A real time system for measuring wind turbine power

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Abstract: This paper deals with a real time system for automatic measurement of wind turbine parameters. The system was designed according to the specifications provided by a Polish company cooperating with the Kielce University of Technology on a project called "*Invention" – Potential of young researchers and transfer of knowledge and innovation as a support for the key areas of Świętokrzyskie economy.*

Keywords: wind turbine, power measurement, real time system

As power consumption is growing and natural resources are diminishing, green energy technologies are becoming increasingly popular. Thus, it is essential that more efficient renewable energy devices are developed. According to the latest BCC report on *Energy efficient technologies: the global market*, the sustainable energy market is constantly growing, with the growth being on average 13 % per year. In 2014, it is expected to rise from 35 to approx. 70 billion US dollars (fig. 1). This implies that the wind energy market will also increase. When renewable energy systems become more efficient, investments in this sector will be more profitable. The requirement by EPRD that the performance of some wind turbines are improved was a key factor to initiate cooperation between this company and the Kielce University of Technology on the *Invention* project.

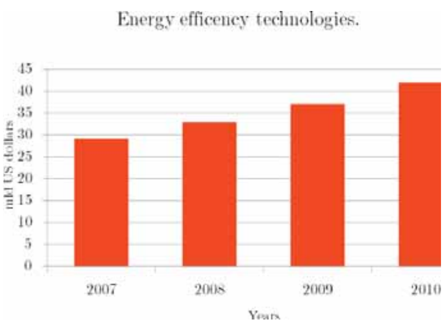

Fig. 1. BCC research on energy-efficient technologies [1]
Rys. 1. Badania BCC dotyczące technologii efektywnych energetycznie [1]

Poland's share of the wind energy market has increased considerably in recent years. According to the European Wind Energy Association, power generated by wind farms rose from about 1.2 MW to about 1.6 MW at the end of 2011. Additionally, after the Fukushima nuclear power plant failure, social support for renewable energy investments has definitely risen. Despite this, Poland still ranks among the lowest in Europe for wind energy utilization (fig. 2). This is expected to change, because Poland's potential in this sector is substantial.

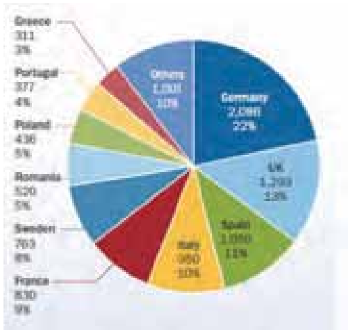

Fig. 2. Poland's share of the EU wind energy market [2]
Rys. 2. Udział Polski w rynku energii wiatrowej UE [2]

The share of wind energy is growing steadily. Wind ranks third in the EU as a source of renewable power generation so efficiency of wind turbines is of crucial importance (fig. 3).

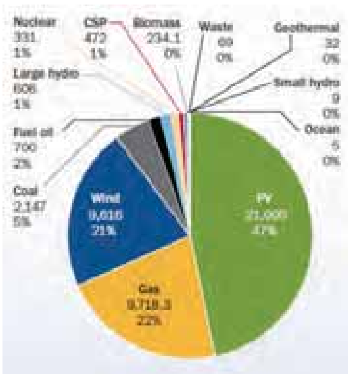

Fig. 3. New power plant installations [2]
Rys. 3. Nowe instalacje siłowni elektrycznych [2]

1. Design criteria for the measurement system

Various reports on the renewable energy market suggest that improvement in the efficiency of wind turbines needs to be prioritized. The cooperation of EPRD with the Kielce University of Technology resulted in the development of a system for measuring the parameters of some newly designed wind turbines.

The measurement system is an autonomous system to be used for in-situ testing of wind turbine efficiency. Conducting such tests under laboratory conditions could be unprofitable, because these require simulations under controllable weather conditions. The cost of generation of air streams to simulate different weather conditions is very high, especially for companies with a limited R&D budget. One of the design criteria for the measurement system was that the maximum values of wind turbine power were approx. 3 kW, 6 kW and 11 kW, which were calculated using the following formula:

$$P = Mn\frac{2\pi}{60000} \qquad (1)$$

where: P – power [kW], M – torque [Nm], n – rotational speed [rpm].

The measurement system is designed to measure torque in order to determine power ranging from 2 kW to 10 kW by means of formula (1). According to the principle of torque measurement, a load is applied at one end of the sensor, as shown in fig. 4.

