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Torsional/Lateral Rotordynamics Software with Variable Frequency Drives (VFD) and Motor Eccentric Force Prediction - Project Number: 00089

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The 3 major goals of the project include (a) total system vibration – life prediction, (2) Experimental measurement of VFD related dynamic torque content, and (3) Motor electromagnetic field – force prediction.

(1) VFD-driven induction motors have an electromagnetic torque rich in harmonics. These torque harmonics may induce torsional vibrations and cause fatigue failure of the machinery trains. Software is developed that includes the coupled electrical and mechanical system models. VFD Software package is developed using MATLAB and VBA and has an Excel User Interface. The VFD Software can simulate the complete VFD-motor electrical circuit considering the effects of power source, filters, and power electronics' device response with open and closed-loop techniques for induction and synchronous motors. The mechanical model can be torsional or coupled torsional-lateral with multiple shafts, couplings, flexible or rigid gears with or without backlash and impact damping. Fatigue life-prediction is performed with either the conservative stress-based method or the more detailed and accurate strain-based method.

(2) To benchmark the key features of the VFD Software, a test-rig consisting of a VFD-induction-motor machinery train is designed and fabricated. The electrical parameters of the motor and VFD are determined, set and modeled in the software along with the rig's mechanical system. The induced torque harmonics and torsional vibrations predicted by the software and literature are then correlated to the values measured experimentally under a range of conditions.

(3) Operation of rotating machinery may induce static eccentricity in the air-gap of electric motors. The eccentricity generates unbalanced radial and tangential forces which may cause an instability problem. Therefore it is necessary to perform comprehensive electromagnetic analysis of the motor. The motor force prediction software uses the Magnetic Equivalent Circuit Method (Motor MEC Software) and the Finite Element Method (Motor FEM Software) to calculate magnetic field intensity, magnetic flux density, and motor air-gap forces. The Excel UI software is capable of performing electromagnetic FEM analysis of squirrel-cage induction motors and permanent magnet synchronous motors for linear or non-linear BH curve assumptions and has excellent correlation with ANSYS Maxwell.

Future work includes prediction of the various short circuit torque analyses (line-to-line, three phase, line-to-ground, etc.) required by API standards 617 and 684. This industry required analysis is especially important in VFD systems where the short circuit torques change with the line frequency and are more likely to cause expensive failures due to interaction with torsional natural frequencies. Also, the electrical modeling within the software will be expanded to work with a wider range of motors (PM, self-levitating, etc.) and a wider scope of experimental validation will be performed by the test rig.