Remote Detection of Abnormal Behavior in Mechanical Systems

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Mechanical systems in industrial and commercial buildings make up a large portion of the energy demand in the United States and are common targets for achieving energy savings that result in cost and emissions reductions. Systems that are of interest for mitigating excessive energy consumption range from small motors that have a power draw of 1-10 kW to large systems such as HVAC, compressors, and large industrial motors which can often draw power in the range of 50 – 500 kW. When operated in an abnormal or faulty state, the efficiency of these systems is decreased and the associated energy demand is inflated. Hence, it is of interest to building science researchers to find novel ways to detect mechanical faults.

Traditionally, faults have been identified through preventative maintenance programs, where manual system checks are performed to evaluate the state of components that are prone to failure. This method can be time intensive, unreliable, and dangerous. Condition-based monitoring (CBM) is a contemporary approach to identifying faults in mechanical systems through spectral analysis of measurements that are taken near the system of interest. The application of local sensors to monitor the health of mechanical systems is often expensive or not feasible due to cost, technical, or computational limitations. This work intends to develop and test a novel method for damage detection of rotating machinery using vibration signatures measured remotely. With novel applications of spectral analysis to CBM that allow for remote detection, it would be feasible to detect damage across an array of mechanical systems from a central sensing location that is displaced from the mechanical systems of interest. This would be especially useful in large commercial buildings, industrial facilities, aircraft and automobiles because it would take away many of the physical and economic constraints that had previously limited the application of localized CBM systems.

Here, the remote fault detection problem is simplified by limiting the scope to a bearing fault in a 1 hp induction motor. The experimental set-up that was used consisted of an induction motor fault simulator and an array of sensors (voltage, current, ULF antenna, and accelerometers) that acquired signals from the induction motor in both healthy and faulty states. The signals are analyzed in the frequency domain and the task of fault detection is approached as a classification problem to be solved computationally. Features for the classification problem are calculated in the frequency domain in order to extract information contained in characteristic frequencies that are related to the operational state of the motor. A one-class support vector machine is used as the classifier because it only requires training data for one operating state (healthy motor operation in this case), which makes it of more use in practical applications, and because of its ability to compute robust decision boundaries in complicated feature spaces.

To date, successful classification has been achieved at a location 7 meters away from the induction motor. Locations at 15 meters and 30 meters will also be tested and analyzed to determine the extent to which the methods and equipment used here are able to successfully classify systems remotely.