Failure Forecast Diagnosis of Small Wind Turbine using Acoustic Emission Sensor

Toshio Bouno*, Toshifumi Yuji, Tsugio Hamada*** and Toya Hideaki ******

Abstract - Currently in Japan, the use of the small wind turbine is an upward trend. There are already many well established small wind turbine generators in use and their various failures have been reported. The most commonly sighted failure is blade damage. Thus the research purpose was set to develop a simple failure diagnostic system, where an Acoustic Emission (AE) signal was produced from the failure part of a blade which was measured by AE sensor. The failure diagnostic technique was thoroughly examined. Concurrently, the damage part of the blade was imitated, the AE signal was measured, and a FFT(Fast Fourier Transform) analysis was carried out, and was compared with the output characteristic. When one sheet of a blade was damaged 40mm or more, the level was computed at which failure could be diagnosed.

Keywords: small wind turbine, AE sensor, failure diagnosis, fast fourier transform, peak value, blade

1. Introduction

Due to its use of natural energy, the technology of the low- voltage distribution system for the distributed power supply attracts attention to its potential environmental problems such as reduction of fossil fuel expenses etc. The facility of the distributed power supply is mostly composed of a small wind turbine, a solar cell, and a fuel cell. If the power generation in which maximum power is possible to supply can be taken out according to each of the features of the power generation capabilities, it would spread even through ordinary homes and may become an effective means in the practical use of an electric power supply. As for these distributed power supplies, it is feared that failure of a unit's simple substance may also cause a fatal accident in an electric power system. Thus, a search for a diagnostic method that can identify early failure in each unit is required.

According to the initial results taken over the past several years, it is expected that the use of wind power as one of the distributed power supplies will increase in popularity. It has also been reported that this yearly trend will continue in not only large-sized windmills but in the use of small wind turbines as well[1]. Moreover, the failure of the dynamo part in the small wind turbine generator due to damage caused by natural is asters etc. [2] and long-term operation of a thunderbolt etc. was reported in proportion to the actual introductory result. However, the failure diagnostic technology in a small wind turbine is not established [3] [4], and therefore it is at present dependent on the monitoring of the output voltage, or it must be visible to the human eyes.

As an installation part of a small wind turbine, it is mostly used for a power supply such as for spare of weather station, for emergency in mountain ranges and for highways. Therefore development of a quick and easy failure diagnostic system [5] is required from a maintenance management standpoint or as an efficient aspect of practical use. As a result, the importance of this was realized by authors who develop the small wind turbine for home use as well as by those who aim at commercial production of a 50W class small wind turbine generator [6].

AE is Acoustic Emission (the slip of the sound) and when the transformation and the crack occur to the material, it is the phenomenon which releases the distortion energy which was stored up at the material as the elastic wave. AE sensor and a magnet folder are shown in Fig.1.

The AE sensor is the converter which changes AE wave into the electric signal using the piezoelectric effect. AE sensor is attached to the working small wind turbine generation, an AE wave is produced in the blade part, and the AE sensor measures the damage in the small wind turbine. Finally, research is done to establish the failure

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* Dept. of Electrical and Electronic Engineering, University of Miyazaki, Japan.(6nhvjcbx@miyazaki-c.ed.jp)

** Dept. of Nuclear Engineering, Tokyo Institute of Technology, Japan.(sadowarashs@yahoo.co.jp)

*** Dept. of Electrical Engineering, Miyakonojo College of Technology, Japan.

**** Dept. of Electrical Control Engineering, Tsuyama College of Technology, Japan .

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forecast diagnostic method that will enable to find failure at an early stage.

In this paper, an imitation of a damaged part is secured (as 'naturally' as possible) in the blade part of a small wind turbine, and an AE wave is produced and is measured by anAE sensor. The failure diagnostic level was detected by considering the degree of a damaged part, change of the AE wave, and comparing the output electric power of a dynamo with AE wave. The experiment and its result are described below.

Fig. 1 The AE sensor and the magnet holder.

