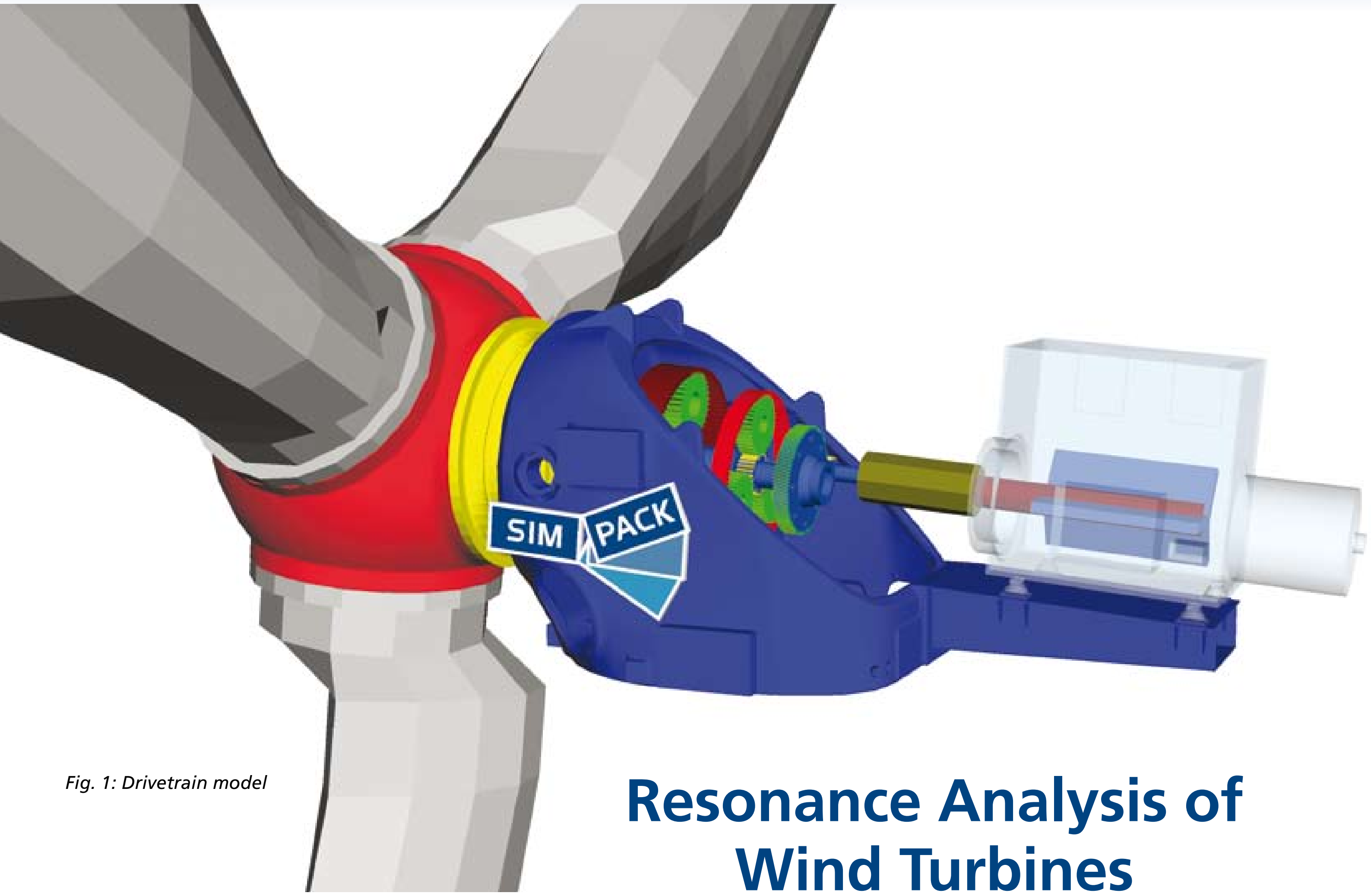

Fig. 1: Drivetrain model

Resonance Analysis of Wind Turbines

DEC
东方电气
DONGFANG ELECTRIC

The intensified efforts to provide alternative and renewable energy led to the quick growth of the wind turbine industry over the past few years in China. The recent successes in increasing power output rates of wind turbines are extremely encouraging. Unfortunately, recurrent drive train failures have plagued the industry and prevented wind turbines from achieving their intended 20 year design life. The dynamic behavior of the wind turbine, especially the gearbox resonance performance, must be fully examined. The multi-body system (MBS) software SIMPACK is a powerful tool for resonance analysis.

"SIMPACK is exceptionally fast, robust and accurate."

