A METHOD OF OPERATING A WIND TURBINE INVOLVING BAT PROTECTION

FIG 1

1. Record click pattern
2. Identify species
3. Create list of local species
4. Set appropriate parameter settings accordingly

Abstract: A method of operating a wind turbine is provided. Sounds of bats are detected and recorded, wherein species of the bats are identified and a list of identified bat species in a vicinity of the wind turbine is created. Parameter settings in accordance with the identified bat species are selected and the wind turbine is operated according to the selected parameter settings.
A METHOD OF OPERATING A WIND TURBINE INVOLVING BAT PROTECTION

FIELD OF INVENTION

[0001] The claimed invention describes a method of operating a wind turbine in order to avoid injuries of bats in the vicinity of the wind turbine.

BACKGROUND OF INVENTION

[0002] Observations in the vicinity of wind turbines show that bats may be killed or injured by wind turbines in operation. According to investigations there are two ways to injure or cause the death of a bat by a wind turbine. The first one is that there is a direct collision of the bat with a blade of the wind turbine, when the rotor of the wind turbine is in operation. The second one is that moving wind turbine blades causes high pressure differences in the surrounding area of the turning blades. These air pressure differences might cause internal injuries to the bat, e.g. the lungs of the bat may be hurt if the bat passes by. Thus the direct impact of the turning blade and/or the caused pressure differences of the turning blade may be fatal for the bat.

[0003] There are bat species which are endangered in a lot of countries. They are recorded and monitored by help of a so called 'red list'. The protection of these bats is very important especially due to their low reproduction rate. In some countries, for example the U.S.A., the protection of bats may also be a legal requirement.

SUMMARY OF INVENTION

[0004] A method for providing a control strategy for a wind turbine is disclosed, wherein injuries of bats are avoided and the associated energy loss from the wind turbine is minimized at the same time.

[0005] Most bats are nocturnal and are active at twilight. Bats use echolocation to detect, localize and even classify their prey in complete darkness. Bat echolocation is a perceptual system where ultrasonic sounds are emitted specifically to produce echoes.

[0006] Bats use unique ultrasonic calls where click patterns can be used to identify
individual species. The click patterns differ from one bat species to another. The sound
even varies when the bat is foraging, migrating or resting, i.e. different sounds are used for
different behavioral patterns.

[0007] According to the method, calls or sounds of bats are detected and recorded. By
post processing, the click patterns are identified, a list of local bats is identified and
appropriate parameter settings for the operation of the wind turbine is selected. Thus, the
operation of the wind turbine is only modified when a bat is present in the area of the wind
turbine.

[0008] The control strategy is prepared according to the following steps:
- detecting and recording sounds of bats,
- identifying species of the bats, and creating a list of identified bat species,
- selecting parameter settings in accordance with the identified bat species, and
- operating the wind turbine according to the selected parameter settings.

[0009] The sound of the bats may be detected and recorded by a detection system which
is located at the wind turbine, for example at the hub, the nacelle, the tower or asides a
blade of the wind turbine. In another embodiment, the detection system may be installed in
the vicinity of the wind turbine, for example at a meteorological station or a separate
construction.

[0010] In an embodiment, the detection system comprises a microphone which detects
the ultrasonic sounds. The detection system may comprise any other device which is
capable of detecting ultrasonic sounds for detecting the sounds of the bats.

[0011] Current devices for detecting sounds of bats, for example a microphone, can
detect the sound of bats only within a very limited range, which means that the limited
range is close to the wind turbine and the blades. It is not sufficient to operate the wind
turbine only based upon detection of sounds of the bats, because by the time a bat is
detected, the bat would already be injured or hurt. It is therefore necessary to prepare a
control strategy for a wind turbine as described above as soon as the wind turbine is
installed and before the wind turbine starts operating. When the control strategy is prepared, the control strategy will be stored in a control system associated with the wind turbine and the wind turbine will operate according to the stored control strategy.

[0012] The detected sound is recorded and analyzed in order to identify bat species and/or to identify a specific behavioral pattern of the bats in the area of the wind turbine.

[0013] Different bat species emit different sounds depending on their behavioral pattern. Thus the relevant bat species and the relevant sound emitted by the bats are preferably saved and stored within a data base or library.

[0014] The identification of the species or the behavioral pattern may be done by a bat specialist. The bat specialist observes the behavior of the bats and evaluates the risk for the species. The specialist sets up a sound library for example, which combines the sound of a bat species with conditions under which these species can be expected to be present in the vicinity of the wind turbine.