2. Experiments

The small wind turbine generator (Matsumura machine CO.LTD.,MWG50) used in this study and its output characteristic are shown in Fig. 2 and Fig. 3 respectively[6]. As for fig.2, as for 3.5 m/s, it is displaying a cut-in speed. From these figures, it turns out that it can be fully obtained at a low wind velocity and it begins to rotate at the output rate of a low wind velocity of 1.5 m/s by 50W[7]. This machine has gear-less design that is taken into consideration of environment and is thus sensitive to sound pollution. Polyamide material is used for the blade part. The bearing of the generator uses a rolling bearing. Details about the exact characteristics and specifications are considered as ref. [8].In the experiment a pole of 2m was attached on a building roof at the ground of 20m on which the MWG-50 was installed. Then wind velocity, output voltage and AE waveform were measured. An AE sensor was attached by using silicone grease at the upper part of the MWG-50 applied. A digital oscilloscope (Sony Tektronix, Model TDS-3100) memorizes the AE signal that was amplified by through the preamplifier (NF Electric Instruments, Model AE-703S frequency: 2 KHz~1.2 MHz).

And then, those data were transferred to personal computer using an A/D board (Keyence Co., Model NR250) and analyzed using the FFT processing techniques.

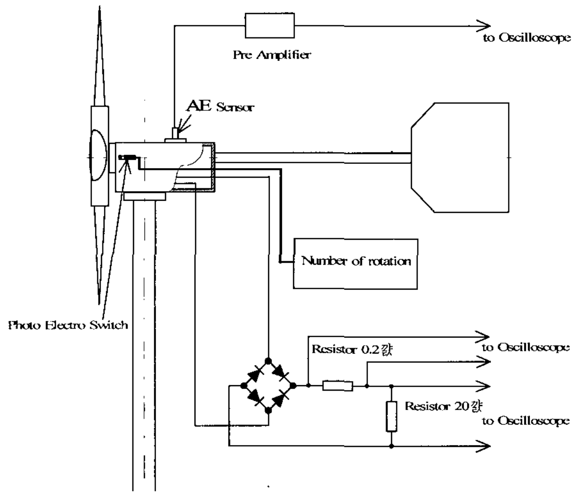


Fig. 2 Measurement equipment setup to small wind turbine.

Experiments were performed in the condition of 'natural' wind. This generator is a single-phase synchronous generator. By being rectified in all wave by the diode bridge in fig.1, direct current output is gotten. n case of experimentally, it took out a part at the diode bridge outside and it did it.

The installation condition of the blade is shown in Fig.4. In Fig. 4, *it is installing one blade of the 60mm cutting.*

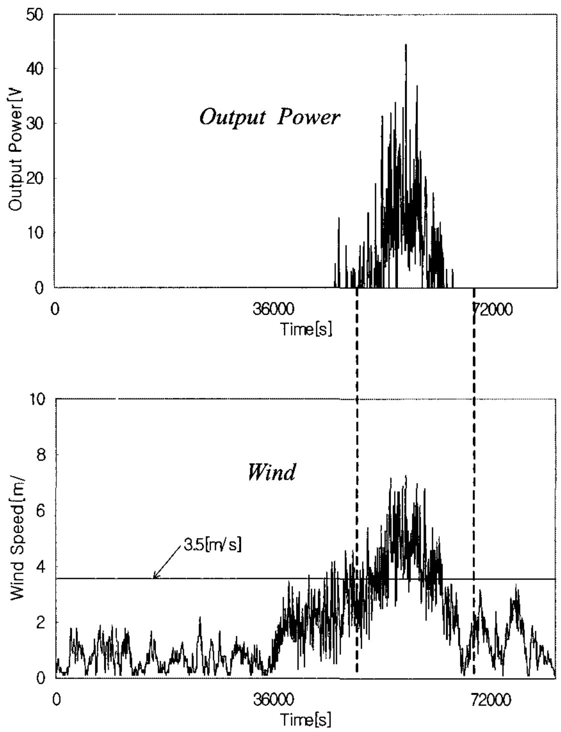


Fig. 3 Output characteristic of MWG-50.

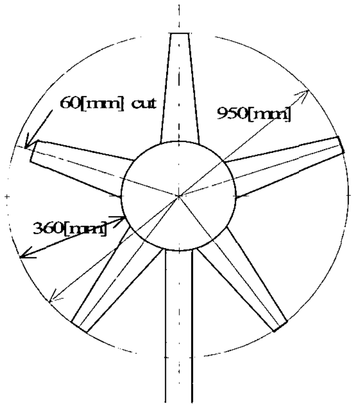


Fig. 4 Status of a cut out of 5 blades.