INTRODUCTION

Dongfang Turbine Co. Ltd., originally Dongfang Turbine factory, a subsidiary of Dongfang Electric Corporation, founded in 1966, is one of the most important companies in research, design and manufacturing of power generation equipment in China. It has developed into one of the big power generation equipment manufacturers in the global market and has an outstanding reputation in the industry after 45 years of development. The main business of Dongfang Turbine Co. Ltd. is design, manufacturing, sale and service of steam, gas, and wind turbines as well as drive devices of ship and turbo machines (including main and auxiliary machines).

MOTIVATION

In comparison to other wind turbine design software, SIMPACK allows for a more precise modeling of drivetrain components. The SIMPACK model of the wind turbine consists of rotor blades, hub, main shaft, gearbox, coupling and generator (Fig. 1). It allows for determination of the natural frequencies of the complete structure, and additionally, shows the mode shapes of all drivetrain components. To detect possible ranges of resonances, the effects of the rotor, the gear meshing frequencies and rotation speed of the components can be compared to the calculated natural frequencies. Simulation in the time domain enables the determination of whether or not the detected resonance frequencies are real resonance points.

THE MODEL OF THE WIND TURBINE DRIVETRAIN

The purpose of the model is focused on investigating the dynamic behavior of the drivetrain in the wind turbine. Therefore, the main frame can be considered as rigid and the tower is not included in this model. The topology graphics of the drivetrain model are shown in Fig. 2. The gearbox and rotor blades are built with SIMPACK substructures. Some of the components in the gearbox are considered as flexible bodies which come from their FE models. If there are two bearings mounted on one flexible part, one is constrained with a "revolute joint" and the other is set as a high stiffness spring in the radial directions. The whole gearbox model in SIMPACK is shown in Fig. 3.

There are two torques acting on the drivetrain: one is the aerodynamic torque from the rotorblades and the other is the feedback torque from the generator.

The aerodynamic torque from the rotorblades is simplified as a torque on the hub center. In real working conditions, this torques changes with the wind speed