[0015] The sound library may be stored in the control system of the wind turbine. Alternatively, the sound library may be stored in a central control system or central storage device in a remote location from the wind turbine, for example the SCADA system associated with the wind turbine. SCADA system means signal conditioning and data acquisition system and generally refers to industrial control systems which monitor and control industrial, infrastructure, or facility-based processes.

[0016] The sound of the bat may be analyzed in an automated way to identify the bat species. The risk of injuries of the bats may be evaluated according to the library. Thus the presence of a specialist is not needed during the operation of the wind turbine.

[0017] The sound library may include suitable control commands for the wind turbine. Thus, according to the sound library the wind turbine may be controlled automatically with reference to the detected bat species.
Such a sound library may be used for generating control strategies for other wind turbines by comparing detected sounds with the sounds stored in the library in order to identify the bat species and/or the specific behavioral pattern of the bat.

The result of the identification of the species and/or the behavioral pattern may be stored in a file for later examination. Therefore, a quantity of bats of a specific species and/or their behavior in a specific location can be studied. Thus the knowledge about bats and the evaluation of the risk for the bat can be improved.

After identifying the bat species and/or the specific behavioral pattern of the bat, the parameter settings for the operation of the wind turbine is set according to the presence of the specific species of the bat and/or the specific behavioral pattern of the bat.

With the claimed invention, bats are protected while the effect on the wind turbine and the energy production loss is minimized, since the wind turbine may even produce energy while in bat-mode operation. This means that operation of the wind turbine is not just stopped when bat species are detected, but rather the operation mode of the wind turbine is changed from normal-mode operation into bat-mode operation. Bat-mode operation means that the wind turbine operates according to the developed control strategies considering the identified bat species in the area of the wind turbine. For example, in bat-mode operation, the wind turbine may be stopped at night from time x to time y and is in idle during certain months of the year.

The parameter settings for controlling the wind turbine in bat-mode operation may include for example:
- altering the rotor speed (rpm), in particular reducing the rotor rpm,
- stopping the rotor,
- changing a pitch angle of one or more rotor blades.

The blades of the wind turbine rotate in normal operation at for example 10 to 15 rpm. When reducing the rotor rpm, the blades may rotate at for example 0 to 9 rpm only. Thus, a drop of the air pressure, which is dangerous for bats, is avoided in the area of
the rotor blades and it is not dangerous for a bat passing a rotor blade.

[0024] The turbine may be set to stop or idle until the bat-mode is no longer active. When the wind turbine rotor is stopped there is no danger for the bats. There is no pressure drop in the vicinity of the rotor and there is no danger of a rotor blade hitting a bat. When the rotor of a wind turbine idles the velocity of the wind turbine rotor is very low. There is nearly no pressure drop in the vicinity of a rotor blade of an idling rotor.

[0025] When the turbine is in idle, the turbine can be started again more easily when the bats have left the area of the wind turbine. Thus the energy production can start again easier. Thus the loss of energy production is reduced, while the bats are saved.

[0026] The control-parameter may be set in a way that the pitch angle of the rotor blades is changed. When the pitch angle of the rotor blade is changed the blade comes closer to a stand still, in particular when the blade is in a neutral position. The pressure drop present in the vicinity of the rotor blade is reduced and rotor speed will be reduced consequently.

[0027] The turbine may not have to be stopped completely. It may return to normal operation quite quickly after the bats have left the area of the wind turbine.

[0028] Wind turbines are usually used in wind farms with a plurality of wind turbines. A detection of bats at one turbine may impact the operation of one or more groups of turbines or the entire wind farm. In an embodiment, the sound of the bat may be detected at a first wind turbine, while the operation of all the wind turbines of the wind farm is controlled according to detected sounds and selected parameter settings consistent with the identified bat species of the detected sounds. The control strategy may be implemented at the turbines directly or the wind turbines are controlled by a central control system which is in a remote location from the wind turbines.

[0029] Behavioral patterns and parameters of different bat species which have to be considered when developing the control strategy are described in the following.
The control strategy and therefore the operation of the wind turbine depend on the identified local bat species and their specific behavioral pattern.

The different behavioral pattern refers to the fact that the bat is foraging, migrating, or looking for a resting spot, for example. Additionally, the behavioral pattern of the bat depends on the season, wind speeds, ambient temperatures and precipitation rates etc.

The operation of the wind turbine needs to be controlled in bat-mode when the bat is present or there is a high likelihood that a bat will be present near the wind turbine.