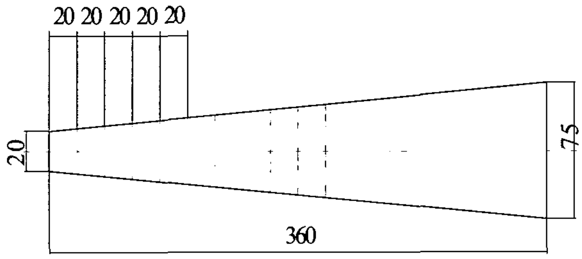


Fig. 5 Test sample of Turbine blade.

Fig. 5 is shown about the cutting of the sample blade. It prepared five samples which cut the blade that the full length is 360 mm to 20 mm, 40 mm, 60 mm,80 mm, from the end 100 mm.

3. Results and Discussions

Typical waveform of the output voltage in the normal state of MWG-50 is shown in Fig. 6. If damage is caused in feather, the maximum value of the output voltage will decline. AE waveforms and those spectrum distributions through FFT processing are shown in left-hand side and in right-hand side, respectively in Fig. 7.

These data were obtained for various blades in which blade one was cut 20~00 mm off for each one blade of the MWG-50 at a time (see Fig.7). Each waveform at the time of cutting was 20mm.

If damage occurred to a blade at 20mm, then from this figure it is checked as to whether the AE wave had arisen or not.

A remarkable change in the degree of AE wave can be observed in relation to the size of the actual damage. For example, when the feather of a small wind turbine was at a normal condition, the AE waveform was not observed at all. On the other hand, if blade damage began to appear at 80mm, then we could check by watching if the AE wave had changed dramatically or not. In addition, when the

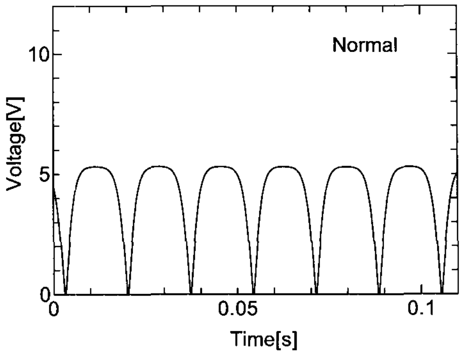
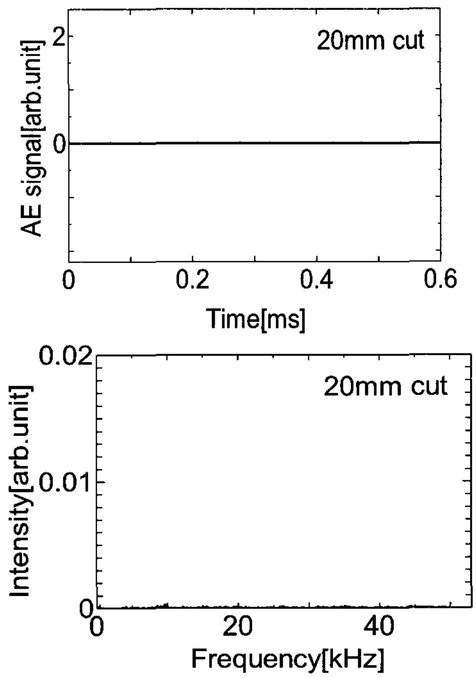
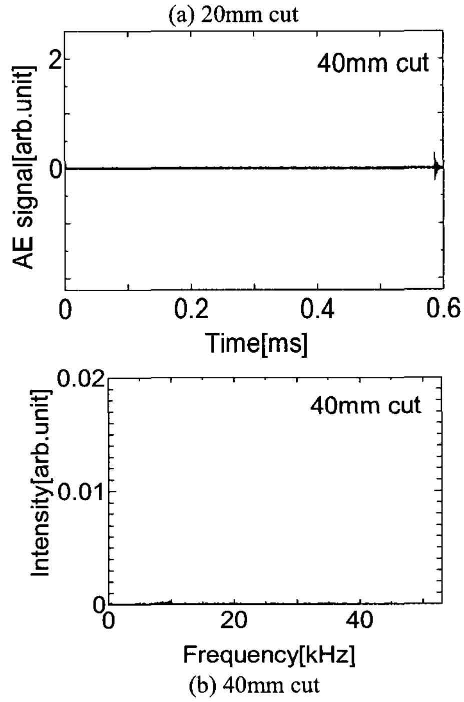


