Floating vertical axis wind turbines (VAWTs) are promising solutions for exploiting the wind energy resource in deep waters due to their potential cost-of-energy reduction. The number of blades is one of the main concerns when designing a VAWT for offshore application. In this paper, the effect of blade number on the performance of VAWTs and dynamic behavior of floating VAWTs was comprehensively studied in a fully coupled aero-hydro-servo-elastic way. Three VAWTs with straight and parallel blades, with identical solidity and with a blade number varying from two to four, were designed using the actuator cylinder method and adapted to a semi-submersible platform. A generator torque controller was also designed based on a PI control algorithm. Time domain simulations demonstrated that the aerodynamic loads and structural responses are strongly dependent on the number of blades. In particular, by increasing the number of blades from two to three reduces the variation in the tower base bending moment more significantly than increasing it from three to four. However, the blade number does not significantly affect the generator power production due to the control strategy employed, and the platform motions and tension in mooring lines because of the compliant catenary mooring system.