# Wind Turbine Simulation Model for the Study of Combined Mechanical and Electrical Faults

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## 1. Introduction:

Many researchers have developed dynamic models for wind turbine drivetrains with some level of accuracy [1]–[2]. However, it is a formidable challenge to understand the dynamic behaviour of a wind turbine and the root cause of any disturbances, owing to the integration of both mechanical and electrical components in an environment subject to significant stochastic environment forcing. Part of the problem is probably due to mechanical engineers are only focusing on mechanical properties without considering the transient stability of the power system such as faults, voltage and frequency dips and unbalanced voltages. Similarly, it is difficult for electrical engineers to consider mechanical events such as (damaging torque variations from the drivetrain, relationships between angular velocity and torque, the impact of the gear ratios, gear stages, etc.). These often separate electrical and mechanical approaches may lead to inaccurate and unrealistic models. Thus, there is a need for robust and reliable model to study the performance of the wind turbine in terms of truly integrated electrical and mechanical responses.

## 2. Approach:

In this work, a new model is built using Simscape in the MATLAB/Simulink environment. Table 1 summarizes the important parameters used of this model.

Table 1: Model Parameters

| Generator | |
|---|---|
| Line-Line Voltage (RMS) | 400v |
| Frequency | 50Hz |
| Stator phase resistance (ohm) | 0.0018 |
| Armature inductance (H) | 0.000835 |
| Inertia J(kg.m^2) | 0.00062 |
| Viscous damping F(N.m.s) | 0.0003035 |
| Pole pairs | 5 |
| **Gearbox** | |
| Gear Ratio | 1: 70 |
| Input speed (RPM) | 21.4 |
| Output speed (RPM) | 1500 |

## 3. Main body:

The performance of the model has been investigated under variable speed conditions in order to understand the impact on the performance of the wind turbine components. Initially, the wind speed is set at 10 m/s, then it is varied between 10 m/s and 11.55 m/s from time t=1s to t=4s as shown in Figure 1.

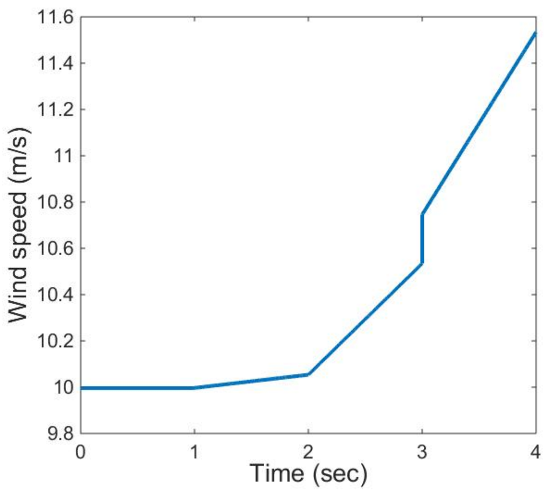


Figure1. Wind Speed Input to the Model

The wind turbine rotor drives the generator through the gearbox that steps up the drive train rotational speed from about 20 rpm at the low-speed shaft to 1500 rpm at the high-speed shaft. The start-up of the simulation where the rotational speed of the low and high-speed shafts increase rapidly from standstill to 21rpm and 1500rpm, respectively at t = 0.5 sec, is shown in Figure 2.