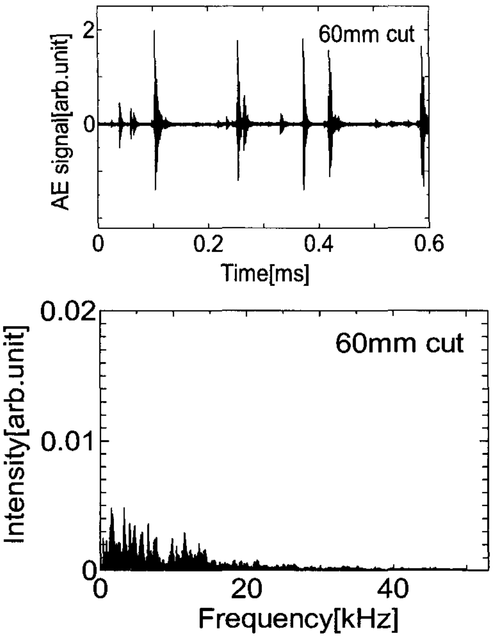
Fig. 6 Output voltage waveforms.



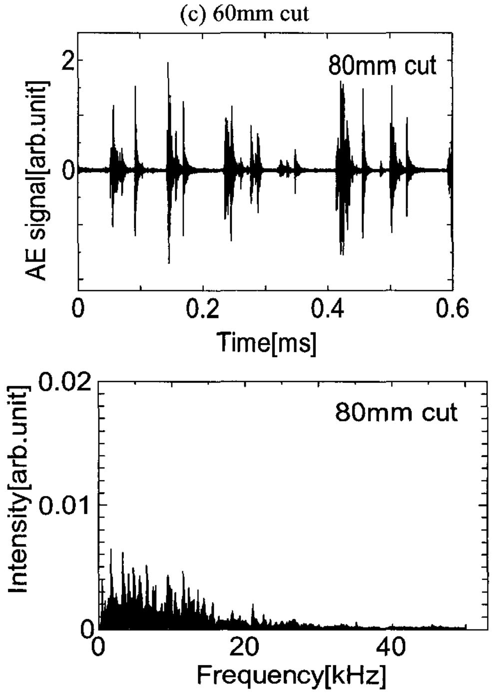
(a) 20mm cut



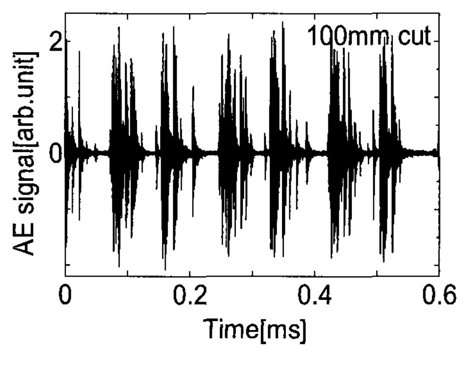
(b) 40mm cut

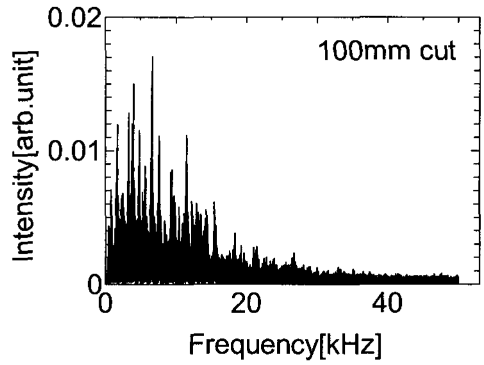


(c) 60mm cut



(d) 80mm cut





(e) 100mm cut

Fig. 7 AE waveforms and spectrum distributions.

spectrum distribution is checked, if a damage part exceeds 40mm, a spectrum will notably appear. From the data obtained, which was especially established the damage at 60mm, remarkable change with the spectrum to 20kHz was observed. In that the part which is hit by the wind after the increase tendency of the AE signal as the deficit of a blade becomes big is seen decreases, the turn becomes unstable. The AE signal, too, becomes unstable.

