Wind turbine condition monitoring system as a source of diagnostic information

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Abstract. The issues relating to the necessity of monitoring the wind turbines' condition and operation are presented in the study. The wind turbines of high powers, are very expensive and complicated machines requiring appropriate control and high quality technical service. The idea of appropriate technical turbine's maintaining, combines its high availability and productivity, as well as minimization of the costs related to failures and unexpected damages. Remote diagnostic systems allow obtaining the basic information, making it possible to maintain and appropriate control, use and high quality technical service.

1 Nuisance of wind power plant

The renewable energy sources are an important element of current life. Their spreading in the environment is consistent with the idea of the scattered energy sources. However, such scattering causes, that the local population coming into contact with them, may have negative feelings. The scientists have been conducting many studies to decrease the negative impact of the renewable energy's sources on the human being's environment. Apart from direct interactions, the manners of the interaction's decreasing by their energy-consumption's decreasing are also being tested [1].

A wind power plant is a complicated system composed of a wind motor connected with an electric generator, together with all the types of systems needed for its functioning. A wind power plant, at the time of its operation, is exposed to variable loadings resulting from wind gusts having an effect both on the rotor's planes but also on the tower and nacelle. These interactions are moved on the foundation's plate, and then to the ground. Considerable speeds of the blades' ends and a rotor's operation in the airstream lapping it, are also a source of noise. Spinning of huge masses consisting of the mass of a rotor, mass of wheels and shafts and bearing, as well as the electric generator's rotor, are the sources of oscillations and noise. Flickering of sunlight and shadow caused by considerable rotor's dimensions, are an additional source of dangerous interaction on living organisms. Even in the domestic environment, a human being and animals are exposed to wind interactions. These are most of all the infrasounds, which may penetrate the concrete barriers, as well as flickering of the electric light powered from the network that the power station is connected to.

Noise is the result of different sounds' overlapping, which we receive as having no order. As it is commonly understood, it is every sound which disturbs us. The impact of noise on a human body is different, however most of all it attacks the nervous system. It is a serious risk as its results very rarely become apparent at once – they more often cumulate in time. Noise affects live organisms in two ways. The first and the most often observed one is its impact on mental state, and consequently the physical health of a human being. The

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second mode is the physical noise's affecting on the hearing organ and the central nervous system. Sound waves, which we receive as sounds or noise, are the changes of the air's pressure surrounding us having a direct contact with the delicate elements of the hearing organ. Exposure to excessive noise resulting in occurrence of an acute or chronic acoustic injury, accompanied by may defensive responses just like for example changes in the heart's action, of the breathing rhythm, of blood pressure, of body temperature, etc. As a result of staying in the environment burdened with excessive noise, there may occur the so-called post-noise syndrome covering: headaches and vertigoes, weakness, increased nervousness, sleep disorders, increased sweating, hearing impairment. Noise received by the ear through nerve connections with the cerebral cortex may interact on other centres located in the brain. It concerns most of all the central nervous system and the endocrine glands system. 75 dB is the boundary value of the physiological functions' disturbance, after exceeding of which there may occur their clear disturbances. For the value of the acoustic pressure within the limits of 55 ÷ 75 dB, there may occur the lack of concentration. Such a bodily's reaction is its defense against the long-term exposure to noise, which may contribute to different types of diseases (for ex. pressure disease, ulcer disease, neuroses).

Infrasounds are the sounds, in the spectrum of which there appear constituents of frequencies from 0 to 20 Hz. The sounds within such a band of frequencies, are theoretically not heard by a human being. However, the level of their reception depends on individual personal features and the level of acoustic pressure. The acoustic pressure thresholds for infrasounds' audibility is high (6 ÷ 8 Hz about 100 dB), and they lower with the frequency's increase. Infrasounds are also received by the vibration sensory receptors. The feeling thresholds are for 20 ÷ 30 dB higher than the hearing thresholds [2].

