Intelligent Wind Turbine

Project overview

Wind turbine project's primary goal is to design a small-scale model of an actual size industrial wind turbine in operation. The intelligence was also planned to have the similar function mainly by detecting wind direction and its speed. These requirements demanded the makers of this project to follow an specific and original design for mechanical components from scratch, so the whole structure is unlike conventional small wind turbine. During the early stages of the project, a simulation-based approach to prepare CAD model of wind turbine was carried out, which determined the major mechanical aspects and dimensional values of the project, according to Figure 1. Even though later on, the CAD model itself was undergone series of changes by imposing the practical issues.

Figure 1. CAD Model of Wind Turbine

The significant outcome of this project from mechanical prospective was engaging with design from a draft up to an actual working prototype that can be built thoroughly inside Mechatronics lab.

Technical description

1. The first component made was blades and hub. So the first suggestion to prospective students who are interested to build /continue this project is to get a proper blade, as achieving results will highly contributes to applicability and efficiency of blades.
2. Second, the upper frame and tower were built. One of the most critical issue is selecting an appropriate bearing to attach between upper frame and tower. Of course, if it supposed to keep its rotational DOF around the axis of tower. it must be designed not only to withstand trust but also radial force.
3. Then, Tail vane mechanism was carried out. Blades and hub mounted to the shaft and shaft placed inside the previously prepared upper frame.
4. Yaw mechanism assembly was completed afterward. Upper frame supplemented by sheet metal reinforcements, shaft gear box, stepper motor, and DC motor as generator.
5. Tower which was already attached to upper frame, got welded to the base and reinforced by sheet metal ribs. Without ribs, the tower structure was unstable.
6. The LCD placement were implemented on a side face. consequently, remaining faces of the upper frame were placed after completing the rest of mechanical and electronics related details.

**Mechanical components**

**Blades and hub:**

![Blades and hub](image)

*Figure 2. Blades, and The hub mounted on the shaft*
Upper frame (nacelle):

Figure 3. Upper cover of conical bearing, and Upper frame with sheet metal reinforcements

Tower and yaw mechanism:
Tale vane mechanism:
Figure 5. Components of tail vane, Tail vain attached, and potentiometer attaching design

Gear train:
Base attachments:

Figure 6. Gear train mounted on the shaft mating with generator fastened on the upper frame

Figure 7. Tower welded to the base and reinforced by welded sheet metal ribs

Electrical components

**LCD and Arduino**

The main components used are:

- Arduino Nano
- LCD Powertip1602
- Switched voltage capacitor LMC 7660

We have used also two capacitors of 10µF and one potentiometer.

**Microcontroller : Arduino Nano v3.0**

Arduino has to be supplied by a voltage between 7V and 12V for an optimal running. A voltage regulator integrated in the microcontroller can feed from this power to create a constant voltage of 5V which then can be used to supply other elements of the electric.

**LCD display and LMC7660**

Documentation of the LCD used specifies than a negative supply voltage is necessary for the functioning. To get it from the +5 V voltage generated by the microcontroller, a switch capacitor voltage converter is used: this component makes it possible to obtain an output voltage of-5V from an input voltage of 5V. The LCD can be used without this negative voltage but the contrast may be lower. These two potentials are then connected to pins of a potentiometer. Its output voltage is connected to pin V0 of LCD and enable to optimize the display resolution.

**Potentiometer : Wind direction measurement**
To measure wind direction, we have used a vane and connected it to the rotating shaft of the potentiometer. One pin of the potentiometer is connected to the ground and the other to 5V (this voltage can be providing directly by the Arduino), the output voltage of the potentiometer is then sent on one analogic pin of the Arduino and is function of the direction of the wind. The resulting voltage on the analog input, give in form of a number between 0 and 1023, will then be used as a command for the stepper motor and thus optimize the performance of our wind turbine, which will be always positioned in order to optimize the energy gained from the wind.

