A data driven frequency-domain virtual sensing method based on cross-spectral density matrices

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ABSTRACT

In vibration monitoring applications, it is rare and expensive to set up dense vibration sensor networks. The specific case of Condition Monitoring (CM) of wind turbine drivetrains is a challenging example, where there are numerous components prone to failure, but a limited number of possible sensor locations. Moreover, sensors must be located on the exterior of the machine, which hinders the sensitivity towards feeble damage signatures. Virtual sensing techniques can alleviate this problem, by facilitating vibration sensing at locations where sensors are not set at the time of inspection. This can be achieved by using information on the dynamics of the structure to extrapolate the vibration time series from available sensors to desired locations. Otherwise, virtual sensing can be attained from a purely data-driven perspective. To this end, an initial dense sensor configuration is used to establish a model of the relation among sensors at different points in the structure. A sparse configuration is subsequently considered, after removing a subset of sensors. Then, the response at the withdrawn sensors can be extrapolated with the help of the model obtained in the first phase. In this work we postulate a data-driven frequency-domain virtual sensing procedure, based on Cross Power Spectral Density (CPSD) matrices obtained from an initial dense sensor configuration. The CPSD matrices are used to build a conditional PDF for the Fourier transform of the withdrawn sensors, based on the response at the still available sensors, in a Gaussian Process (GP) regression fashion. In this way, it is possible to estimate the Fourier transform of the vibration responses at the absent sensors, based on those from the available sensors. The proposed method is assessed in a wind turbine drivetrain diagnostics simulator, characterised by two speed reduction gearboxes (parallel shaft and planetary), and three shafts. The drivetrain is instrumented with accelerometers located on different bearings and on the gearboxes. The full sensor set is used to build the reference CPSD based on an initial dataset at a fixed speed and load. Later, the acceleration response at some of the sensors is estimated with the proposed virtual sensing method, based on measured responses of a limited set of accelerometers.