For the acoustic pressure on the level of 100 dB, the infrasound may be perceptible as an unpleasant feeing of internal vibration caused by the internal organs' resonance phenomenon. Another occurring symptom is the feeling of compression in ears and the occurring state of excessive tiredness, discomfort, drowsiness, balance disorders, psychomotor physical fitness and physiological functions' disorders. Changes caused by infrasound in the central nervous system are similar to lowering of the standby.

For the acoustic pressure above 140 - 150 dB, the infrasound may result in permanent, harmful changes in the organism [3].

Infrasound come into existence in a different manner. In the nature it is waving of oceans, leaves' rustle. The anthropogenic sources are most of all the vehicle transport, industry, ventilation in buildings. Huge flow machines just like wind turbines, have also become a noticeable source of infrasound.

The issues related to the noise are the object of a special interest of scientists. Particularly important, as far as the noise is concerned, there becomes the correct assessment of a wind farm's condition. It's used elements may cause the noise's emission increase. As presented by [4,5] wind farm plants' noise may influence the animal's productivity, their stress, fodder's consumption. Noise is also important in case of another green energy's processor, just as agricultural biogas plants [6].

Mechanical vibrations generated by a wind farm plant are transmitted through foundation on the surrounding land. A human subject to that factor is exposed to damage of tissues and blood vessels. Long-term exposure to vibration may result in disease changes in the vascular system, musculo-articular system and nervous system.

Changes in the musculo-articular system of a hand arise mainly as a result of local vibration of frequencies lower than 30 Hz. There are observed among the others, deformations of joint spaces, calcification of joint capsules, changes in bone texture.

Disorders in the internal organs' functioning are mainly the result of individual organs' stimulation for resonant vibrations (frequencies of own vibrations of most of the organs are within the range 2 ÷ 18 Hz).

The following ones are the most important constructional elements deciding on a typical wind turbine's efficiency:

- Main transmission with a generator (gear wheels, bearings, shafts and intermediary couplings),
- Turbine's blades with their angle's adjustment mechanism,
- Turbine's tower (foundation on the base, the tower's connections).

Incorrect operation or these elements' damages should be disclosed earlier, in the initial phase of their damage. When disclosed too late, it may result in damaging elements or whole installations by destructive feedback.

The main transmission is exposed to variable, cyclical loadings [7]. Their impulse nature results in occurring of fatigue damages and revealing of material defects. Exposed to damages in the main transmission are most of all the main bearings and the planetary transmission.

The wind turbine's blades are the elements converting the wind energy into the rotor's rotational motion. Due to big dimensions and moments having an impact on a blade, they should be under special supervision. Incidental influences such as strokes in birds, icing, are also disadvantageous.

Due to that, slight damages in a blade's critical places may result in very rapid increase of a damage's scope till a blade's complete destruction.

A tower is the next constructional element of a wind turbine, supporting the whole construction. Damages or loosening of the fixing elements in the tower result in the increase of the risk of the complete turbine's damaging [8]. Figure 1 shows the course of ground vibration at a distance of 50 m from the tower of the power plant.

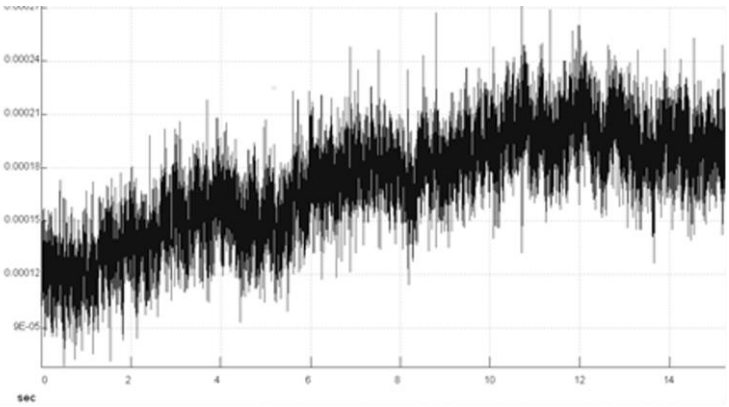

Fig. 1. The time course of vibrations generated by the wind turbine at a distance of 50 m from the tower of power plant.