**Stepper motor and EasyDriver**

![Stepper motor driver](image)

*Connection details*

- **M+:** 12V (supply by the battery)
- **GND:** ground
- **Phase A and B:** stepper motor
- **Direction:** Arduino digital input without PMW (2, 4, 7, 8, 12 or 13)
- **Step:** Arduino digital input with PMW (3, 5, 6, 9, 10 or 11)

To get a maximum of energy from the wind, our wind turbine has to be able to adapt itself with regards to the wind direction. It is attached to a stepper motor that will rotate depending on the data received by the potentiometer (optimization) and output DC motor (protection). To facilitate the connection and control of the stepper motor, an easy driver is used; it receives the command to be applied from the microcontroller in the form of a PWM sequence and will transmit it directly to the stepper motor. The EasyDriver module is supplied by the 12V from the battery output.

**Limitation of input voltage**
In output of the DC motor, a continuous current is available but before to use it to supply battery and, voltage must be limited with a regulator to not damage these components. For our application, we will use a 12V battery: the output voltage is 12V but to supply the battery input voltage has to be superior (mainly between 13 and 13.6V for a 12V battery). The regulator chosen is a LM317L, which allow to parameter easily the limit voltage using two resistances:

![Figure 9: Circuit diagram of LM317L](image)

The component has then to be connected between the DC motor (Vin) and the battery (Vout).

But we can also limited input voltage of the battery using the stepper motor. To do this, we have to get on the Arduino voltage supplied by the DC motor, by connecting his output to an analog pin: if this value is too high, we first send a command to rotate the stepper motor slightly to the left. Once this first movement carried out, there are then two possible cases:

- **voltage is lower**: the chosen direction reduces windage of the wind turbine and another command can be sent to rotate again the stepper motor in the same direction if the DC motor’s output voltage is still too high.

- **voltage is higher**: the wind must be directing in the opposite direction to decrease the production of energy.

A diode is also necessary between the DC motor and the battery to ensure that it doesn’t provide energy to the motor.

The treatment of energy between the generator output and the battery has not been made on our wind because we ran out of time. Components installed shall enable to limit the output voltage to the motor to 13.5V in order to not degrade the battery. An other solution more complex but more efficient than the use of a voltage regulator is possible: a switching converter that makes the constant current charging of the battery when the motor’s output voltage is lower than the limit voltage, then a regulation at constant voltage when the energy is too large to be stored in the battery. This type of control law is called "cascade control" and different configurations can be used.

**Use of LCD**

The LCD is used to display the energy produced by the wind turbine. The output voltage of the motor can reach 30V but it must be reduced in order to read accurately read this value on one of the analog pins of the Arduino. Indeed, the read value between 0 and 1023 is proportional to a default voltage of 5V. To bring the output voltage within this range of values, a voltage divider bridge is used:

![Figure 10: Circuit diagram of Voltage divider](image)

Using \(R1=33k\) and \(R2=148k\), a voltage \(Vs=5V\) correspond to a motor’s output voltage \(Ve\) equal to \(5xKp\) (about 27.4V) with \(Kp = R1/(R1 + R2)\). With Arduino software, the function “map” enable from the read analogic value to get the corresponding voltage between 0 and 5V. By multiplying this value by \(Kp\), we obtain the motor’s output voltage.
In following table is shown budget and component used in the project.

Table 1: Components and preises.

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Preis</th>
<th>Total preis (€)(incl. Shipping)</th>
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<td>Housing</td>
<td>Sides, roof and bottom blade</td>
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</tr>
<tr>
<td>Base plate(wood)</td>
<td>Base for the frame tube</td>
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<td>Got from desing factory</td>
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<td>Small gear</td>
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User manual

