# Full Scale Measurement of Wind Intensity Using *in situ*Method

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Abstract—The emergence of wind energy as a crucial source of the world's at late 20th century makes the manipulation of the wind intensity in selected potential area becomes significant. In this research, an appropriate method, formula, and concept that shall be low-cost and simple to accomplish the in situ wind measuring operating system will be produced. This implemented system is comprised of three parts; an I/O hardware system, a host computer and the controlling software. This system enables that the wind velocity to be measured in three dimensions in order to determine the absolute velocity and direction. The measurement cycle will be once every 1 second to achieve the highest accuracy. The data obtained will be transmitted by analog to digital converter circuit (ADC) to the computer (PC). This is then followed by the mapping of wind velocity and direction at different selected area in Kota Kinabalu, Sabah. This enables the calculation of a typical profile of mean wind intensity for different territory and to obtain some information about the statistical and dynamic properties of the wind.

Index Terms—In situ, mapping, wind intensity.

# I. INTRODUCTION

Wind energy is a green power technology because of its minor impact on the environment. The use of wind as a source of the most widely utilized form of energy began in the 19<sup>th</sup> century [1]. Wind turbines contributed greatly to the economic development of countries such as Netherlands, Denmark and the USA in that century. At the early of the 19<sup>th</sup>century, about 10,000 turbines with rotor blades measuring up to 28m were in operation in Netherlands. As for Denmark, wind energy prevailed until the latter half of the 19<sup>th</sup> century. At that time, Danish industry relied on wind power for one quarter of its energy demand. However, the exploitation of coal, oil and gas resource was then causing that the use of wind started to decline everywhere to a negligible level. This made that the old wind turbines were no longer economically competitive with the conventional sources of energy which are non-renewable [2].

In the mid 1970s, the development of wind turbines to generate electricity was resumed as response to the energy crisis during 1973. In spite of that, the wind technology improved considerably and in turn decreased the cost of electricity produced by wind turbines. The development of megawatt rated wind turbines was initiated by governmental R&D organizations to provide renewable energy technology which could accommodate public utilities. The MOD-2 was a multi-megawatt prototype developed which achieved its

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operational status [3]. Five units of this type were built and tested from 1979-1982.

The German project, GROWIAN with a hub height of approximately 100 meters was established for technology testing into the 1980er years in the emperor William Koog with Marne. GROWIAN was earlier largest wind energy plant of the world. However, it only achieved some hundreds of operational hours. On the other hand, the turbine built in Sweden, WTS-3 and WTS-4, were able to operate for twenty thousand and ten thousand hours respectively.

Experiment in Canada had a special focus on vertical axis wind turbine. This machine developed is a Darrieus type with an installed capacity of 4MW [4]. Overall about fifteen large wind turbines with power ratings in excess of 1MW were developed in the late 70s and early 80s extending through 1987. Over a twelve years period from 1983 to 1995 commercial wind turbines underwent 10 fold increases in power rating from 55kW to 500kW. The European Commission started to support the research and evaluation of large wind turbines in the mid 80s. Commission support was provided through an R&D program known as JOULE in developing the specific action, WEGA (Wind Energie Grosse Anlagen) program. This WEGA program was extended into two phases; WEGA I and WEGA II.

The commission of the European Union published its white paper (CEU, 1997) claiming that for 12 percent of the gross energy demand of the European Union to be contributed from the renewable sources of energy by 2010. Wind energy was recognized as playing an important role in the supply of renewable energy with an increase in installed wind capacity from 2.5 GW in 1995 to 40GW by 2010 [2]. From 1995 to 2000, the average annual growth rate of the installation of wind turbine in Europe was approximately 40 percent. In USA, there was nearly 2.5 GW of installed capacity of wind turbines of which 65 percent is in California. Germany, Spain, United States of America (USA), India and Denmark were the top five wind electric power generating countries at the end of 2006 [5]. In India, the strong thrust given by Ministry of Non-Conventional Energy Sources (MNES), Government of India also make that the wind energy in their country is well utilized.

The turbine being installed in Emden, Germany by Enercon, E-126 is now the world's largest wind turbine. To enhance performance, the rotor diameter has been increased to127 m which is 13 m larger than the rotor diameter of the E-112. The hub's height is also increased by 11m to reach a towering of 135 m. In addition, the E-126 is featured with new ENERCON rotor blade profile with the extended trailing edge designed to boost output. Its capacity is rated at 6+ MW, but most probably will be ramped up to 7+ MW (20 million

kilowatt hours per year). This is enough to power about 5,000 households of four in Europe.