4. Discussions

The corrugation of the output voltage when the damage of the 100 mm cutting occurs to the blade is shown in Fig. 8. When comparing with the normal case, the that the area which is hit by the wind was decreased part output voltage, too, declines. However, distortion isn't seen by the corrugation.

Fig.9 shows the relation between cut scale and the output voltage or AE signal. In Fig.9 the graph depicts the FFT analysis of the AE signal, which extracted the maximum value in the data. If the AE wave would change, the output-voltage descent can be checked. The data for a feather with a 40mm-cutting shows that the level of AE wave increases and the output voltage also declines. Moreover, the data for a feather with 80mm-cutting shows that AE wave changes remarkably and that simultaneously the output voltage also changes markedly.

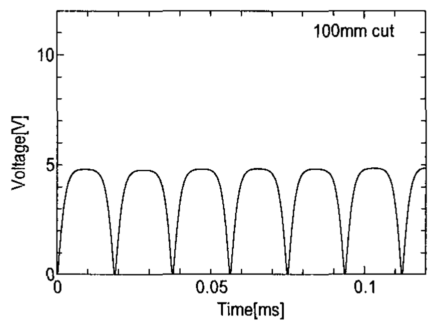


Fig. 8 Output voltage waveforms

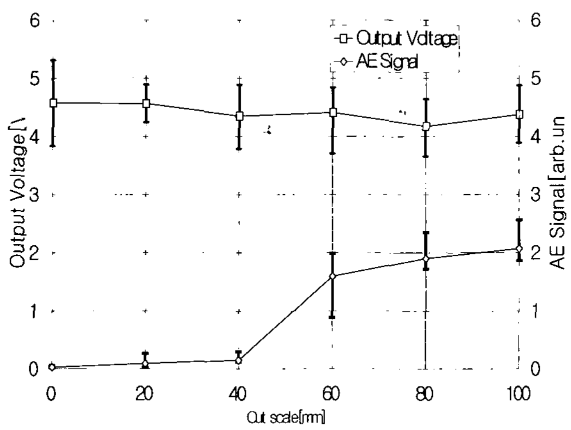


Fig. 9 Relation between output voltage or AE signal and cut scale.

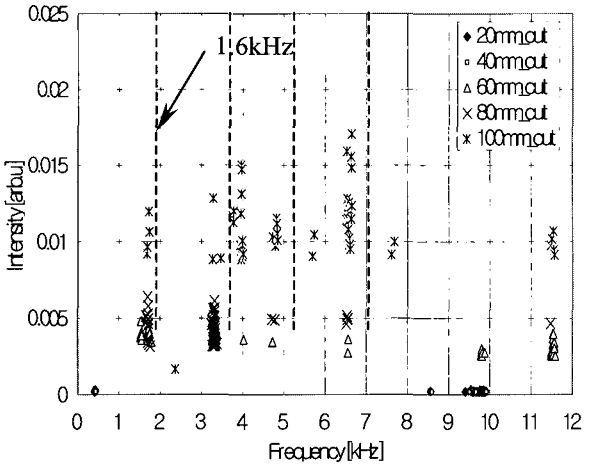


Fig. 10 Peak of spectrum.

It turns out that data both of the AE wave and the outputvoltage most notably changes for a 40mm-cut feather. Therefore this order can serve as a big fiduciary point for the failure diagnosis. The MWG-50 of which damage place on the feather has exceeded 40mm is considered failure.

Since this is judged dangerous, it is important to diagnose this failure at the earliest possible moment. When 'normal' conditions are artificially orchestrated in an experiment, there simply is not a sufficient amount of wind. Therefore, it is extremely difficult to get the results from any experiment exact. However, what can be ascertained from the present experimental results is that, since the diagnostic level can be checked, future data accumulation can be finely arranged according to a diagnostic standard level.

But, as we have shown, failure could be diagnosed at an even earlier stage, and could aim at the simple system. And as many parameters are able to be collected, the construction of a positive system becomes desirable. Therefore, as a future subject, an actual broken apparatus that needs the measurement of all parameters, which are acquirable from MWG-50, should be diagnosed.

