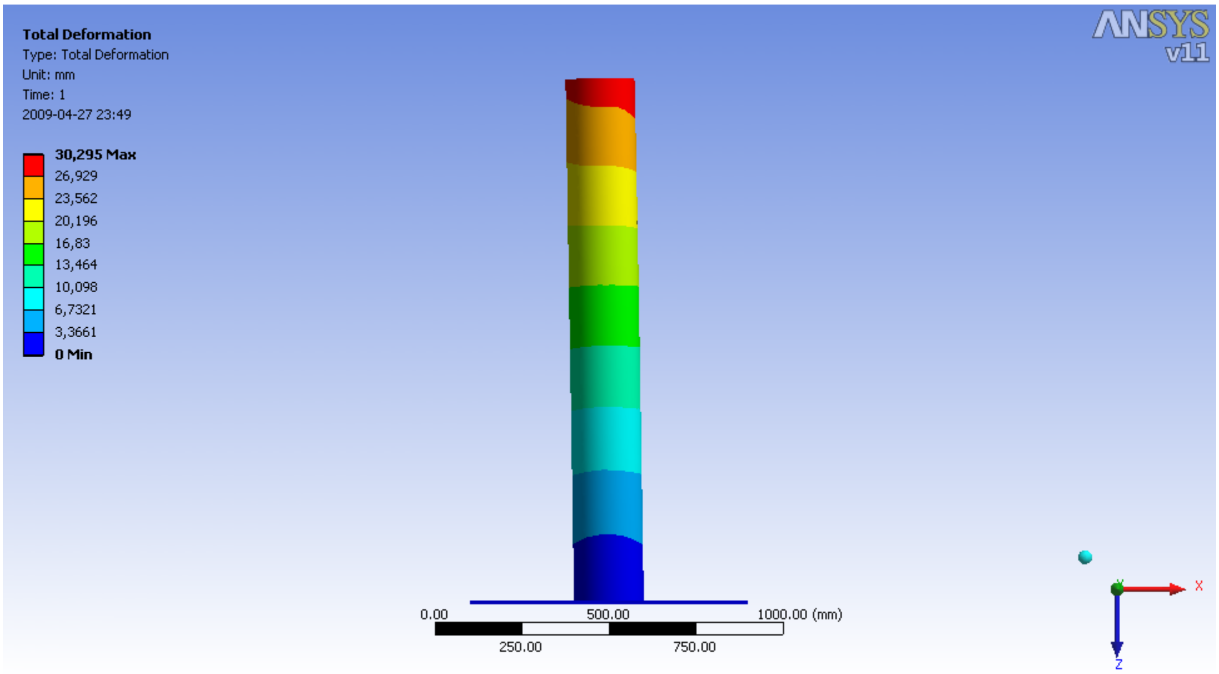


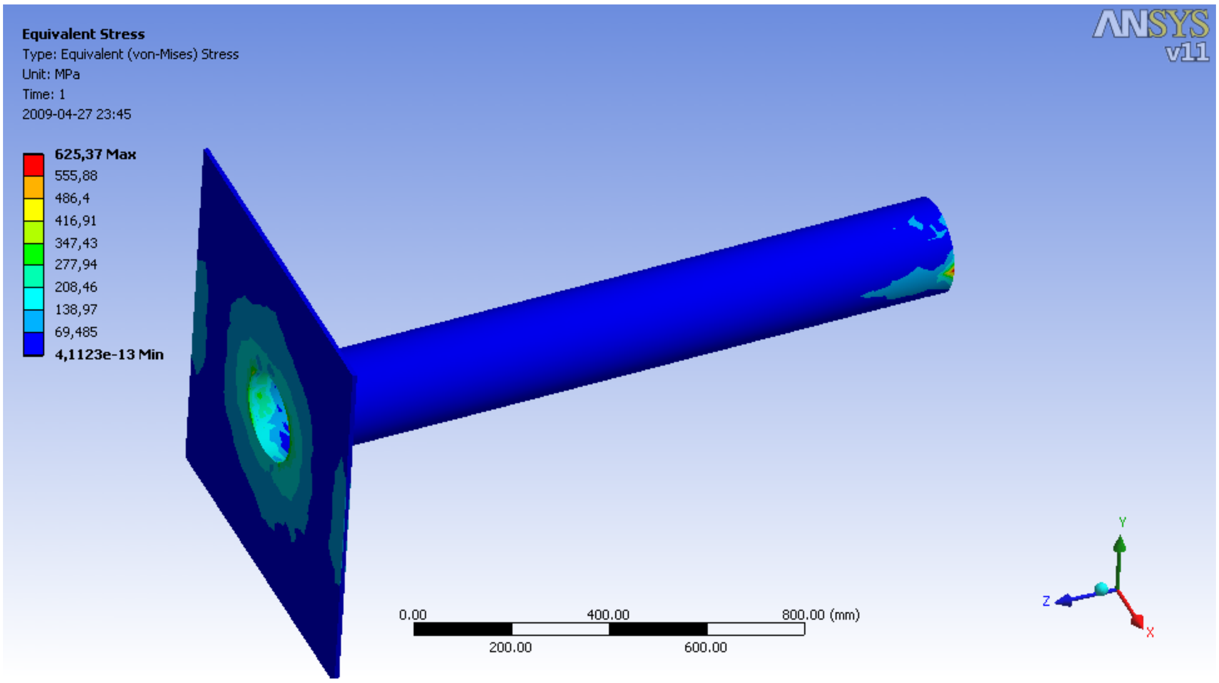
Appendix 3: Initial investment estimation