The reemergence of the wind energy as a significant source of the world's energy is one of the significant developments of the late 20th century [6]. The emerge of the global wind energy markets are being driven by a number of factors, including the wider context of energy supply and demand, the technological capacity, the rising profile of environmental issues and it is understood that wind energy is on track to saving 10 billion tons of carbon dioxide (CO<sub>2</sub>) by 2020 (Global Wind Energy Council News).

One of the largest problems of wind power is its dependence on the volatility of the wind which is directly related to the meteorological conditions [7]. The amount of potential wind energy depends mainly on wind speed, but is also affected slightly by the density of the air, which is determined by the air temperature, barometric pressure, and altitude. Therefore, the wind power output cannot be guaranteed at any particular time. Knowledge of the expected wind power several days in advance would be a solution allowing avoiding problems of power system operation caused by fluctuating wind power.

#### II. SYSTEM DESIGN FEATURES

#### A. Overview

The wind velocity is measured with propeller anemometer using in situ method in order to determine absolute velocity and direction. This research work can be generally divided into three parts: anemometer design, I/O hardware (driver circuit) development and software interfacing.

## B. Designing of Anemometer

Propeller anemometers use the wind blowing into a propeller to turn a shaft that drives an AC generator to produce a pulse signal. This AC generator has a voltage of operating range between 1.5~6.0V and nominal 3V at constant. The Table I shows the operation spec while Table II shows the details of the characteristics of this generator.

TABLE I: OPERATION SPEC OF RF-300FA-12350.

Voltage		No Load		
Operating	Nominal	Speed	Current	
Range		r-min <sup>-1</sup>	A	
1.5~6.0	3V Constant	3500	0.022	

TABLE II: CHARACTERISTICS OF RF-300FA-12350.

Maximum Efficiency					Stall		
Speed	Current	Torque		Output	Torque		Current
r/min	A	mN- m	g-c m	W	mN-m	g-c m	A
2830	0.093	0.48	4.9	0.14	2.51	26	0.39

This anemometer system utilizing a low moment of inertial bearing as to ensure a faster response and behave linearly corresponds to the changing in wind speed. This is crucial to increase the accuracy of measuring system. When mounted on a fixed vertical arm, the propeller anemometer is especially suited for measuring the vertical wind component and vice versa.

# C. Development of I/O Hardware

The developed ADC circuit consists of a LM393 comparator as a voltage comparator to compare an input signal  $V_{in}$  with a reference voltage  $V_{ref}$ . 0.42  $\mu$ F, 0.1  $\mu$ F, 100  $\mu$ F and 0.0047  $\mu$ F capacitors are connected to ground to decrease the noise of the seldom area. The theory of the circuit can be proved by finding a voltage reference which is suitable to the ADC circuit. Table III shows that comparison voltage reference between 5.0 V and 12.0 V. From this Table III, we can see that the voltage reference 12.0 V have a large range but low resolution. While for the voltage reference 5.0 V, it has small range but high resolution. This proves that the voltage 5.0 V is more suitable to be applied as maximum voltage reference for ADC circuit is 5.0 V.

TABLE III: COMPARISON OF VOLTAGE REFERENCE BETWEEN 5 V AND 12 V.

Parameter	Voltage Reference		
	5.0 V	12.0 V	
Range of Measurement	0 V – 5 V	0 V – 12 V	
Resolution of Voltage ADC	$\frac{5V}{2^8 - 1} = 0.019V$	$\frac{12V}{2^8 - 1} = 0.047V$	
ADC component	Ideal	Unideal	

#### D. Software Interfacing Development

The software can be separated to three parts. The first part is the startup interface for the user of this system. It lets the user to choose their option: generating the wind velocity or plotting the graph from the data obtained. The second part which is created to manipulate the wind velocity will read the input bytes from the analog to digital converter (ADC) circuit and generate the output velocity at every second as long as the circuit is get connected. The third part is created to find out the comparisons between data obtained. Since the dependencies and variables are not set in this program, the user can easily switch to their dependent or independent variables.

## E. Experimental Setup

The anemometer is then connected to the I/O hardware and a computer equipped with the software interfacing. The wind data is transmitted by the analog to digital converter (ADC) circuit to the computer. This data is stored simultaneously every one to five seconds.

