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Examination of optimum shape of 3-stage Savonius wind turbine using CFD technology

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Purpose of Research & Background

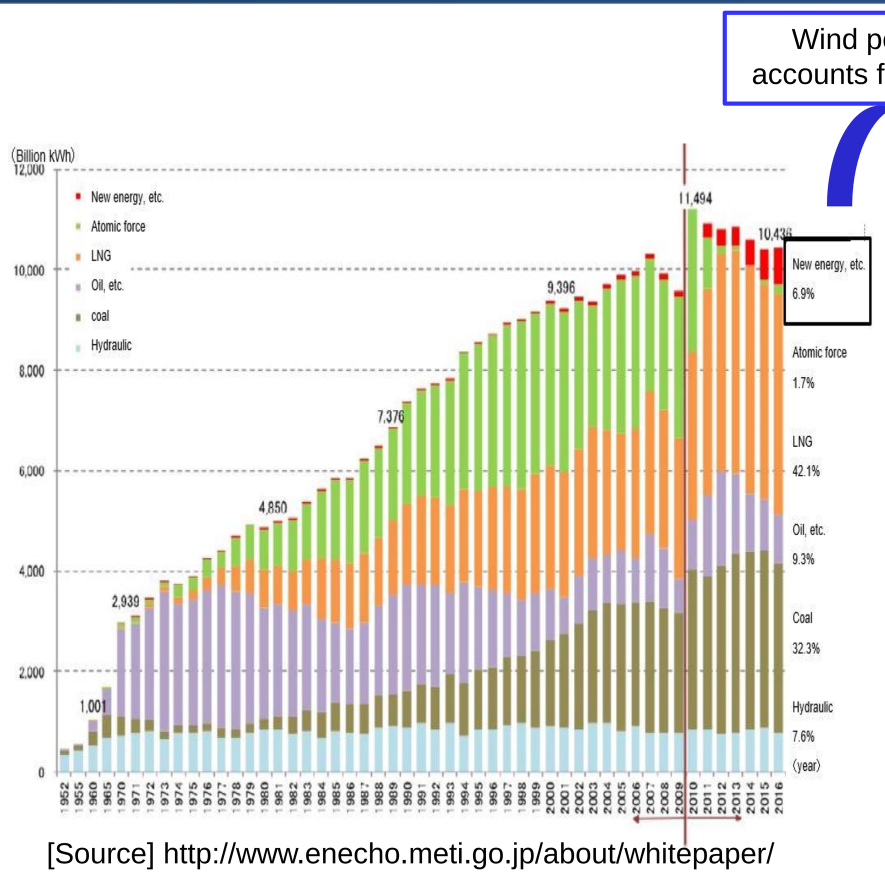
Research Background

In Japan, offshore wind power is attracting attention as a new energy source.

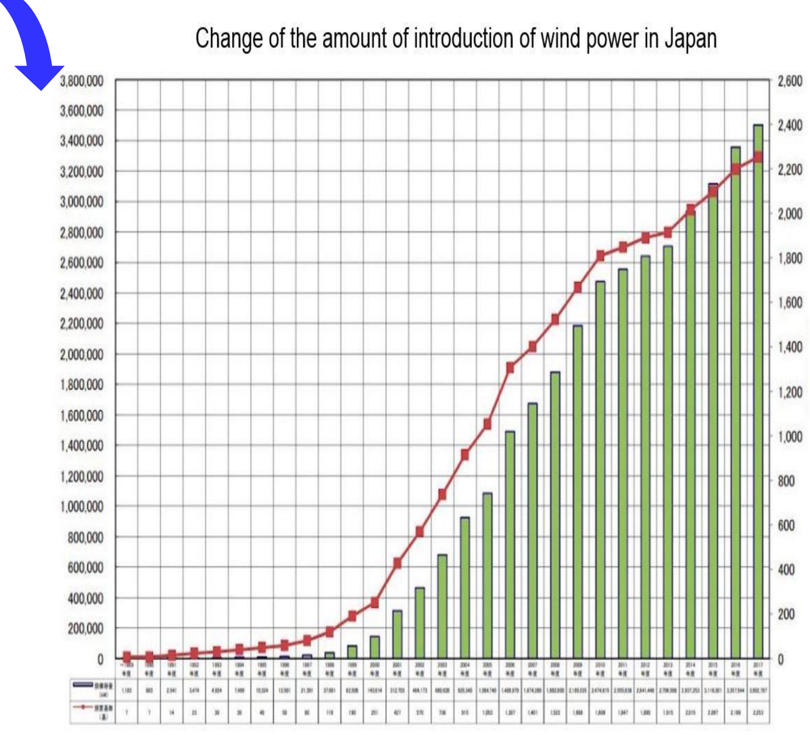
In this research, we focus on vertical axis type wind turbines with low center of gravity and high stability.