Component	Water heating system	Stand alone	Grid connected
generator	30000	30000	30000
wind blades / mounting	9000	9000	9000
roof frame	10000	10000	10000
Wind meter	1000	1000	1000
controller	15000	30000	30000
brakes	5000	5000	5000
inverter	0	2500	4000
batteries	0	30000	0
Total	70000	117500	89000

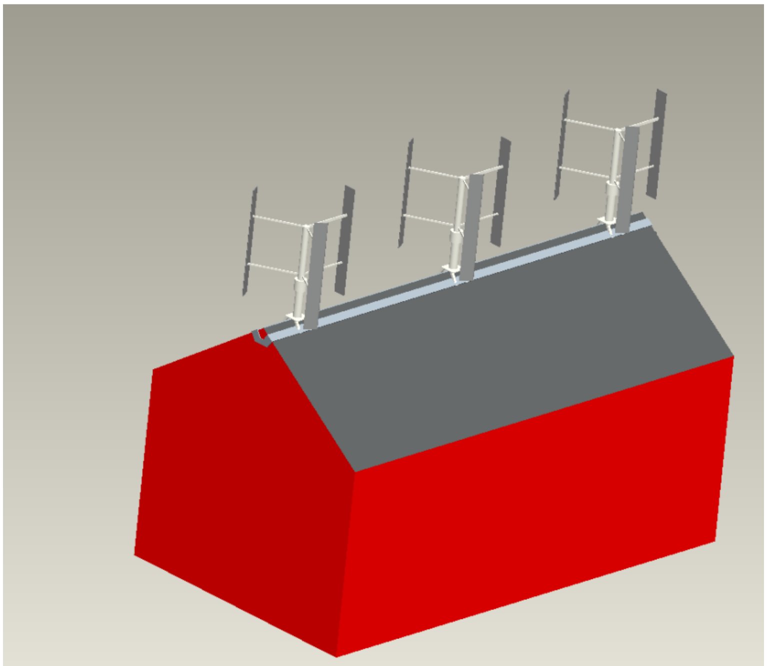
Appendix 4: Stress and deformation for the mounting



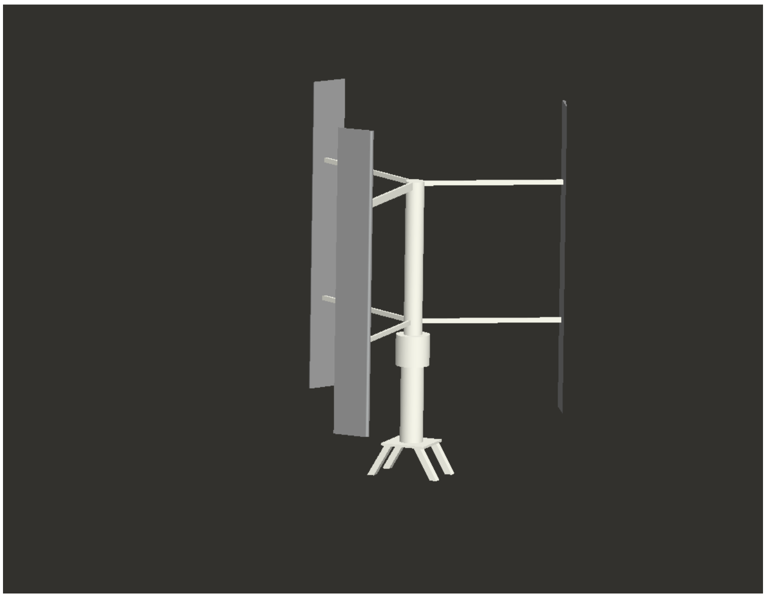

Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
2009-04-27 23:49
30,295 Max
26,929
23,562
20,196
16,83
13,464
10,098
6,7321
3,3661
0 Min
ANSYS
v11
0.00
500.00
1000.00 (mm)
250.00
750.00
X
Z


Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
2009-04-27 23:45
625,37 Max
555,88
486,4
416,91
347,43
277,94
208,46
138,97
69,485
4,1123e-13 Min
ANSYS
v11
0.00
400.00
800.00 (mm)
200.00
600.00
Y
Z
X

Appendix 5: Design for mounting



Dimensions of the model house are 5 x 9 m



Length of the blades 2m, diameter 2m