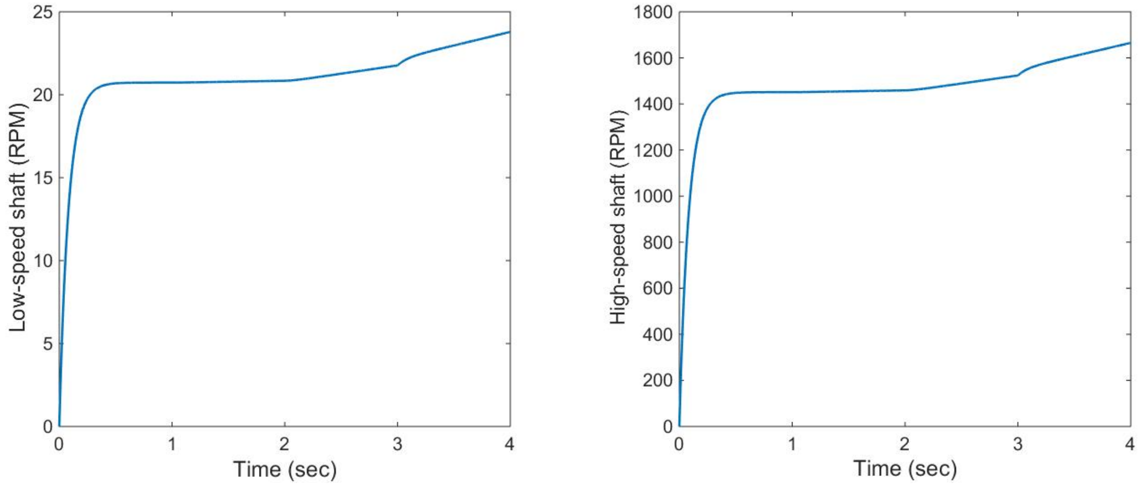


Figure 2: Low and high speed shaft rotational speeds during simulation start-up

In addition, the stator current of the generator and the typical starting torque are shown in Figure 3 and 4 respectively. It is important to note that the oscillations in the stator current which are caused by the torque pulsations arise from the wind variation. Detailed physical and experimental modelling will be discussed in the full paper.

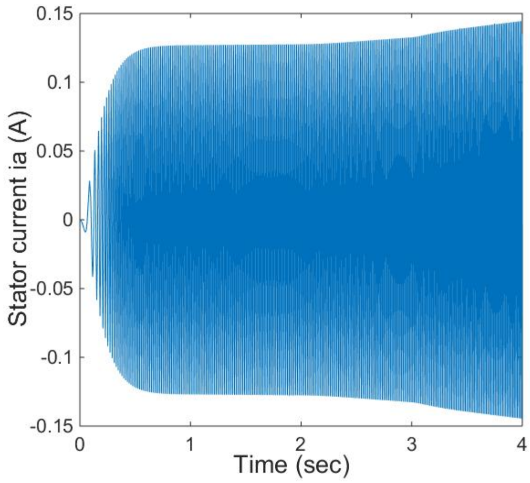


Figure 3: Stator current variation

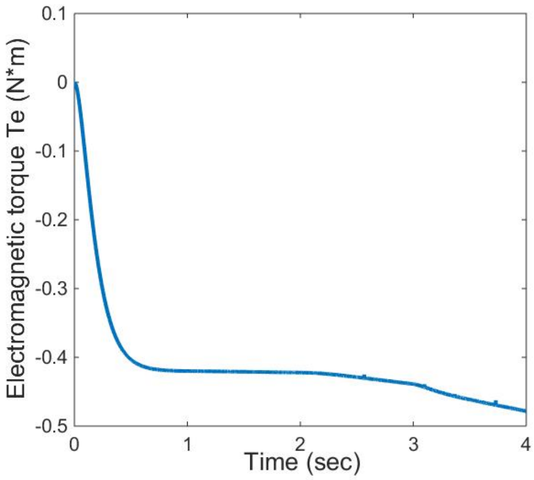


Figure 4: Electromagnetic torque

Another case study, is investigated in this model, is a grid fault. The fault event is a single- line to ground fault on one of the transmission lines. It begins at t= 2 sec and after 20 msec the fault is cleared. In order to further quantify the numerical accuracy of this case study, the fault has been repeated at t= 3 sec and after 20 msec the fault is cleared. The simulation results are illustrated in Figure 5 and 6 respectively, the voltage at the generator drops and the current increases during the fault period, which leads to block the generator and reduce the electromagnetic torque. This reduction causes rotor acceleration. After the fault clearance, all the parameters recover to the original values. In this case study, the impact of electrical fault on the generator and mechanical properties is clearly examined.