Vertical axis wind turbines have many advantages compared with the propeller-type wind turbine.

Japan's Energy Distribution



[Source] http://www.enecho.meti.go.jp/about/whitepaper/



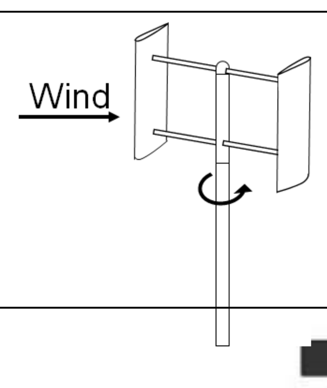
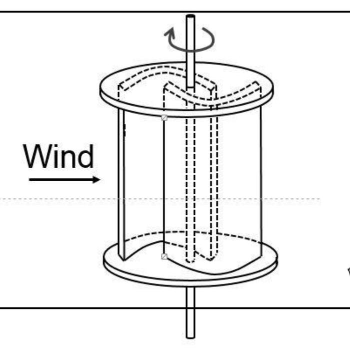
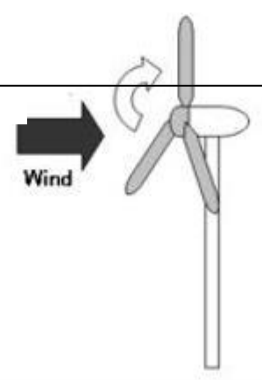
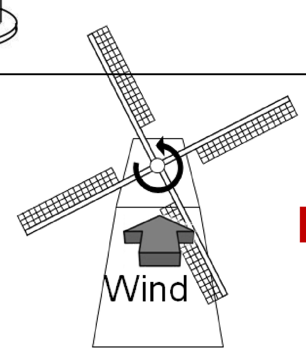
[Source] http://www.nedo.go.jp/library/fuuryoku/index.html

Offshore wind power generation is attracting attention as a new energy source in Japan.

[Source] https://www.mugendai-web.jp/archives/933

Scope of This Research

Ford Types of Wind Turbine

	Lift Type	Drag Type
Vertical Axis Type		
Horizontal Axis Type		

Lift type: Rotate quickly. →Power generation

Drag type: High torque →Ventilation, Pumping, For startup.

Vertical axis type: It can be placed on the bottom of the wind turbine such as a generator →Stable

Horizontal axis type: It is necessary to follow the change of the wind direction

Characteristics of VAWT

Advantages of Vertical Axis Type

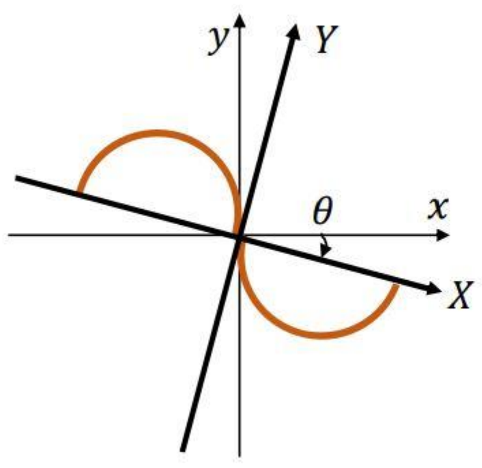
- Wind in any direction is available and there is no dependence on wind direction.
- Heavy materials can be installed on the ground.
- Manufacture of blades is easier than propeller type.
- Compared with horizontal axis wind turbine, its efficiency is low and setting area is large.

Purpose of This Work

In this research, we study the optimum shape of the wind turbine using simulation technology for fluid phenomena.