The extreme relation of the spectrum is shown in Fig. 9. It extracted these 60 figures from the peak value of the extreme data of the spectrum which changed each AE signal in FFT. It takes a frequency in the transverse about Fig. 10, and it takes the strength of the spectrum from the vertical axis and it is displaying it. This is to see that the difference of the spectrum as much as which occurs to the cutting of each blade. Also, the distribution of the peak value can be examined. Then, it is possible to do the confirmation whether or not the influence comes out, too, to the frequency with degree. This figure showed that the big change didn't appear in the peak value of the spectrum until 40 mm cutting.

However, in the 60 mm cutting, a big change was seen and the part which becomes a threshold among from 40 mm to 60 mm was ascertained. As for figure 10, in the frequency, when attempting to pay attention to the neighborhood of 1.6 kHz, the tendency that the extreme strong one of the spectrum is further gathered near twice, 3 times, the frequency which becomes quadruple is seen.

5. Conclusions

It is a tough job to establish the positive diagnostic technique from all parameters in the wind generator (which will be future subject) and to build a remote surveillance system. This study aimed to get a clue for failure forecast diagnosis for a small wind turbine. The results derived are summarized as follows:

1. An early failure diagnostic system for the small wind turbine with AE sensor was proposed and relation of AE signal to the failure level was investigated.
2. The AE-waveform change notably appeared when the damage to the blade exceeded 40mm.
3. Distribution of FFT spectrum changed at the domain of 20 kHz. Since the change was remarkably seen especially in the 10 kHz zone, it was considered a fiduciary point for the failure diagnosis.
4. According to the experimental data of Fig10, it thinks that it does the standard of the 1.6 kHz frequency neighborhood and the diagnosis which is on extraordinarily with the change of the twice, 3 times and the quadruple frequency.
5. It turned out that the output electric power also fluctuates while AE waveform does, and the output characteristic changes as well as damage to the blade.
6. It is expected that a positive diagnostic system can be built by using this technique - not only in small wind turbines but also in large-sized one.

This experiment was blessed with the wind speed condition and could maintain a 5 m/s wind speed almost. It is data in the field, and it considers a change part and the acquisition of the data by the severe status, too, needs revive blade. However, as the data in usual operation, it is possible to be satisfactory.

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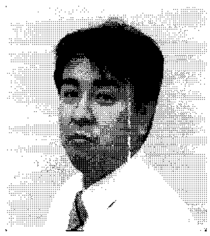
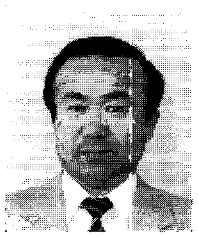
Toshio Bouno

He was born in Miyazaki, in Japan in 1955. He graduated from the Science University of Tokyo in 1982. He has been working at Sadowara high school from April, 1998 and he is a student of Graduate School of Doctor course at University of Miyazaki in 2003. His research interest is a new energy application and electric power installation.



Toshifumi Yuji

He was born in Miyazaki, Japan on June 2, 1976. He graduated from Miyakonojo College of Technology in 1997. He received his M.E. degree from the University of Miyazaki in 2003. He has been working at Nichinan Technical High School and he is a student of Graduate School of Doctor course at Tokyo Institute of Technology in 2004. His research interest is a plasma application and electric power installation.



Hideaki Toya

He was born in Okayama, Japan on October 1, 1951. He was received the B.S., M.E. and Ph.D. degrees in electrical engineering from Osaka University, Japan in 1974, 1976 and 1989, respectively. He joined the Central Research Laboratory, Mitsubishi Electric Corporation, Amagasaki, Japan in 1976 where he had been devoted in the study of the arc-discharge devices and dielectric phenomena in vacuum. Since 1998, he has working at Tsuyama National College of Technology where he is engaged in the study of the micro-wind power generator and other power devices.

Tsugio Hamada

He was born in Kagoshima, Japan in 1962. He received a B.E. degree from Nagaoka University of Technology in 1986, M.E. degree from Kagoshima University in 1988, and Ph. D. degree from Toyohashi University of Technology in 1999, respectively. He is currently belonging to Miyakonojo National College of Technology. Since 2001 he has been a professor in the department of Electrical Engineering. From 1995 to 1996. He has been engaged in the research fields concerning Energy Conversion Engineering in the micro-wind power generator and Electromagnetic Properties in Superconductors.