Torsional/Lateral Rotordynamics Software with Variable Frequency Drives and Motor Eccentric Force Prediction – Project #: 258124-00089

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Introduction and Justification

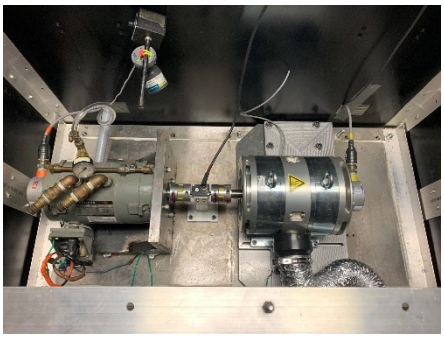
Coupled VFD Machinery Train Dynamics and Life Prediction Software:

- VFD motor driven machinery can experience unpredicted and costly failures due to the rich harmonic spectrum of motor torque.
- VFD-Motor Machinery Train Software (VFD Torsional) provides the feature of simultaneously solving VFDs, motors, and mechanical gear trains with various open and closed loop control techniques via an easy to understand Excel UI.
- Users can quickly identify transient and steady state torque harmonics, natural frequencies and mode shapes, and system life prediction (cycles until failure).

API Short Circuit, Resonance, and Life Prediction Standards:

- API 617 and 684 outline specific standards for short circuit fault, resonance, and life prediction analyses and reports.
- These analyses are especially important when the system is controlled by a VFD where the line frequency often varies.
- It is therefore valuable to have a software that outputs the generated torques and performs a failure analysis on the connected mechanical system.

VFD Harmonic Torque Measurement Test Rig

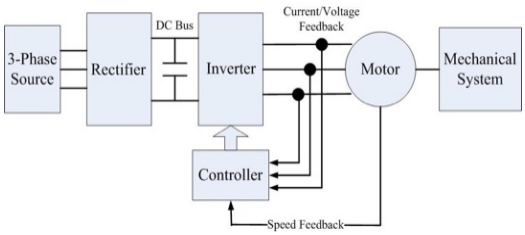


- A VFD motor test rig allows for the benchmarking of key features in the software that are not provided in other industry standard tools.
- VFD switching frequency, line frequency, and bearing loads are all altered to produce various dynamic torques and torsional vibrations to be measured.

Motor FEM Software for Equivalent Circuit Identification and Eccentricity Force Effects:

- Electric motors may have static eccentricity due to operating conditions.
- Static eccentricity results in unbalanced eccentric shaft forces in the radial and tangential directions.
- Eccentric shaft forces may result in an instability problem.
- Motor-FEM Software provides electromagnetic FEA of motors to calculate eccentric shaft forces.

Deliverables



The included deliverables for the project involve three software packages: VFD Torsional, Motor FEM, and Motor MEC. The software (programed in MATLAB) utilizes an easy to use, Excel based, user interface to input the various required parameters for the VFD, mechanical system, motor, fault conditions, etc. Other deliverables for this year include features to perform various short circuit torque/system analyses, a continuation of the VFD test rig results to further benchmark the innovative features of the VFD Torsional software, and other software advancements. Finally, a report which details the benchmarking data and results along with explanations of all software improvements and changes throughout the year will be delivered.

STATUS OF CURRENT WORK

Excel GUI based software. Does not need MATLAB/ANSYS etc.

VFD Software

- Synchronous/Induction Motor Open/Closed Loop Simulations.

- Both steady-state and transient stress or strain-based life-prediction and vibration response of mechanical systems with the pure torsional/coupled lateral-torsional model using either a user-defined or motor generated torque. Mechanical train may consist of shafts, couplings, gears, etc. Gears could be rigid/flexible with/without backlash and impact damping.

VFD Test Rig

- Complete test rig that allows for a wide range of generated torque harmonics caused by varying VFD carrier and line frequencies and bearing loads.
- Test rig results that correlate to software predicted torque frequencies and torsional vibrations.

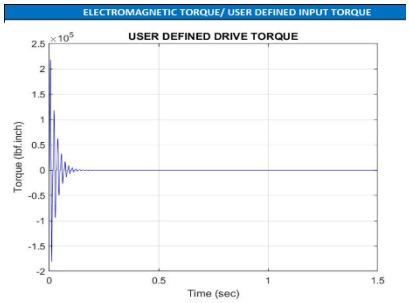
Motor MEC Software

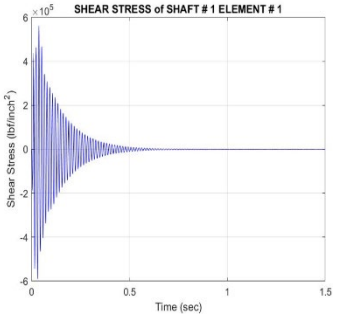
- Radial and tangential magnetic forces and stiffness calculated using Maxwell stress tensor method.
- Bounded limit cycle with mass unbalance included. Combination of the synchronous whirling due to mass unbalance and the whirling limit cycle due to the motor radial and tangential forces.

Motor FEM Software

- Linear and Non-linear Electromagnetic FEM of induction and synchronous motors to calculate motor force.
- Simulate motor eccentric fault condition to calculate radial and tangential force.

PROPOSED WORK





VFD Software:

- Identify causes of 1x, 6x, and other integer harmonics in data.
- Match predicted and measured natural frequencies.
- Expand the coupled torsional-lateral module to include transient and imbalanced response, as well as system stability analysis.
- Create an electrical circuit model to simulate 2 and 3 phase shorts.
- Add sensorless vector control for induction motors.
- Add ability to apply static and dynamic torques to motor and non-motor locations.
- Expand 2D motor FE magnetic modelling to 3D
- Generate natural frequency and short circuit reports according to API standards.
- Compare results to manufacturer specifications for motors and generators.

VFD Test Rig

- Implement DAQ control of testing sequences to automate experiments.
- Perform further experiments with higher running speeds and load torques.
- Study the current harmonics present in the 3 phase motor lines and correlate them to the current harmonics outlined in Song's paper.
- Test synchronous motors.
- Compare measured torques to those inferred from voltage and current measurements and motor properties
- Correlate the vibrations in the system to the VFD software given the present harmonic torque spectrum.
- Experimentally test coupling damping to increase system modeling accuracy.
- Investigate torque harmonic suppression through controller and switching adjustments.

Motor FEM Software

- Evaluate motor equivalent circuit parameters.
- Add other types of motors: reluctance/hysteresis, synchronous motor, and wound rotor induction motor.

BUDGET FOR 2022-2023

- 1 MS student - $2,250/mo. Salary × 12 months, $3,000 insurance and fringe benefits, Tuition and fees $15,000, equipment and supplies $5,000. Total Cost: $ 50,000