Numerical Method

Wind Turbine Calculation Formula



$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}+\frac{\partial W}{\partial Z}=0$$

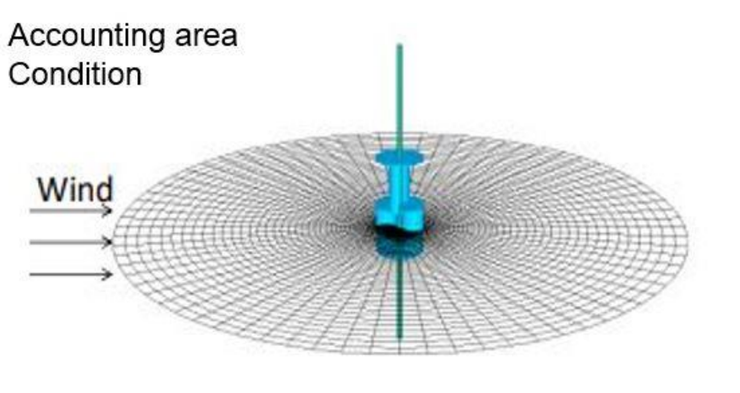
$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}+W\frac{\partial U}{\partial Z}-\omega^2X+2\omega V=-\frac{\partial p}{\partial X}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}+\frac{\partial^2 U}{\partial Z^2}\right)$$

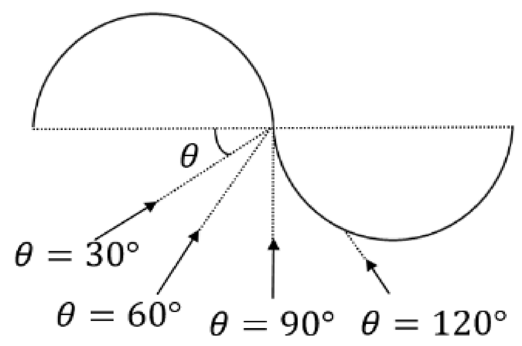
$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}+W\frac{\partial V}{\partial Z}-\omega^2Y-2\omega U=-\frac{\partial p}{\partial Y}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}+\frac{\partial^2 V}{\partial Z^2}\right)$$

$$\frac{\partial W}{\partial t}+U\frac{\partial W}{\partial X}+V\frac{\partial W}{\partial Y}+W\frac{\partial W}{\partial Z}=-\frac{\partial p}{\partial Z}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 W}{\partial X^2}+\frac{\partial^2 W}{\partial Y^2}+\frac{\partial^2 W}{\partial Z^2}\right)$$

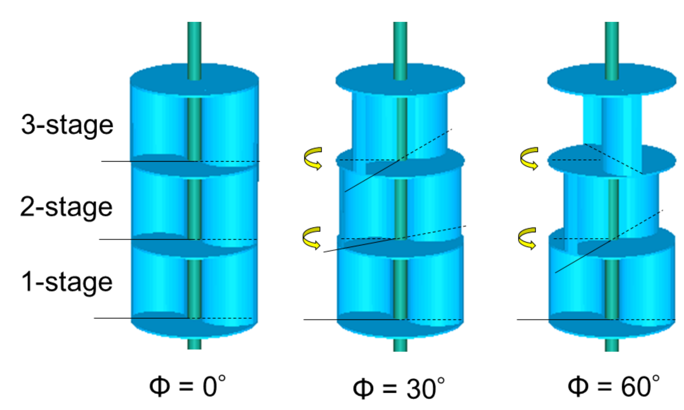
(X,Y,Z): Position component in rotational coordinate system
(U,V,W): Velocity component in rotational coordinate system
p: Pressure t: Time ω: Angular velocity of wind turbine
Re: Reynolds number based on wind turbine radius and uniform flow $(=10^5)$

