A vortex system consisting of a bound vortex disk, a root vortex and a vortex cylinder is presented and applied for skewed wake situations. Both the longitudinal and tangential components of vorticity of the cylinder are considered. A subset of this system leads to a model, which is commonly used in Blade Element Moment method codes for yawed conditions. Here, all the components of the full vortex system are analyzed in view of extending Blade Element Momentum models. The main assumptions of the current study are a constant uniform circulation, an infinite number of blades, an unexpanding wake shape and a finite tip-speed ratio. The investigation remains within the context of inviscid potential flow theory. The model is derived for horizontal-axis rotors in general, but results are presented for wind-turbine applications. For each vortex element, the velocity components in all directions are computed analytically or semi-analytically for the entire domain. Simplified engineering models are provided to ease the evaluation of velocities in the rotor plane. The predominant velocity components are assessed. Copyright © 2015 John Wiley & Sons, Ltd.