การศึกษาความเป็นไปได้ในการผลิตไฟฟ้าจากความเร็วลมต่ำในประเทศไทย

Study of the Electricity Generating from Low Wind Speed in Thailand

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บทคัดย่อ

งานวิจัยนี้ศึกษาความเป็นไปได้ในการผลิตไฟฟ้าจากความเร็วลมต่ำในประเทศไทย จากกังหันลมแบบหลายใบสำหรับเครื่องอัดอากาศด้วย CFD การใช้โปรแกรมในการทำนายผลลัพธ์ ใช้เวลาลดลง ประหยัดงบประมาณเพื่อสร้างโครงสร้างที่มีค่าใช้จ่ายสูง แบบจำลองนี้แสดงการไหลของอากาศในการไหลแบบปั่นป่วน ความเร็วลมที่มีผลต่อการยกใบพัดกังหัน วิธีการได้กำหนดค่าที่ใช้ในโมเดลแบบเซลล์ Tetrahedra ใน CFD ความเร็วลมต่ำสุดคือ 1 เมตร / วินาทีและความเร็วลมสูงสุดคือ 5 เมตร / วินาทีและมีแรงบิด 2.54076 N.m และ 64.0231 N.m ตามลำดับ มีโหนดในการคำนวณ 3915694 โหนด ผลลัพธ์ของแบบจำลองมีความสอดคล้องไปในทิศทางเดียวกันกับทฤษฎี สามารถนำผลลัพธ์จากแบบจำลองไปคำนวณเพื่อสร้างกังหันลมหลายสายสำหรับระบบอัดอากาศสำหรับการผลิตกระแสไฟฟ้า

คำสำคัญ: กังหันลมแบบหลายใบ การอัดอากาศ ความเร็วลมต่ำ CFD

Abstract

This research studied the ability to produce electricity from low wind speed in Thailand from multiblades wind turbines for compressed air with CFD program to predict the results by spending less time, saving budget to create a high cost structures. The model shows the flow of air in a turbulent flow, wind speed that affects the lifting of the turbine blade. The configuration method used in the model is Tetrahedra Cells in CFD. The minimum wind speed is varied 1m / s and the maximum wind speed is 5m / s and the torque is 2.54076 N.m and 64.0231 N.m, respectively, there were 3915694 Nodes. The consistency in the same direction can bring results from the model to the calculation to create multiblades wind turbines for compressed air energy storage systems for electrical generation.

Keywords: Multi-blade wind turbines, Compressed air, Low wind speed CFD

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INTRODUCTION

Wind power is an alternative energy generally found in nature, clean, unpolluted, and unharmed to human beings commonly applied into two types: water pump system and electrical generation system. Especially the electricity generation system generated by the wind power in Thailand may be limited in terms of low speed of wind and improper technology application leading to technology imported in a high price and incapability of maximum efficiency due to the fact that the producers only designed their wind power systems based on their regional wind description which is different from Thailand.

The paper is present the design multiblade wind turbines for compressed air energy storage systems for electrical generation, the new electrical generation system based on the compressed air energy storage system, can be applied by using domestic instrument. According to its principle, when the turbine with core connected to the piston evolves, the compressed air is stored in the energy storage tank until the air is full, the valve tank is opened with appropriate pressure, then the air is sent to drive the piston with shaft connected to the electrical generator producing the alternating current feeding the distributing system of Electricity Authority.

The analysis of both experimental and program CFD simulation software that is very reliable (Valde & Raniriharinosy, 2001) by using the basic technology of pumping technology, low efficiency. The advantages are the price is not high (Altan & Atilgan, 2008) which can produce high torque design wind turbine and a non twist blades can reduce energy loss compared with the turbine twist (Lanzafame & Messina, 2009). CFD is another tool for research today as it has been proven that it can be used for long term results. Solution to flow more efficiently and accurately enough. Lower time and expense of finding a solution by trying out the truth. Simulation the external flow (Thumthae & Chitsomboon, 2009) The appropriate size of the grid used to calculate how much it should be. It is too grid specific, it would be wasteful. However, it is small, it may affect the accuracy of the results. This system can store the wind power in every speed which blowing capability of the turbine evolves. Fig 1. show multiblade wind turbines for compressed air energy storage systems for electrical generation suitable for low wind speed such as Thailand (Palasai, Vongmanee, Thepa & Monyakul, 2010)