2 Detection of damages in wind power plants

A properly designed machine in modern CAD/CAM systems seems to be free of defects. However, each operating process must be monitored and monitored on-line in order to avoid major failures [9].

The purpose of monitoring is early detection of damages with the use of the below listed methods:

- measurements of vibration and vibrodiagnostics,
- monitoring the condition of the blades based on the elastic waves' propagation and deformations' measurements,
- monitoring of the tower with the use of the own vibration frequencies' measurement techniques and monitoring of the screw connections' condition.

The systems of the transmission vibrations' monitoring enable recording and analyzing of vibrations from the transmission. Such a system consists of the set of sensors (vibration, process values such as power, speed and direction of wind, etc.) and the module of data acquisition and processing. The data is collected and then processed by a data server. In order to increase the performance, the data registering system has been divided with respect to the type of data and their priority, there are also recorded the events connected with crossing of the alarm thresholds. From the events like these, there is drawn up a protocol which, in an electronic form is automatically sent to the diagnostic centre.

The systems of the blades and the tower's monitoring make it possible to:

• detect the blade structure's damages (stratification of the composite material, cracking, comings off) – systems based on generation and measurement of elastic waves,

• detect the problems with unequal blades' burdening (icing, loosening of connections with a hub) – systems based on measurements of deformations with the use of optical fibre sensors,

• easy integration with the transmission's monitoring system – data are sent to the same database and are processed by the expert algorithms.

The complement of the whole monitoring system is most often the system of the measurement type SCADA data acquisition and visualization. It is the system supervising the course of the process. The following may be considered to be the basic tasks of such a system:

- remote controlling of the measuring devices,
- control of the measurement process,
- collecting and recording of the current measurement data in the database,
- analysis of the signal data,
- steering the technological process,
- alarms and notifications' generating,
- visualization of the parameters measured on the synoptic screens,
- visualization of the current and historical measurement data on the diagrams,
- export of data to other systems.

The following ones are also the indispensable features of the software:

- modeling of an object's kinematics,
- automatic setting of the controlled machines' characteristic frequencies,
- automatic setting of the alarm thresholds' values,
- creating reports.

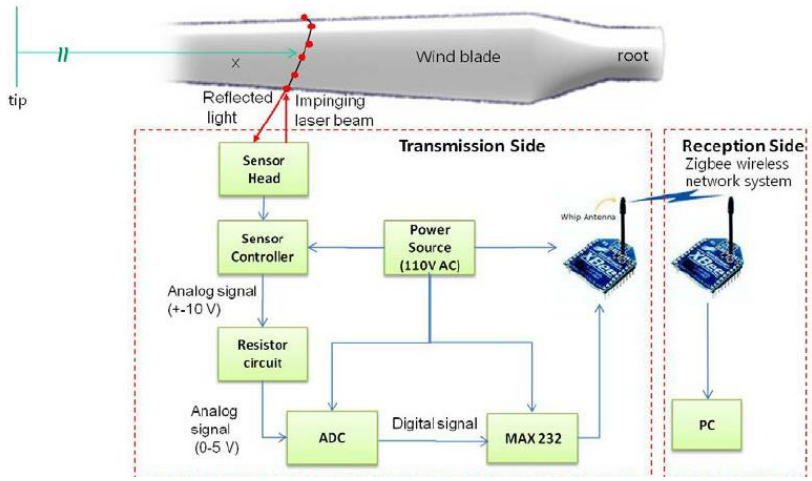

Fig. 2. Block diagram for wireless deflection monitoring system of wind turbine blades [10].

To protect the turbine blades, various types of control systems are used. The experimental wireless system is shown in Figure 2 [10].