Before the experiment can be done, the following additional requirements are taking into account:

- Sensor performance.
- Visual inspection and dismantling of cup anemometers.
- The boom is mounted perpendicular to the prevailing wind direction, in this case perpendicular to the direction of the wind mean vector.
- There should be no sheltering obstacles close to the anemometer, especially in the upwind sector.
- The anemometer should be easily accessible for operation and maintenance.
- The anemometer should preferably be fenced in and/or guarded, to protect the instruments and accurate set-up

from any changes caused by human activity.

- Any fence in the upwind direction must interfere as little as possible with the wind flow.
- Mean hourly wind speed and direction versus time-of-day.
- The gust wind intensity.

The measured wind speed will be examined and correlate to the various altitude level as to investigate the variation in altitude element on the wind speed. A higher altitude level will have higher measured wind speed due to the absence of surrounding obstacles. This in turn will increase the accuracy of the measuring system. The portable propeller anemometers will be located at different area yet close to each other as to correlate the measurements taken at different times and altitude.

Moreover, the measuring system will collaborate with several sensors such as temperature, humidity and pressure as to investigate the influences on the wind intensity. All the collected data from different sensors will be analyzed and correlate with the measured wind intensity. In addition, this will further enhance the overall geographical data of the selected testing area as important elements to justify and verified the potential provinces to establish the wind turbine.

#### III. RESULTS AND DISCUSSIONS

The first set of the experiment is conducted at Tanjung Aru to test the accuracy of the system developed. The data was collected daily at latitude 05-56-N and longitude 116-03-E. The wind data at this selected area can be served as a guided test for accuracy as it was the only location where the wind data was monitored by Meteorological Department Sabah in the regions selected.

Anemometers are generally calibrated in wind tunnels, where the air flows are steady. Under these conditions, the system developed can produce a signal that is accurate to within 2% of the true wind speed. In gusty winds, however, anemometers speed up faster than they slow down and, as a result, indicate wind speed that are slightly high. In these conditions, the accuracy is within 12.5% of the true wind speed. Under normal use in the atmosphere, good anemometers should be accurate within 5% to 10%. The limitation of information available on wind systems in the real environment indicates that good quality; relatively expansive systems meet these accuracies. However, insufficient information is available to draw any conclusion with respect to the performance of relatively inexpensive wind systems in the real environment.

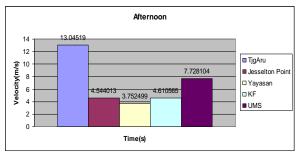


Fig. 1. The wind velocity comparison between the selected locations in the afternoon.

After the accuracy test, the wind intensity of the following selected areas are being monitored: Jesselton Point, Yayasan Sabah, Taman Kingfisher and Universiti Malaysia Sabah. Fig. 1 shows comparison of the wind velocity in the afternoon between the locations of Tanjung Aru, Jesselton Point, Yayasan Sabah, Taman kingfisher and Universiti Malaysia Sabah. The data for afternoon section is taken from 12:00 until 14:00. The graph shows that the Tanjung Aru had the highest wind velocity, which is 13.04519 ms<sup>-1</sup>.

Fig. 2 shows the wind velocity comparison between the selected locations in the evening. The data for evening section is taken from 17:00 until 18:00. Readings taken showed that Tanjung Aru remained as the highest wind velocity region between the selected areas; that is 9.753514 ms<sup>-1</sup> while Taman Kingfisher had the lowest wind velocity at evening.

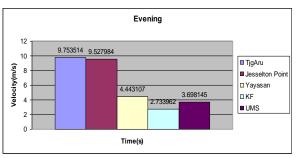


Fig. 2. The wind velocity comparison between the selected locations in the evening.

The wind velocity is strongly related to the latitude of the selected location. The rate of increase of wind speed is given by

$$\frac{V}{V_o} = \left(\frac{Z}{Z_o}\right)^{1/7} \tag{1}$$

where V is the predicted wind speed at height Z and Vo is the wind speed at height  $Z_o$ . So, we can say that the wind speed increases with height because of friction at the earth surface.

#### IV. CONCLUSION

The wind measuring system with the data acquisition system connected to the computer unit will eventually play a major role in analyzing and determining the geographical aspect of the particular test locations. The data acquisition system guided by data retriever software will ensure reliable data collection. The Weibull distribution is then used for modeling the probability distribution of wind velocity measured in a certain time and places [8]. Estimation procedure will also be carried out using the wind velocity data obtained from the observation. This is to ascertain the potential area for the manipulation of wind energy. This is very crucial in determining the needs of installing a wind turbine to generate the electricity based on the statistical data collected.

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