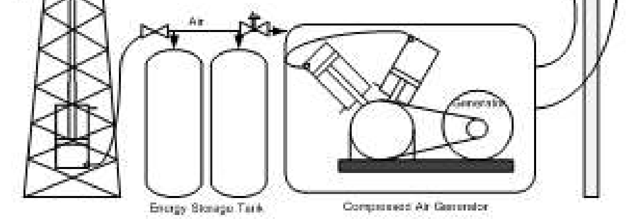

Fig 1. Show multiblade wind turbines for compressed air energy storage systems for electrical generation.

Objective

To study and determine the maximum torque from multiple wind turbines for air compressors by CFD

Research Methodology

1. THEORY

One-dimensional model (Lysen, 1983)

This one-dimensional model is simple and does not describe the true nature of the physical flow around wind turbines; however, it does bring to light several concepts that are key to understanding wind turbine operation. If the rotor is to extract any power from the wind, the wind must slow down as it passes through the rotor. An ideal wind turbine would have to slow the wind velocity at the rotor plane to two-thirds of the free stream value if it is to extract power at maximum efficiency.

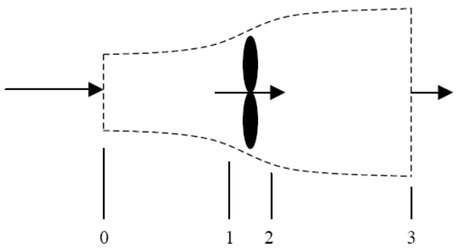

Fig 2. Control volume for actuator disc model

Fig 2. show control volume for actuator disc model. The parameters include:

$A =$	area of the rotor disc (m^2)
$A_3 =$	area of the outlet cross section of stream tube (m^2)
$V =$	wind velocity (m/s)
$V_0 =$	wind velocity at inlet of Control volume (m/s)
$V_2 =$	wind velocity far behind the rotor (m/s)
$P_0 =$	ambient atmospheric pressure (N/m^2)
$P_1 =$	upstream pressure to rotor disc (N/m^2)
$P_2 =$	downstream pressure from rotor disc (N/m^2)
$\rho_{air} =$	1.225 kg/m^3
$Q =$	torque $(N.m)$

Applying the conservation of mass to the control volume yields:

$$\rho A_0 V_0 = \rho A_1 V_1 = \rho A_2 V_2 = \rho A_3 V_3 \quad (1)$$

The thrust at the rotor disc, T, applying the conservation of linear momentum to the control volume in the axial direction.

$$T = \rho A_0 V_0^2 - \rho A_3 V_3^2 \tag{2}$$

The thrust at the rotor disc, T, is also the differential pressure between stations 1 and 2

$$T = (p_1 - p_2)A \tag{3}$$

Bernoulli's equation can be applied to obtain the pressures incorporated into

$$p_0 + \frac{1}{2}\rho V_0^{\,2} = p_1 + \frac{1}{2}\rho V^2 \tag{4}$$

and

$$p_3 + \frac{1}{2}\rho V_3^{\,2} = p_2 + \frac{1}{2}\rho V^2 \tag{5}$$

Eliminating the thrust at the rotor disc from Eq. (2) the velocity of the flow through the rotor disc is the average of the upwind (free stream) and downwind velocities:

$$V = \frac{V_0 + V_3}{2} \tag{6}$$

An axial induction (or interference) factor, a, is customarily defined as the fractional decrease in wind velocity between the free stream and the rotor plane:

$$a = \frac{V_0 - V}{V_2} \tag{7}$$

or equivalently:

$$V = V_0(1-a) \tag{8}$$

and $$V_3 = V_0(1-2a) \tag{9}$$

The velocity lost at the rotor plane, V0 – V, in Eq. (7) is known as the induced velocity. As a increases from zero, the downwind flow speed steadily decreases until, at a = ½, it has completely stopped and the simple theory is no longer applicable.