3 SCADA systems in wind power plants

The SCADA systems consist of several crucial components. The basic one is the controlling computer located at the area of a wind farm, permanently connected to the operating turbine. In case of installation on one power plant, such a computer most often is installed in its interior. With the use of the internet links, the collected data from monitoring are transferred to a final recipient – a customer – operation of a wind farm, who reads them out with the use of a special computer application.

SCADA has the input data entered to the system, which with the use of the sensors located in the power plant, monitor its condition. Data is used not only for monitoring purposes, but also to different types of analyses often showing dependencies between given parameters. Thanks to algorithms, it is possible to detect the causes of failures of the elements' wear and tear. The following ones are the other important functions of the SCADA systems: data archiving, alarming of diagnostic centers, transfer of information to a wind farm's owner, diagnostics, cooperation with power generation plants, analysis of data already mentioned.

The service, thanks to SCADA software, is able to perform remotely diagnostics of the conditio, what reduces the costs and speeds up the work. The technical division, thanks to performing of the cause-effect relations' analyses, may avoid underestimation of a small defect, knowing on its future negative impact of a turbine's operation.

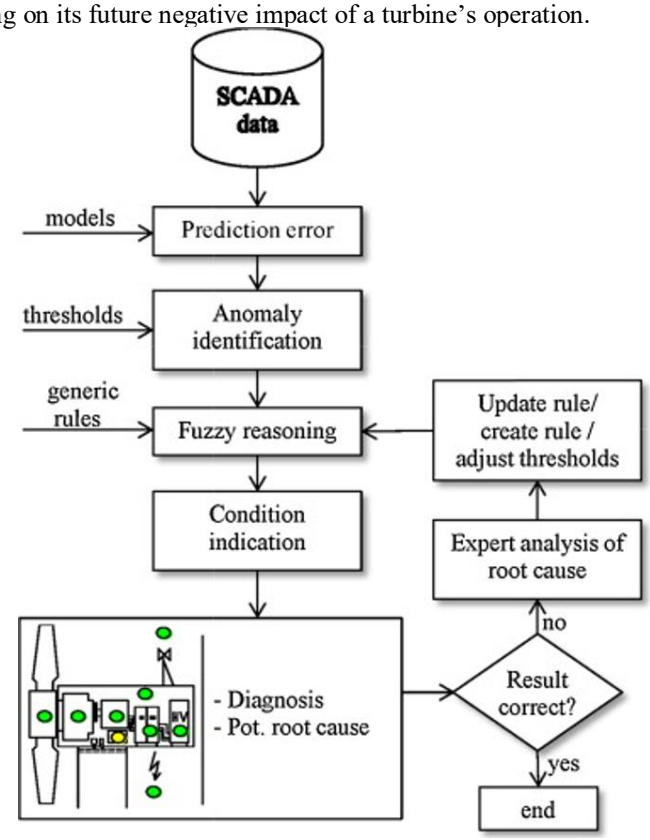

Fig. 3. The Information flow [11].

Thanks to the management systems, it is possible to choose the settings aiming at reduction of the noise emitted by wind turbines. One of the basic methods of noise reduction is to manipulate the speed of rotation of the wind turbine rotor's propellers.

Slowing down of the rotor's rotation is connected with the acoustic emission's reduction. The angle of the turbine blade's inclination also plays an important role here.

Its appropriate increase shall result in the decrease of the air masses' angle of incidence. So, selection of such settings of the inclination angle may considerably reduce the noise generated by the influence of air masses on the wind turbine rotor's surface. Such a method is very often used to reduce the acoustic interaction.

The diagnostic systems of that type may minimize considerably the number of the service's field inspections, and consequently, reduce the time of a turbine's shutdown from use. On the market there are available different types of systems – the author's SCADA of the manufacturers of wind turbines and independent systems [11].

The general flow of information using SCADA systems and the optimization of diagnostics has been highlighted in Figure 3.

3 Summary

A modern monitoring system enables not only measurements and signaling of a current machine's condition. They are most often used to analyze and forecast its condition in the subsequent moments. Such a task requires most often the simultaneous analysis of many parameters and using of different, often computationally advance methods.

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