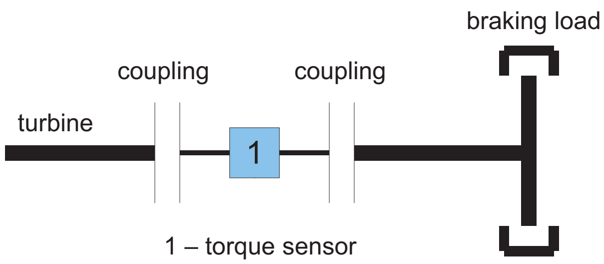

Fig. 4. Principle of torque measurement
Rys.4. Zasada pomiaru momentu obrotowego

In the system, the braking load is provided by a moto-reducer co-operating with a power inverter. Most inverters are equipped with an optional braking module, whose power is generally equal to 10 % of the inverter nominal power and which is responsible for dissipating the braking energy. As the inverter is designed to operate continuously in the braking mode, it needs to dissipate 100 % of the braking power. Tab. 1 shows the values of power calculated for the system. The inverter has to generate the braking load with high accuracy, so it is usually equipped with an additional closed-loop feedback controller using a velocity signal from the moto-reducer encoder.

Tab. 1. Maximum power calculated for different turbines operating with a rotational speed of 200 rpm
Tab.1. Moc maksymalna obliczona dla różnych turbin pracujących z prędkością obrotową 200 obr./min

Max. torque [Nm]	Turbine power [kW]	Moto-reducer power [kW]	Inverter power [kW]
500	10.47	11	11
200	5.24	5.5	5.5
100	2.09	3	3

The system is equipped with meteorological sensors to read out the necessary parameters such as humidity, temperature, barometric pressure, and the velocity and direction of wind. The system employs a touch panel as a human-machine interface. Optionally, we can use a PC station to download the logged data via the FTP connection.

2. Real time system hardware

The real time system shown in fig. 5 consists of a CompactRIO controller with a cRIO-9012 Real-Time PowerPC controller, a 4-slot chassis, a 24-bit Current AI module, a 4-Ch 20 mA 16-bit Current AO module, and a 4-Ch 50 ns LV TTL Digital I/O module. The Power PC of the cRIO-9012 Real-Time controller uses a 400 MHz clock, which is suitable for control, and data acquisition and logging with a frequency of 100 Hz. The controller may be used with a touch panel for data visualization. Additionally, the controller enables downloading files via the FTP connection. The current modules are responsible for gathering signals from all sensors, except for the velocity values from the torque sensor, with this being done by the fast Digital I/O module. The current output module is used to generate a torque-speed characteristic of the braking load predefined by the user in the application. The system logs in data directly on the flash drive. In the system, there may be an industrial wireless connection between the desktop PC and the controller located at a distance of up to 40 km away from the testing platform. The CompactRio controller has one major advantage: it can operate at a temperature range of –40 °C to 70 °C.

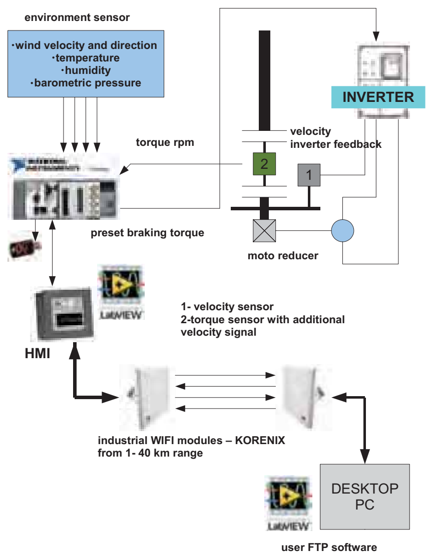

Fig. 5. Power measurement system
Rys. 5. Układ do pomiaru mocy

3. Real time system software

Laboratory **V**irtual **I**nstrument **E**ngineering **W**orkbench (**LabVIEW**) is an innovative method of programming, using a graphical language where icons are connected to create a diagram (fig. 6). It enables fast and easy prototyping of applications. Mathematica codes used in LabVIEW enable implementation of advanced algorithms for signal processing or control (fig. 7). The code created here is easy to check for errors. It is possible to slow down the code execution and observe step by step how the application works.