The power extracted from the wind by the rotor and the wind velocity at the rotor plane, V, from Eq. (8)

$$p = \frac{1}{2}\rho A V_0^{\,3} 4a(1-a)^2 \tag{10}$$

Power coefficient, C_p, representing the fraction of available power in the wind that is extracted by the turbine, is defined as:

$$C_p = \frac{P}{\frac{1}{2}\rho A V_0^{\,3}} \tag{11}$$

Substituting the extracted power from Eq. (10) into Eq. (11) yields:

$$C_p = 4a(1-a)^2 \tag{12}$$

The theoretical maximum power coefficient from an idealized rotor, $C_{p\max}$,can be found by setting the derivative of Eq. (12) with respect to a equal to zero, and solving for a:

$$\frac{\partial C_p}{\partial a} = 4(1-3a^2) = 0 \ldots yields.\, a = \frac{1}{3} \tag{13}$$

Substituting this result into Eq. (12) yields:

$$C_{P_{max}} = \frac{16}{27} \approx 0.59259 \tag{14}$$

The maximum possible efficiency for an idealized wind turbine is roughly 59.3%, power,torque and speed are made dimensionless with the following expressions:

Power coefficient $$C_P = \frac{P}{\frac{1}{2}\rho A V^3} \tag{15}$$

Torque coefficient $$C_Q = \frac{Q}{\frac{1}{2}\rho A V^2 R} \tag{16}$$

Tip speed ratio $\lambda = \frac{\Omega R}{V}$ with rotor area $A = \pi R^2$

Substitution of these expression:

$$C_P = C_Q \lambda \tag{17}$$

An empirical formula to estimate the starting torque coefficient of a rotor as a function of its design tip speed ratio is:

$$C_{Q_{star}} = \frac{0.5}{\lambda^2} \tag{18}$$

Experiment of Design and Creation of Multi-Blades Wind Turbine Prototype for Compressed Air

The guideline to use the wind energy at highest efficiency of this research focuses on the design of the turbine to be suitable for air compression and for areas to install the turbine. The wind turbine can produce energy if the wind speed is not too high or too low. Once the turbine is stopped, the rotor cannot produce energy. It is important to find the proper wind speed to obtain the maximum power.

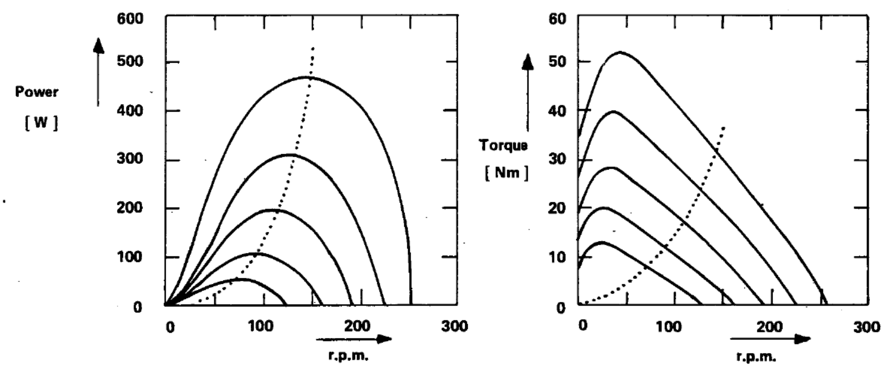

Fig. 3 Relationship between the power and torque of rotor at different wind speed (Lysen, 1983)

Power coefficient $$C_P = \frac{P}{\frac{1}{2}\rho A V^3}$$

Torque coefficient $$C_Q = \frac{Q}{\frac{1}{2}\rho A V^2 R}$$

Design and simulation of muti-blade wind turbine for air compresssion

Here is the design before calculating by Computational Fluid Dynamics, CF

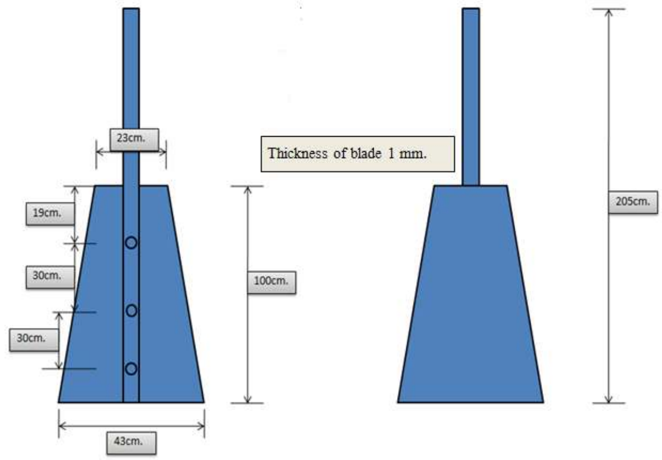

Fig 4 Shapes and dimensions of multi-blade turbine

The model was design and engineered by using the CFD including with the momentum theory verification.

