Numerical Simulation of a Wind Turbine with Hydraulic Transmission System

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Abstract

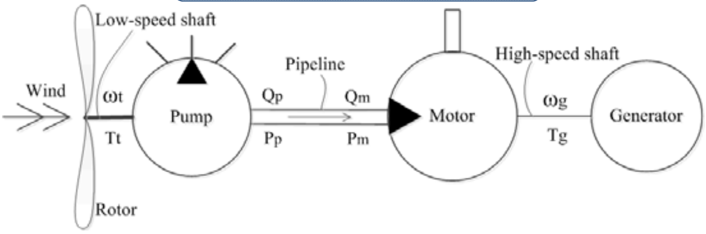
We investigate numerical modeling and analysis of wind turbines with high-pressure hydraulic transmission machinery. A dynamic model of the hydraulic system is developed and coupled with the aeroelastic code HAWC2 through external Dynamic Link Library. The hydraulic transmission system consists of a hydraulic pump, transportation pipelines, a hydraulic motor, and check valves. By use of the Runge-Kutta-Fehlberg method with step size and error control, we solved the Ordinary Differential Equations of the hydraulic system with a time step smaller than the one used in the HAWC2 main program. Under constant and turbulent wind conditions, the performances of a land-based turbine during normal operation are presented.

Objectives

During the study, the research objectives are the following:

- To model the hydraulic transmission system by Ordinary Differential Equations
- To propose an approach for numerical simulation of hydraulic turbines

Mathematical Modeling



Main shaft $$T_t = J_p\dot{\omega}_t + D_p(P_p - P_{low})$$

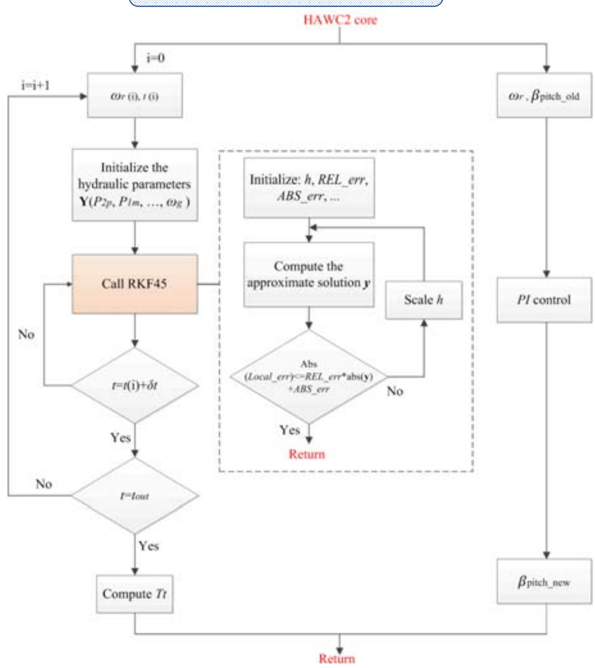
Pump $$\dot{P}_p = \frac{\beta}{V_p}[\omega_t D_p - Q_{ip}(P_p - P_{low}) - Q_{ep}P_p - Q_p]$$

Motor $$\dot{P}_m = \frac{\beta}{V_m}[Q_m - Q_{im}(P_m - P_{low}) - Q_{em}P_m - D_m\omega_g]$$

Transmission line $$\begin{bmatrix}\dot{Q}_{p0}\\ \dot{Q}_{m0}\end{bmatrix} = \omega_c\left[A_0\begin{bmatrix}Q_{p0}\\ Q_{m0}\end{bmatrix} + B_0\begin{bmatrix}P_p\\ P_m\end{bmatrix}\right] \quad \begin{bmatrix}\dot{Q}_{p1}\\ \dot{Q}_{m1}\end{bmatrix} = \omega_c\left[A_1\begin{bmatrix}Q_{p1}\\ Q_{m1}\end{bmatrix} + B_1\begin{bmatrix}P_p\\ P_m\end{bmatrix}\right]$$

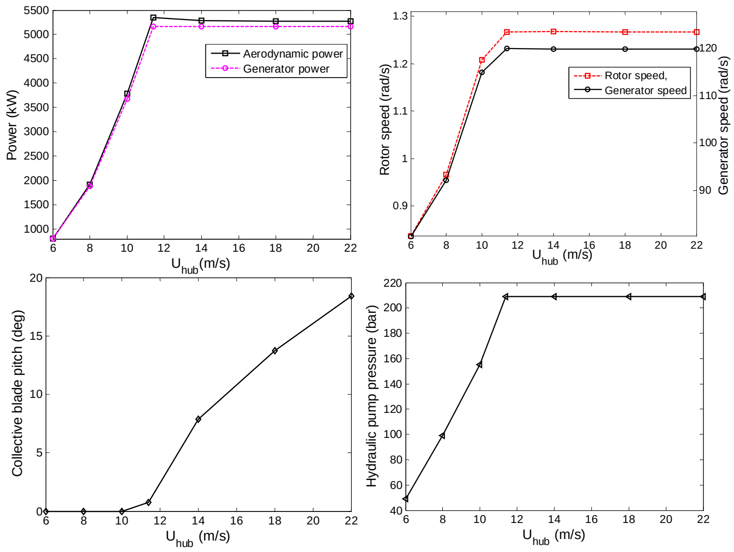
Generator $$\dot{\omega}_g = \frac{1}{J_m + J_g}[D_m P_m - C_m\omega_g - T_g]$$

Numerical Approach

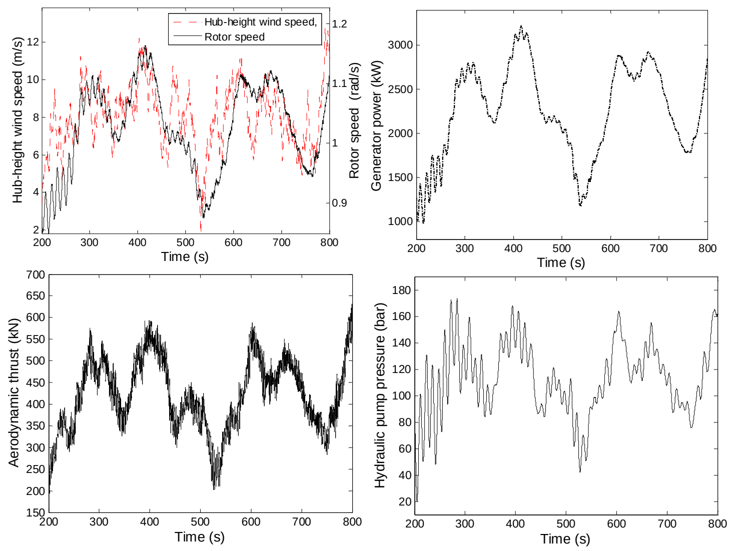


Results

Constant wind, Turbulence Intensity=0



Uhub=8 m/s, Turbulent wind, Turbulence Intensity=0.23



Conclusions

- ➢ The presented numerical approach is robust and efficient
- ➢ The hydraulic wind turbine has decent performance under constant and turbulent wind conditions

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References

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2. Skaare , B., Hornsten, B., Nielsens, F.G. (2012). *Modeling*, simulation and control of a wind turbine with a hydraulic transmission system, *Wind Energy*, 1-19.

Refer to the paper for more.