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# Research of Behavior of Large Rotary Pontoon of Offshore Wind Turbine in Waves

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## ABSTRACT

New results of numerical hydrodynamic analysis of the novel offshore cross-flow vertical axis wind turbine with large floating rotor (WEMU design) are presented. The research goals are to investigate a spatial movement of rotary pontoon in incoming regular and irregular waves as well as their influence upon the water ring. Waves are launched by two components of flow velocity and free surface elevation at inlet boundary. Irregular wave is presented according to Pierson – Moskowitz spectrum by sum of first order waves with random phases. Wave loads acting on the pontoon are predicted and hydrodynamic power loss due to waves is calculated.

KEY WORDS: offshore wind power; CFD; floating turbine, water ring, regular and irregular waves, dynamic mesh, power loss

## NOMENCLATURE

$a_i$: amplitude of $i$-th wave component
$d$: water depth
$d_i$: depth of immersion of pontoon
$d_s$: diameter of the pontoon's cross-section
$D_P$: pontoon's diameter
$D_\zeta$: dispersion of water surface elevation
$F$: total hydrodynamic force acting on turbine
$(F_{c1}, F_{c2}, F_{c3})$: reactive force applied to rotor by cables
$F_i$: hydrodynamic force acting on module $i$
$H$: blade span
$h_{3\%}$: wave height with 3% probability
$(M_{c1}, M_{c2}, M_{c3})$: reactive moment applied to rotor by cables
$k_w$: wave number
$L$: wave length
$M_h$: total torque of hydrodynamic resistance
$M_{hi}$: hydrodynamic resistance torque of module $i$ ($i$ =1…n)
$M_w$: total aerodynamic torque of the turbine
$n$: number of pontoon's modules
$n_C$: number of columns
$p$: pressure
$R$: radius of the blade circle
$s_\zeta$: normalized spectral density of waves
$T$: flow time
$T_w$: wave period
$(u_1, u_2, u_3)$: mean absolute velocity
$(u'_1, u'_2, u'_3)$: fluctuating component of absolute velocity
$(U_1, U_2, U_3)$: mean relative velocity
$(U'_1, U'_2, U'_3)$: fluctuating component of the relative velocity
$u_{10}$: mean wind velocity at 10 m height
$x_{wi}$: normalized wave circular frequency = $\omega_i / \omega_m$
$(x_1, x_2, x_3)$: position in stationary coordinate system
$(X_1, X_2, X_3)$: position in coordinate system fixed to rotor
$(x_{cg1}, x_{cg2}, x_{cg3})$: position of rotor's center of gravitation
$y^+$: nondimensional wall unit
$\delta_{ij}$: Kronecker delta
$\theta$: azimuth angle ($\theta = 0$ corresponds to $+x_1$ - direction)
$(\theta_1, \theta_2, \theta_3)$: rotor's pitch, roll, and yaw angles
$\eta_h$: relative hydrodynamic power loss = $M_h / M_w$
$\lambda$: nondimensional blade speed = $\omega_{rot} R / u_{10}$
$\mu$: viscosity
$\mu_t$: turbulent viscosity
$\rho$: fluid density
$\omega_i$: circular frequency of $i$-th wave component
$\omega_m$: wave circular frequency at maximum of spectrum
$\omega_{rot}$: rotor angular velocity
$\zeta$: water surface elevation

## INTRODUCTION

Offshore wind power engineering is among leaders in the renewable energy sector already for years. And potentially, after solving essential technological and economical problems, its leadership can become absolute. Offshore wind power plants have obvious advantages against located onshore. First, their ecological restrictions are softer; blade speed can be higher, and therefore, an increased efficiency is reachable offshore. Moreover, visual impact of distant offshore wind farms is diminished and territory cost is practically excluded. At the same time, modern offshore turbines inherited their design (propeller installed on tall tower) from onshore and differ only by support structures. So, well-known drawbacks of propellers could not be excluded. We must indicate here the limited unit power capacity, infrasound emission, and harmful effects on birds and animals. Wind energy cost is still higher than that from conventional power plants. In spite of some new projects of huge offshore horizontal-axis wind turbines, evidently their power capacity has already come close to a limit. Technological problems quickly grow in large-scale turbines so some research (e.g., Klinger F. et al, 2002) has revealed that an efficient 10MW turbine could not be developed in the one-propeller concept. In this case, wind energy cost will remain relatively high. A technological breakthrough in offshore wind power engineering is still absolutely necessary.