Blade materials = Flat plate

Blade radius = 2.75 m

Number of blades = 30

Wind turbine = Non twist blade

Cut in wind speed = none

Cut out wind speed = none

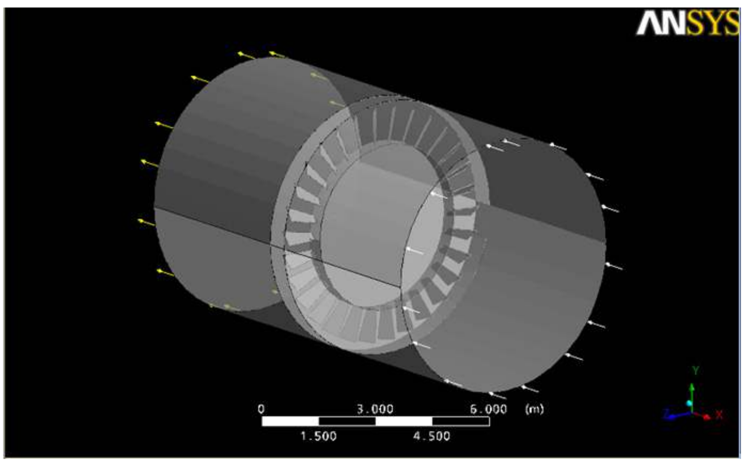

Fig 5. Model multiblade wind turbines

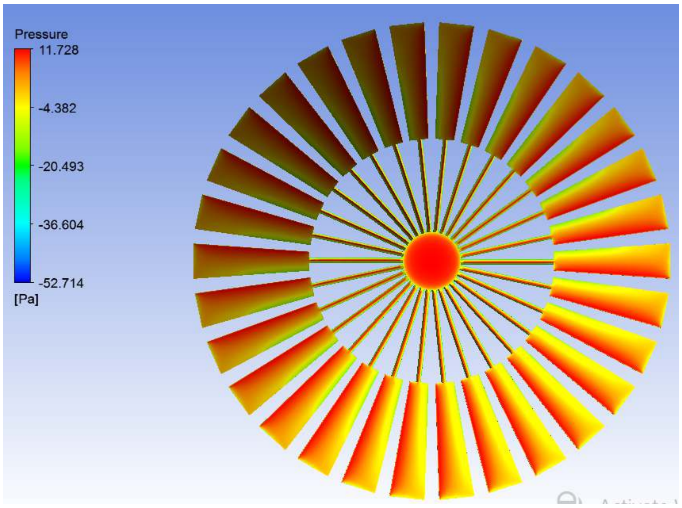

Fig 6. Pressure Contour ant Inlet velocity 4 m/s

Sketch follow the instruction Fig 4. in CFD there is a sketching format in order to tetrahedral cells. Determine the suitable formats before using the program will be identified as turbulent, after that CFD will determine the Torque wind speed at 1m/s, 2m/s, 3m/s, 4m/s and 5m/s similar to low wind speed in Thailand region.