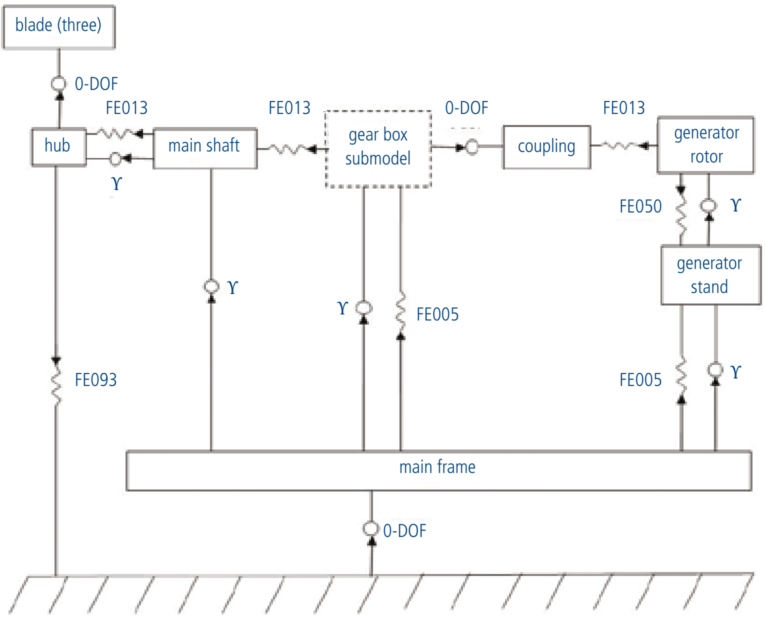

Fig.2: Topology graphics of a drivetrain model

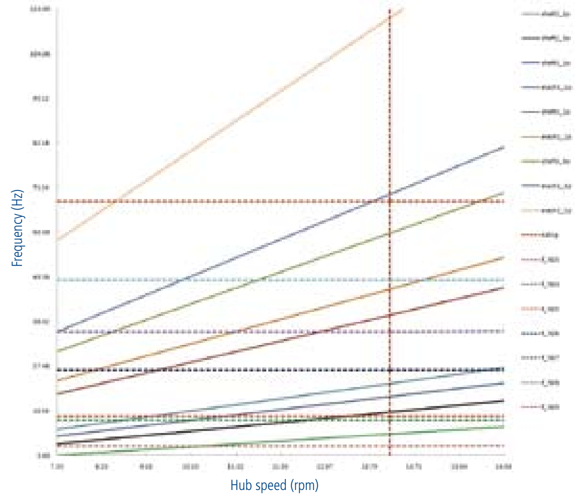

Fig. 4: Campbell diagram

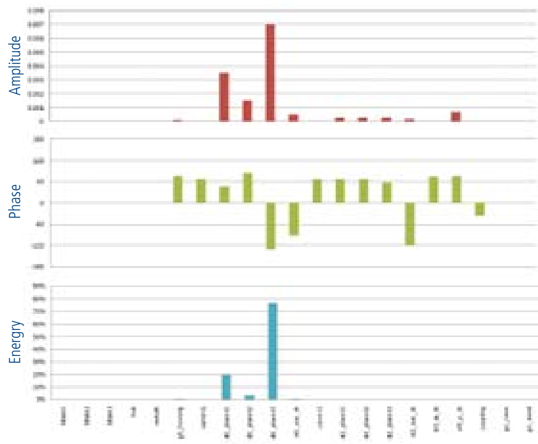

Fig. 5: Amplitude, phase and energy distribution

and pitch angle. In these simulations, the torque are added on the hub as excitations (SIMPACK FE 093). There are two sets of torque applied to the model for different calculation conditions. One is a dynamic equilibrium calculation; another is a velocity sweep analysis. In the first condition, the torque on the hub is set to a constant value until a constant rotational speed, under loaded conditions, is reached. The eigenfrequency can then be calculated from the equilibrium state.

The feedback torque is set between the generator rotor and the shell (SIMPACK FE 050). When the generator is working, it changes with the speed of the generator rotor.

ANALYSIS IN THE FREQUENCY DOMAIN

A Campbell diagram with frequency data is plotted to investigate the potential resonances in the drivetrain. The horizontal lines in the diagram are natural frequencies, and the diagonal lines are excitation frequencies. The cross points in the diagram can be used to determine if there are possible resonance concerns with the model. In order to make the diagram easy to interpret, the excitation frequencies are separated into several parts by the range of frequency. Fig. 4 is one of the Campbell diagrams. All the natural frequency lines have cross points with excitation lines. But to decide if the cross point is a potential resonance point or not, it is necessary to plot the energy distribution of the components over the eigenfrequencies (Fig. 5).

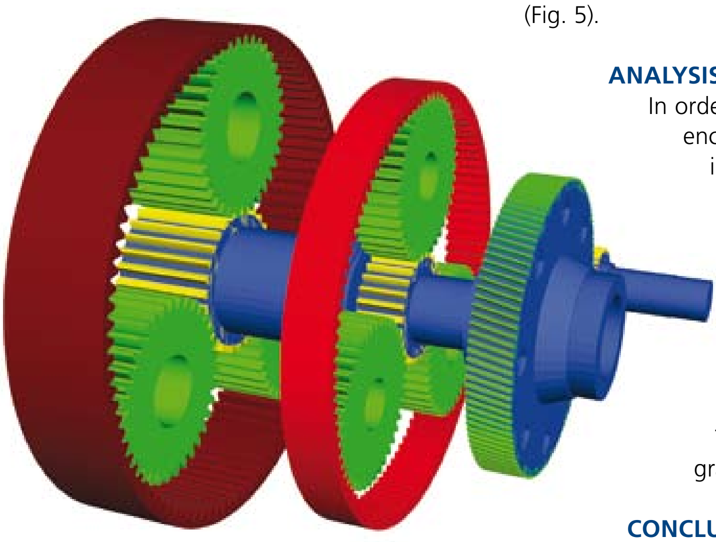

Fig. 3: SIMPACK gearbox model

ANALYSIS IN TIME DOMAIN

In order to investigate the influence of danger frequencies in Campbell diagrams, it is necessary to check the model with time domain simulation. The time domain calculation is set as a "run up" procedure covering the entire working speed range. The 3D Campbell diagram is shown in Fig. 6.

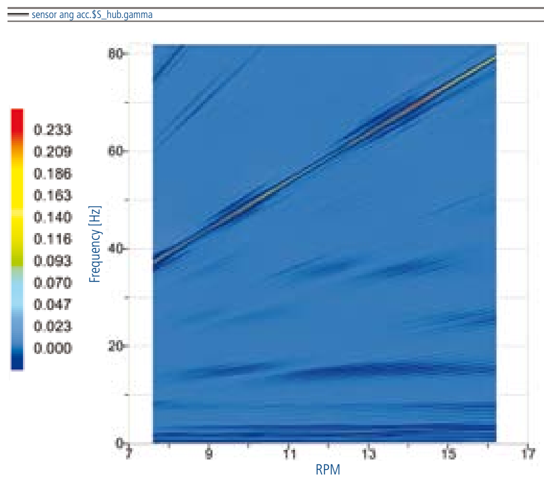

Fig. 6: 3D Campbell diagram

CONCLUSION

SIMPACK is a powerful tool that can be used to investigate the resonance of wind turbine drivetrains. SIMPACK is exceptionally fast, robust and accurate. With SIMPACK, the dynamic behavior of wind turbines can be further understood.