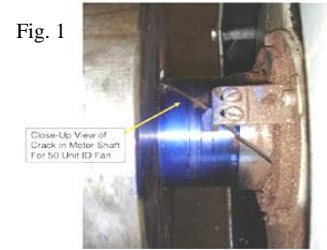


Torsional/Lateral Rotordynamic Software with VFD Effects and Motor Eccentric Force Prediction

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INTRODUCTION and JUSTIFICATION

Variable frequency drives (VFDs) and motors are widely used in industry for its relative low cost and wide speed range. However, it may induce torsional vibration problem in rotating machinery trains (Fig. 1 motor shaft crack in reference) due to the rich harmonics in motor torques from the PWM switching. The motor torque harmonics due to VFD are hard to predict because they vary with PWM switching frequency and motor operating speed. Thus, to accurately predict the mechanical vibration, it is required to model the entire machinery train with coupled electrical and mechanical fields, including power source, power inverter, VFD controller, motor and mechanical system (Fig. 2 Entire machinery train driven by VFD motor).



DELIVERABLES

The proposed work to be finished based on previous work done includes the following.

(1) Stand-Alone VFD Simulation Software Development

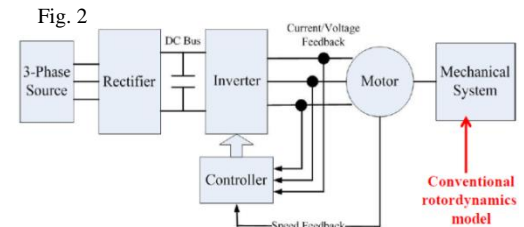
- Add other pulse width modulation (PWM) generation techniques
- Add torsional steady state response (torque/stress vs. speed) analysis with user defined excitation.
- Add additional methods for life prediction, such as nominal mean stress theory and residual mean stress theory.
- Add nonlinear mechanical component (Holset coupling).
- Add gear teeth fatigue prediction.
- Add fault condition analysis for corresponding torsional vibration responses, including 2-phase/3-phase short/open circuit transient analysis and voltage unbalance analysis, which can induce torsional vibrations and the coupling/drive train components have to be sized accordingly.
- Add steady state analysis with ideal voltage input to skip long transient simulation.
- Add mechanical database (library) of parameter values, including common material properties and stress limits.
- Add electrical database (library) of parameter values, including general motor parameters for different HP rating.
- Planetary gear system
- Convert code to FORTRAN and write a subroutine of the electrical system to fully integrate it into XLTRC-2.
- Collaborate with TRC members on field study to test and verify simulation model.

(2) Stand-Alone Code for Motor Eccentricity Force Prediction

- The effects of nonlinearity and saturation of motor back iron will be studied to maintain full feature.
- The estimation of radial and tangential forces/stiffness, studying stability effects, nonlinear system behavior will be Extend to other types
- Model the entire machinery train with dynamic eccentricity

(3) Finite Element Modeling of Motor

- Nonlinear finite element analysis of motor
- Equivalent circuit parameter
- Including eddy current
- Capability for eccentric rotor and mechanical system modeling



COST

1 PhD Student, 12 months \$2,200/mo. Salary, \$187/mo. Insurance, 2.3% Fringe on salary, approx. \$9000 Tuition and Fees
Total: \$38,500

STATUS OF CURRENT WORK

In the past TRC years, the following work has been finished.

(1) Stand-Alone VFD Simulation Software

- Stand-alone code with Excel user interface (Fig. 3). Matlab NOT required to run code.

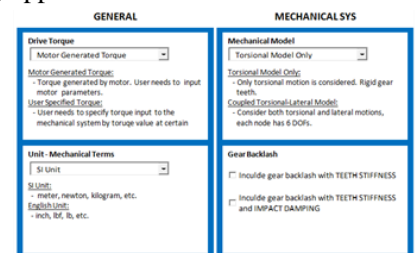


Fig. 3

- Torque internally generated by code in motor model or specified by user vs. time.
 - Internal modeled motor drive system with ideal DC bus and power switches.
 - Induction motor modeling with open-loop control (constant Volts/Hertz, line-start and soft-start) and closed-loop control (field orientation and direct torque).
 - Synchronous motor modeling with open-loop control (constant Volts/Hertz, line-start and soft-start) and closed-loop control (vector control).
 - Mechanical system code with torsional model and torsional-lateral coupled model, including unlimited multiple shafts, multiple gears, multiple coupling flanges, proportional shaft internal damping, concentrated in-line and ground referenced damping.
 - Gear backlash model included, with or without impact damping.
 - Load torque specification for any node as a cubic function of node angular velocity.
 - Shear stress vs. time data output in Excel for user to implement their own life estimation approaches.
 - Several examples provided to illustrate the use of the software.
 - Animated illustration of mode shape of torsional analysis.
 - Long power cable model option with different dv/dt filter options
 - User initial condition input option
 - Output export option
- (2) Radial and Tangential Forces due to Motor Rotor Eccentricity
- Modeled motor magnetic field with equivalent magnetic circuit model.
 - Radial and tangential magnetic forces and stiffness calculated.
 - Stand-alone code with Excel user interface developed.
 - Verified by comparing results with ANSYS (finite element model).
- (3) Finite Element Analysis of Induction Machine
- Transient linear finite element field analysis of induction motor
 - Nonlinear finite element field analysis of inductor coupled with external circuit