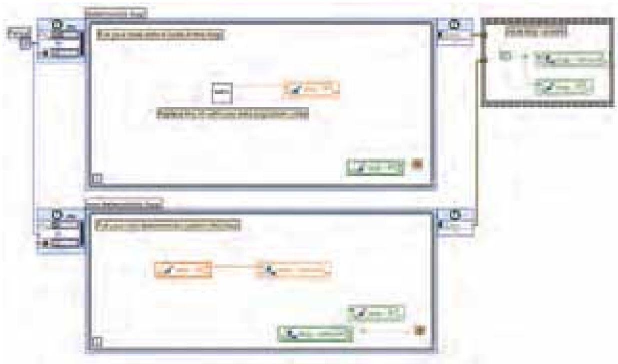

Fig. 6. Example of a LabVIEW code
Rys. 6. Przykładowy kod w LabVIEW

Fig. 7. Mathematica code in LabVIEW
Rys. 7. Kod zgodny z Mathematica w LabVIEW

The application to be used with the measurement system was created using the LabVIEW Real-Time Module, which offers a reliable and efficient deterministic technology, i.e. one of those found in time-critical applications. The main part of the application created for the CompactRIO controller is called the target. The real time application uses three separate loops, which are different in functionality and priority, as shown in fig. 7. The most important is the deterministic loop, which is responsible for acquisition and scaling of all measurement signals as well as signal generation for the inverter to set the braking load from the user-defined characteristic. The measurement process starts once the wind velocity reaches a value predetermined in the application and is performed until the wind turbine is powered down to idle mode. During testing, the deterministic loop continues sending information to the communication loop, which is like a major artery in a system transmitting information between the touch panel and the real time system. The data transmitted between the control loop, the communication loop and the data logging loop go through the RT FIFO, which is the best way of lossless transmission of data. Additionally, this kind of communication does not affect the determinism in the application. The second in priority is the file I/O loop, which collects data from the deterministic loop and stores it in TDMS (Technical Data Management Streaming) files. The TDMS files are very easy to use and can be read with Excel. TDMS enables high speed data streaming, which is the best solution for continuous data storing. Data storing takes place continuously before, during and after measurement at various sampling rates, because measurement can be performed over a period of several days or even a month. The sampling rate is changeable. There is no need to record weather conditions with a frequency of 100 Hz while the turbine is at idle, i.e. before and after a test. The sampling rate for the idle mode can be defined by the user. The touch panel application allows the user to observe the real-time parameters of the system, set up an experiment, and observe the results.

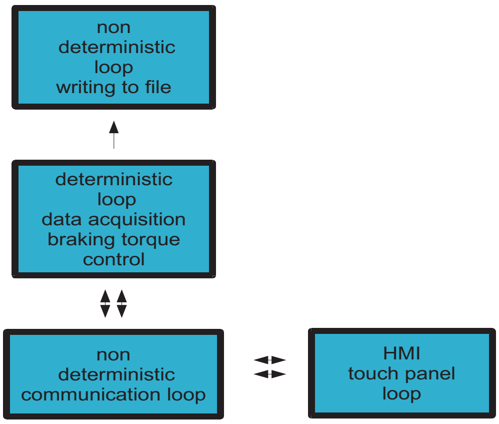

Fig. 8. Measurement system schematic diagram
Rys. 8. Schemat systemu pomiarowego

4. Conclusion

The measurement system presented in this paper has to fulfill the following functions: control, measure and logging. It remains ready for operation for several days, waiting for the user-defined weather conditions. It can be easily used to improve the performance of wind turbines tested in their natural environment. The components are heavy-duty, which enables the system to operate in extended temperature ranges and meet other requirements specified by the user.

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System czasu rzeczywistego w pomiarach mocy turbin wiatrowych

Streszczenie: Niniejszy artykuł przedstawia system czasu rzeczywistego, który służy do zautomatyzowanego pomiaru mocy turbin wiatrowych. System został zaprojektowany zgodnie z wymogami przedstawionymi przez jedną z polskich firm, która współpracuje z Politechniką Świętokrzyską w ramach projektu *„Inwencja" – Potencjał młodych naukowców oraz transfer wiedzy i innowacji wsparciem dla kluczowych dziedzin świętokrzyskiej gospodarki.*

Słowa kluczowe: turbiny wiatrowe, pomiar mocy, systemy czasu rzeczywistego

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