Results and Discussion

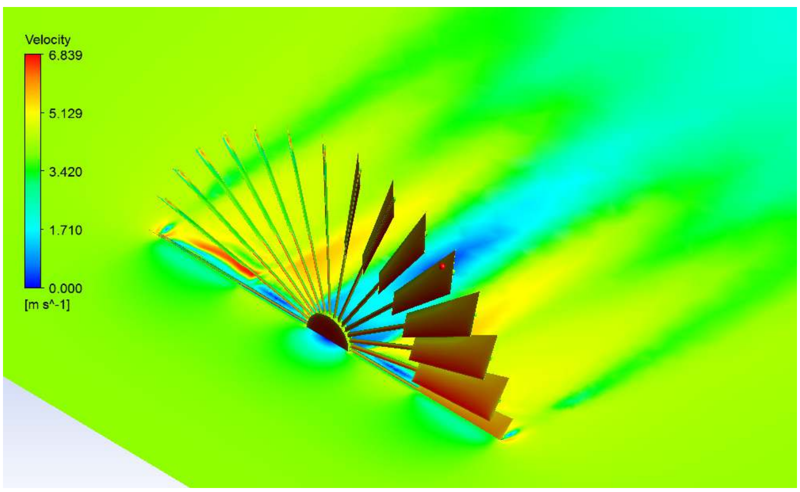

Fig 7. Velocity Contour and Inlet velocity 4 m/s

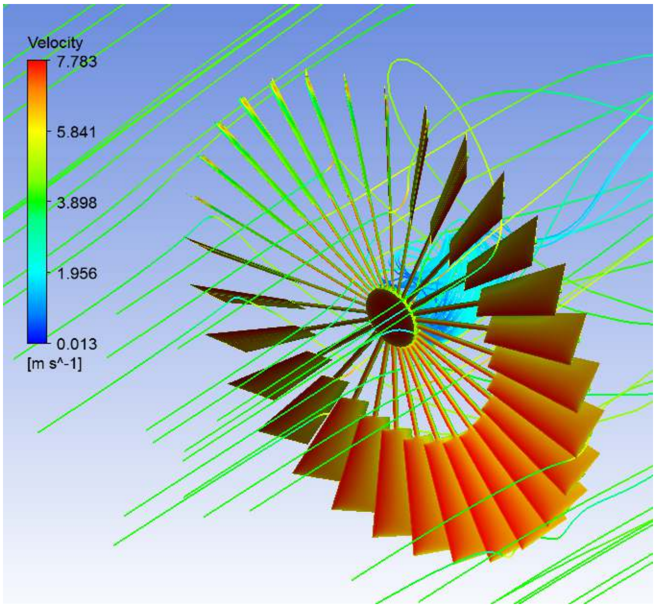

Fig 8. Velocity Stream line at 4 m/s

Table 1. Show Mesh Statistics.

Velocity Variations	Torque (N.m)	Tetrahedra Cells	Nodes
1	2.54076	22628191	3915694
2	10.2086	22628191	3915694
3	23.0118	22628191	3915694
4	41.4414	22628191	3915694
5	64.0231	22628191	3915694

wind speed at 1m/s, 2m/s, 3m/s, 4m/s and 5m/s. The result of the torque model are 2.5407 N.m, 10.2086 N.m, 23.0118 N.m, 41.4414 N.m and 64.0231 N.m, When the wind speed rises and flow through the turbine blades, the flow is turbulent. The CFD has a similar value to the real condition corresponding to the reference theory. The resulting high torque (Fig 3) in the model shows that the flow of wind behind the turbine will provide the most turbulent flow in the middle of the wind turbine (Fig 8.) and the number of Tetrahedra cells are 22,628,191with high resolution quality.

Conclusion

The results showed that when the wind speed is higher, the torque will increases, which corresponds with the theoretical theory and the air flow behavior behind the turbine will cause turbulence at the core as well due to the air passes, it causes the lifting of the leaf blade. This model has clearly showed the excludes of the power obtained from the turbine blade motion and the quality of the model. The use of Tetrahedra cells, which is suitable for the turbulent flow model is the closest to real condition. If Polyhedra cells are selected from the results of previous research, the effect of turbulent flow is not complete with the resolution of the cells and knowing the torque of multiple wind turbines can be useful in applications for compressing compressed air into a compressor if the compressor is used. This requires the torque of the piston to move up and down before compressing the air into the compressed air cylinder.

Suggestion

The torque generated from the rotation of the multiblade wind turbine is a feature that can be used with compressed air and can be used to compress compressed air to produce the electricity. This method is a way to accumulate energy before using it. Thailand has low wind speed and it is not suitable to produce the high capacity electric directly from the wind turbine. For agriculture area, the compressed air system used in aquaculture from the air out of compressed air to increase oxygen enrichment in aquaculture ponds.

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