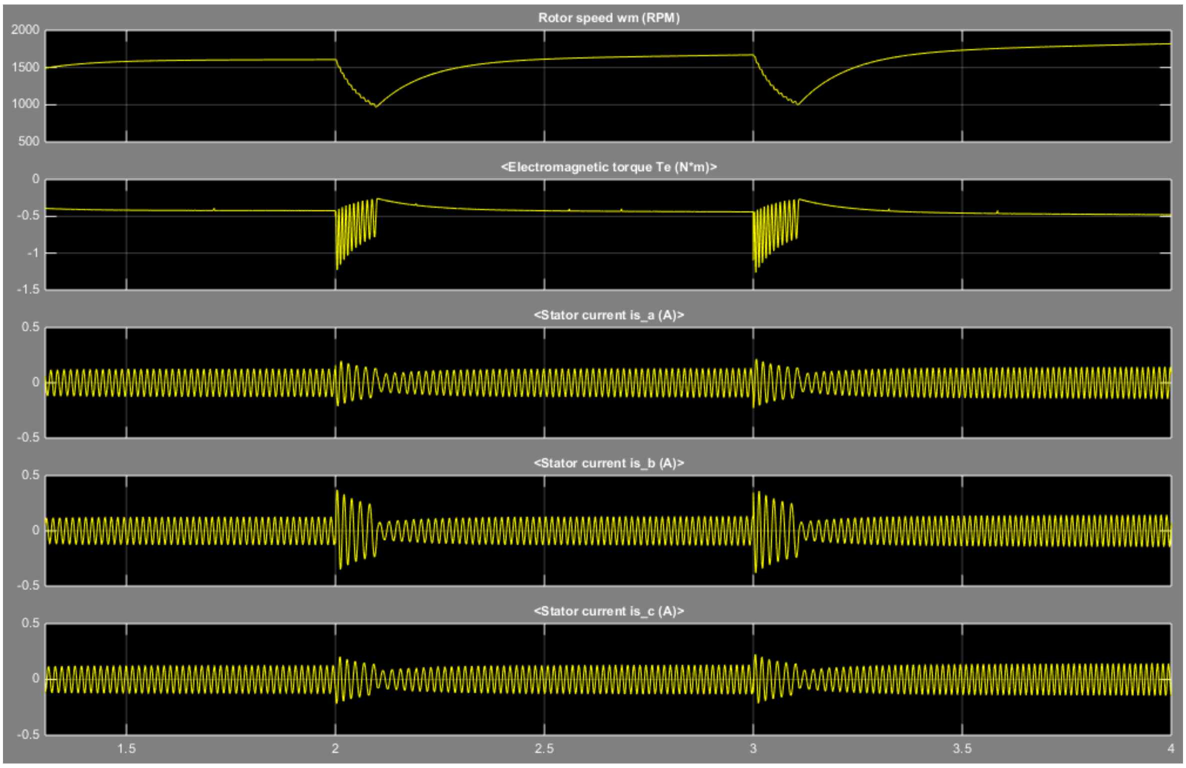


Figure 5: Wind turbine parameters during the fault

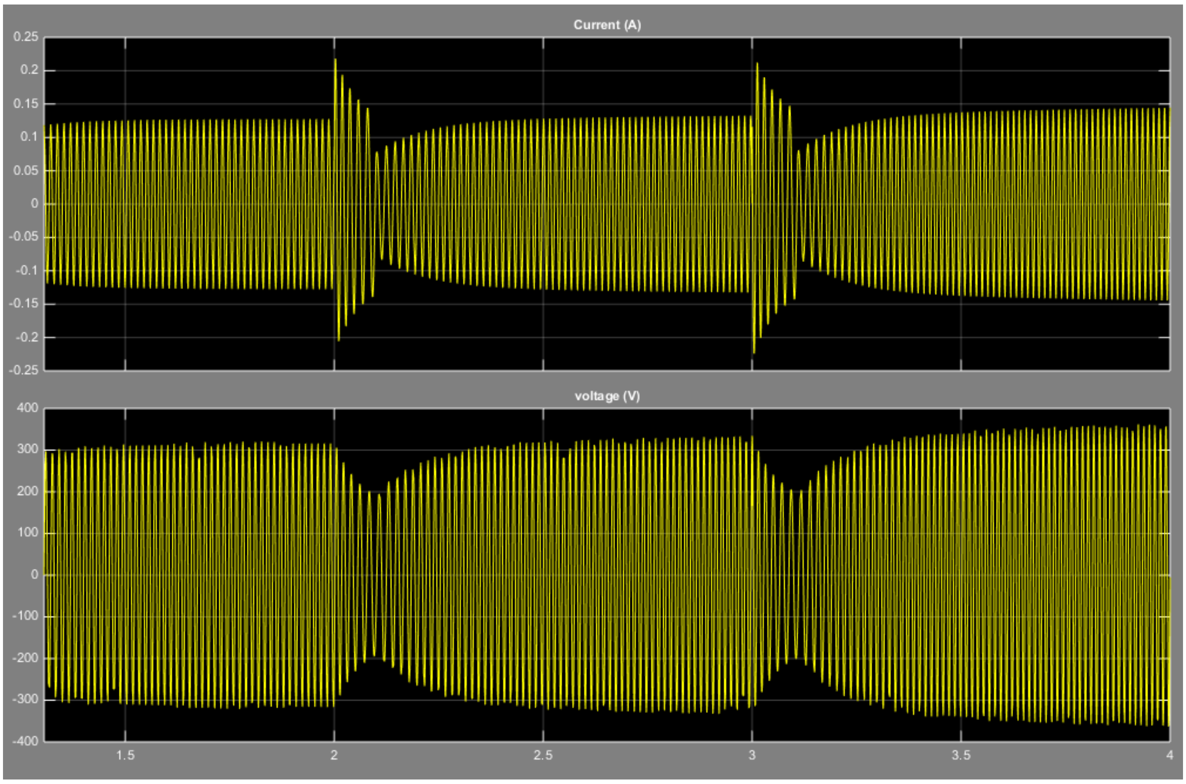


Figure 6: Voltage and current generator during the fault

**4. Conclusion:**

In this work, a wind turbine model is built using Simscape in the MATLAB/Simulink environment. This model can be used in a variety of ways. For example, it can be simulated under various operating conditions to yield valuable information for condition monitoring and effective algorithm development for fault detection. Moreover, it is useful for understanding transient loads and their couplings across the drivetrain components. Furthermore, the model can be used to understand the consequences of a particular decision support structure for designing and optimizing the various components of the drivetrain. Several case studies will be presented in the full paper as examples of what can be performed using this model to study potential drive train faults.

**5. Learning objectives:**

The model described enables studies involving the integration of both electrical and mechanical properties of a wind turbine drive train. For example, from a mechanical perspective the model allows the study of the impact of variable loading conditions and the potential to preserve the life of the gearbox or mitigate against the impact of transient events occurring on the generator (e.g. faults, voltage and frequency dips, unbalanced voltages, etc.). Similarly, from an electrical viewpoint, the model allows the study of the impact of high-ramping wind speed events on the power system, as well as the impact of turbulence on the voltage and frequency. Furthermore, the model can be used to develop a decision support structure for designing and optimizing the various components of the drivetrain.

## References


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2. Ochs, David S., Ruth Douglas Miller, and Warren N. White. "Simulation of electromechanical interactions of permanent-magnet direct-drive wind turbines using the fast aeroelastic simulator." *Sustainable Energy, IEEE Transactions on* 5.1 (2014): 2-9.