The activity of a bat is limited to a certain time of the day. The parameter settings of the control strategy may be active when the time of day is between dusk and dawn since bats are active between dusk and dawn. For example, in bat-mode operation, the wind turbine may be stopped from [dusk -x] to [dawn +y] where x and y represents respectively the time before dusk and after dawn that bats are expected to be present.

The parameter settings of bat-mode may be set according to weather conditions. The activity of the bat species may depend on the wind speed, the direction of the wind, the air pressure and the presence of rain. Bats fly in calm conditions up to a certain wind speed. For example, above a certain wind speed, bats of a certain species do not fly. Other bat species might not fly in certain weather conditions like rainy weather. Thus, in these certain weather conditions when the bats do not fly, the control of the operation of the wind turbine does not have to be modified. The influence on the control of the operation of the wind turbine may be limited to weather conditions when the bat species is active and there is a risk of injuring bats.

Certain bat species may not be active or fly when it is raining. Therefore, in another embodiment, the wind turbine or a meteorological station comprises a rain sensor which detects rain. The signal of the sensor is then transmitted to the control system of the wind turbine or the SCADA system.
The control system or SCADA system is configured to switch from bat-mode operation to normal-mode operation when signals from the rain sensor are received. When the control system does not receive a signal from the rain sensor within a predetermined time period, the normal-mode operation will switch back to bat-mode operation unless the control strategy allows staying in normal-operation mode.

The parameter may be set according to an illumination which is present at the wind turbine site, for example full moon illumination. Certain bat species may behave differently during full moon nights. This means that the bat-mode may be set according to the moon phase, for example the rotor of the wind turbine may be in idle or event stopped during a full moon night.

There exist different bat species in different parts of the world. The existence and behavior of certain species of bats vary dependent on the geographical position of the wind turbine. As already mentioned, the local species of bats in the area of the wind turbine will be identified by detecting and recording the click pattern of the bats.

The parameter settings may be selecting according to a specific time of year. Bats are in most regions only active during part of the year, so bat mode may be entered for region A from date x to date y of the year. In tropical regions this may include the entire year and on the southern hemisphere this may stretch across new years for example. In most parts of Europe the activity of the bats starts in spring and end in autumn, for example. The seasons are different or begin at a different time due to the influence of a coast or in the middle of a continent. Thus, the activity of the bats might start earlier in the year or last longer in a certain geographical region.

The sounds of the bat species in the area of the wind turbine and the specific conditions on which the parameter settings are based may be monitored, for example using the detection system, over time in order to decide if the wind turbine may return to normal-mode operation. It may be that the identified bat species in the area of the wind turbine have left the area over the years, for example because the climate has changed, which means that the wind turbine can be operated in normal operation without bat-mode operation.
In a further embodiment the operation of the wind turbine is only modified when an endangered bat species is detected or when a bat species with a high harm exposure is detected.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG 1 shows an embodiment for preparing a control strategy,

FIG 2 shows an embodiment of different control strategies for different species, and

FIG 3 shows an embodiment of a control strategy.

DETAILED DESCRIPTION OF INVENTION

FIG 1 shows the method by help of a block diagram. According to the block diagram a list of parameter settings to control the wind turbine is created.

The first step S1 is to record the click pattern, which is part of the sound of the bat. The result of S1 is the input for the second block S2. In the second step S2, the species of the bat is identified. Based upon S2, a list of local species of bats is created (step S3).

The last step S4 includes setting appropriate parameter settings according to the created list of identified species.

FIG 2 shows an embodiment of different control strategies for different species. FIG 2 shows a table listing species and control strategies. For example, bat species A requires a control strategy which includes the parameter settings A. For the identified bat species B, parameter settings B are chosen. FIG 2 also shows that different bat species may require the same strategies because the different species show a very similar or identical behavior pattern. For example, bat species D requires the parameter settings D which are the same settings as for bat species A.

FIG 3 shows an embodiment of a control strategy, for example for the control strategy according to parameter settings A (FIG 2). The table according to FIG 3 lists the
control strategy and the detailed parameter settings for this strategy. The list of parameter settings includes for example time of year, time of day, flight wind speed, and minimum flight temperature and if a rain sensor is required. The list of parameters is only exemplary and may comprise more parameters.