The intelligent wind turbine is based on Horizontal-axis wind turbines (HAWT) principle. The rotor, DC motor, wind vane with potentiometer and stepper motor are placed at the top of tower. The top of tower is a cuboidal wooden frame having dimension 43 mm X 30 mm X 28 mm. The rotor with blade is placed in the front end and DC motor with gear is placed in rear end of the frame. The tower of wind turbine is attached with the frame about 2:3 ratio from front face. The equilibrium situation is developed by the selecting the pivot of tower as well as load distribution in left and right arm. The pivot between the tower and the frame is facilitated by using cylindrical roller bearing system. The top of the tower is attached with the gear which is ultimately connected with stepper motor. The details of mechanical parts, electrical parts and technical information are described in above respective headings of the report. The picture with the name of different parts of the intelligent wind turbine is depicted in the following picture.
Figure 11: Wind Turbine
The wind turbine is designed based on a yaw mechanism. It is used to turn the wind turbine rotor against the wind. The lift and drag force of wind rotates the blades in counter-clockwise direction. The big gear fixed at shaft rotates when rotational motion developed at rotor. The big and small gears are aligned so that shaft of DC motor rotates and current begins to generate. The generated current is stored in 12 V batter.
The potentiometer is attached with wind vane at the top surface of rare end of the frame. The wind vane is designed to revolve at own center axis ranges from 0 to 180 degree. When wind vane revolves, the potentiometer also revolves. The coding of the potentiometer is developed in such way that the degree of rotation of potentiometer can describes the direction of wind. The information about current direction of wind vane measured by potentiometer transfer to Micro-controller. When micro-controller gets the information about wind direction, it proceed the data and forward command to stepper motor. Based on the received command, the stepper motor rotates the alignment of frame with rest to wind direction. All the information regarding to wind direction, wind speed and magnitude of current generation are displayed in LCD screen.

Wind turbine needs an external power source (for example 12V battery) to where direct charging voltage and also for energizing arduino microcontroller and stepper motor. Otherwise, usage of wind turbine is relatively easy just place it to windy location and let it produce energy. If the code in Arduino microcontroller is wanted to change roof plate of the frame has to be removed.

Precaution:
- The wind turbine is heavy in weight, therefore be careful during the moving of wind turbine.
- Lift the whole structure by grabbing only at tower not at frame.

Conclusions and suggestions

The intelligent wind turbine is purely innovative design for efficient generation of current. The structure consist of two parts i.e tower with foundation and wooden frame. The tower is made from cylindrical stainless steel tube welded with base foundation made up of sheet metal and plywood. The upper end of tower is connected with the frame and the rotation of frame is feasible with respect to tower due to roller bearing connection. Most of electronics as well as mechanical components are placed at the frame. The wind turbine is based on Horizontal-axis wind turbines (HAWT) and is design on Yaw mechanism. The efficiency increment of current generation in wind turbine is a tough job. This project was intended to enhance the efficiency of wind turbine. The Arduino nano is used as micro-controller for controlling the wind turbine. The potentiometer detects the intensity and direction of wind and forward the data to controller. Based on received data about wind direction and intensity, micro-controller commands the stepper motor to align the frame with respect to wind direction.

This project was relatively challenging because we build everything from the beginning. We also tried to actualize the project as low budget as was possible, that made some pressure for the time schedule because of long and in-depth components search process. Nonetheless the budget rose above 300€. It should be also noted that shipping fees for the components were app. 20% of total costs.

Due to time limitation we weren't able to test the turbine with every components installed, but short test was executed without generator and rotor turned relatively fast. With generator installed rotation torque demand increases. Voltage produced by the generator is relative to rotation speed of the rotor. During desing process estimation of blades efficiency, start-up rotation speed and normal operational rotation speed was extremely difficult. Main gear ratio desing was done based on information gained from the rotation speed diagrams of other small wind turbines. In every case, because of these uncertainties most probably rotor does not rotate in small wind, but that is the case with every wind turbines.

All the mechanical components work as planed. Arduino stopped work just before wind turbine was ready to test. We are not sure is it damaged or just has some temporary misfunctionality. We were not able to realize charging mechanism due to time constrains. So at the moment there is not intelligent for controlling voltage produced by the generator. However, with some basic electrical components like diode, voltage regulator, capacitor, transistor and fuse it should be executable relative easily. For the next group working with the turbine we suggest to carry out these modifications for the turbine. Also controlling logic in the microcontroller should be modified to utilize these changes.
Code

In following link is shown the code for operation of the Intelligent Wind turbine.

StepperLCD.ino

Circuit diagram

The voltage +12V is supplied by the battery. The value of P1, used to get wind direction, is 500 and the value of P2 is 250.