Condition of Simulation



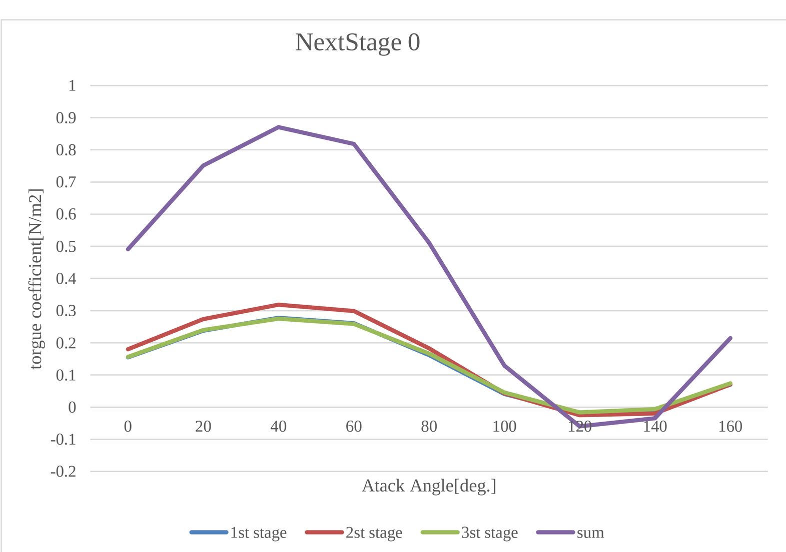


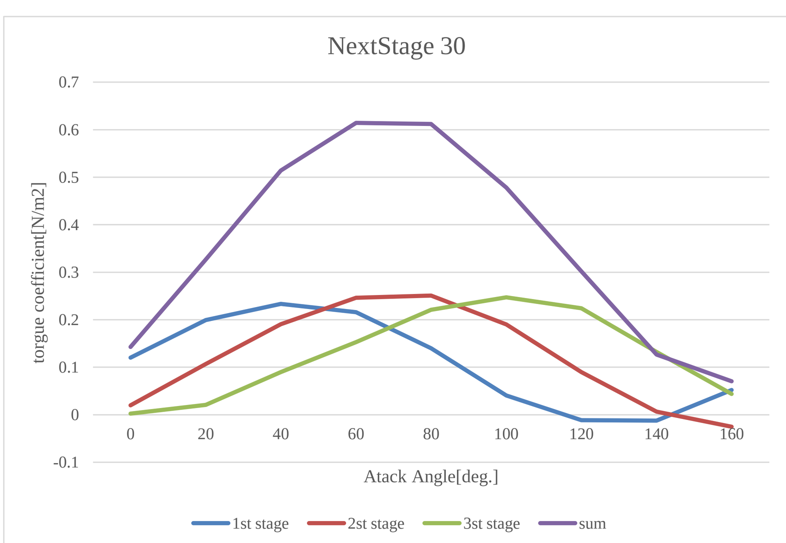
Number of grids: Circumferential direction72 × Radial direction 60 × Height direction 80

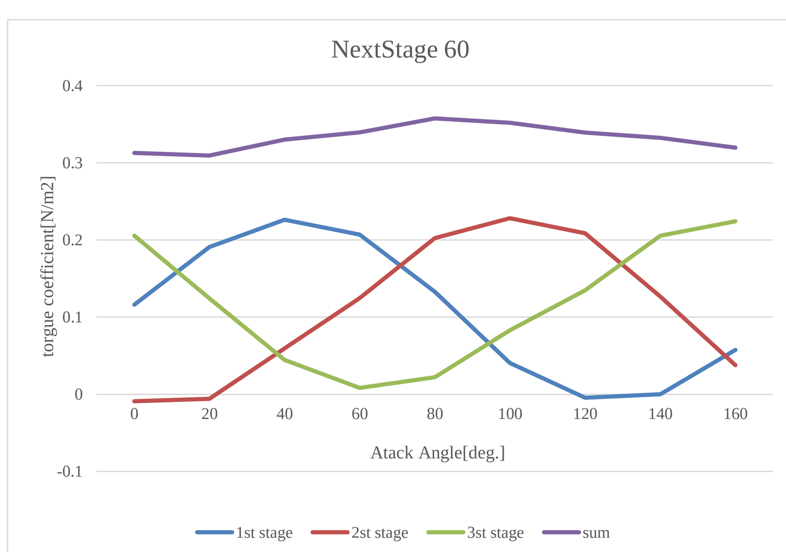


Simulation Results

Comparison of Simulation Results







Summary

- $\phi = 0$
  - the highest torque coefficient 😊
  - negative torque 😟 ==> can't start to rotate.
- $\phi = 60$
  - the total torque is low 😟
  - no negative torque ==> can rotate smoothly 😊

J.V. Akwa, H.A. Vielmo, A. Prisco "A review on the performance of Savonius wind turbines"Renewable and Sustainable Energy Reviews, 16 (5) (2012), pp. 3054-3064