5 [0049] The parameter settings A include that the wind turbine is in bat-mode operation from January to December from dusk -1h to dawn +1h each day. Also, the wind turbine operates in bat-mode operation when the wind speed is less than 5 m/s and when the ambient temperature is above -5°C, because the identified bat species does not fly when the wind speed is 5 m/s or more and when the ambient temperature is below -5°C. Furthermore, a rain sensor is required because the bat species A and D (see FIG 2) do not fly when it is raining. All the mentioned criteria time of year, time of day, flight wind speed, minimum flight temperature etc. have to be met for the bat-mode operation to be activated.
CLAIMS

1. A method of operating a wind turbine, comprising:
   detecting a sound of a bat in an area of the wind turbine;
   identifying a bat species based upon a detected sound; and
   setting a parameter for operating the wind turbine according to the identified bat species.

2. The method according to claim 1, further comprising:
   recording and storing the detected sound in a database or a sound library, wherein
   the detected sound is stored in connection with the identified bat species.

3. The method according to claim 2, further comprising:
   comparing the detected sound with sounds stored in the sound library or database
   prior in order to identify the bat species.

4. The method according to claim 2, wherein the data base or sound library are
   stored in a control system of the wind turbine.

5. The method according to claim 2, wherein the data base or the sound library
   are stored in a central control system or a central storage device in a remote location from
   the wind turbine.

6. The method according to claim 1, wherein the parameter for operating the
   wind turbine includes
   altering the rotor speed (rpm), in particular reducing the rotor rpm, and/or
   stopping the rotor, and/or
   changing a pitch angle of one or more rotor blades.

7. The method according to claim 6, wherein the parameter is set according to
   the identified local bat species and their specific behavioral pattern.
8. The method according to claim 7, wherein the parameter is set according to the time of day.

9. The method according to claim 8, wherein the parameter is set from \([\text{dusk} - x]\) to \([\text{dawn} + y]\) where \(x\) and \(y\) represent the time before dusk and after dawn when a bat is expected to be present.

10. The method according to claim 7, wherein the parameters are set according to weather conditions.

11. The method according to claim 7, wherein the parameter is set according to a geographical position of the wind turbine.

12. The method according to claim 7, wherein the parameter is set according to a specific time of the year.

13. The method according to claim 1, wherein a control strategy for the wind turbine includes parameter settings according to identified bat species, and wherein the control strategy is stored in a control system associated with the wind turbine.

14. The method according to claim 1, wherein the sound of the bat is detected by a detection system which is located at the wind turbine.

15. The method according to claim 1, wherein the sound of the bat is detected by a detection system near the wind turbine.

16. The method according to claim 1, wherein the sound of identified bat species in an area of the wind turbine and associated specific conditions on which parameter settings are based are monitored over time in order to decide if the turbine may return to a normal-mode operation.

17. The method according to claim 1, wherein parameter settings associated with one wind turbine are used for controlling other wind turbines.
18. The method according to claim 1, wherein a rain sensor for detecting rain is
located at or near the wind turbine, wherein an operation of the wind turbine is modified
according to signals of the rain sensor within predetermined time periods.

19. The method according to claim 1, wherein the wind turbine comprises a
plurality of sensors for detecting and/or measuring ambient conditions.
FIG 1

1. Record click pattern (S1)
2. Identify species (S2)
3. Create list of local species (S3)
4. Set appropriate parameter settings accordingly (S4)

FIG 2

<table>
<thead>
<tr>
<th>Bat Species</th>
<th>Control Strategy</th>
</tr>
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<tbody>
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<td>Bat Species A</td>
<td>Parameter Settings A</td>
</tr>
<tr>
<td>Bat Species B</td>
<td>Parameter Settings B</td>
</tr>
<tr>
<td>Bat Species C</td>
<td>Parameter Settings C</td>
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<tr>
<td>Bat Species D</td>
<td>Parameter Settings A</td>
</tr>
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<td>...</td>
<td>...</td>
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FIG 3

<table>
<thead>
<tr>
<th>Parameter Settings A</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Year</td>
<td>Month a to Month b</td>
<td>Jan. to Dec.</td>
</tr>
<tr>
<td>Time of Day</td>
<td>Time x to Time y</td>
<td>dusk -1h to dawn +1h</td>
</tr>
<tr>
<td>Flight wind speed</td>
<td>Wind speed $s \leq x \text{ m/s}$</td>
<td>$s \leq 5 \text{ m/s}$</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>Temperature $t \geq x \text{ °C}$</td>
<td>$t \geq -5 \text{ °C}$</td>
</tr>
<tr>
<td>Rain sensor</td>
<td>Yes/No</td>
<td>Yes</td>
</tr>
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<td>...</td>
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A. CLASSIFICATION OF SUBJECT MATTER

INV. F03D7/02  F03D7/04

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. X See patent family annex.

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Authorized officer Krol, Marcin
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