Abstract

Induction motors are widely used for industrial and domestic applications due to their ruggedness, high efficiency, low cost, and low maintenance. The environments in which they are installed impart various electrical, thermal, and mechanical stresses on various parts of the motor. These stresses lead to the development of incipient faults that are non-detectable in nature due to the low sensitivity of conventional protection systems. Incipient faults do not instantaneously affect the motor's operation. However, they can converge into major faults leading to complete shutdown in the long run, which may lead to catastrophic downtime and high financial losses. Early detection of these faults helps to prevent such circumstances. Hence, many fault diagnosis methods have been proposed to detect and classify incipient faults.

Majority of the incipient faults include bearing faults, stator winding faults, and broken-rotor bar faults. Statistical survey reveals that bearing faults which are due to deterioration of various parts of the bearings range from 40-50% of total induction motor faults. Stator winding faults such as inter-turn, insulation failure have been estimated to be 30-40%. Broken rotor bar faults occupy 5-10%. Various signals analysed to detect these faults include vibration, flux, voltage, stator current, temperature and acoustic. Proposed research work is based on stator current signals since they are affected by both electrical faults (stator and rotor faults) and bearing faults (due to electromechanical energy conversion). The other advantage of using stator current signals include the economy (non-expensive sensors) and non-invasiveness. Hence, the proposed research is aimed to develop an algorithm to detect, classify and locate various incipient faults by exploring the capabilities of signal processing methods in association with machine learning tools. The algorithms developed in this work make use of spectral analysis, Stockwell transform (ST) and machine learning techniques such as Support Vector Machine (SVM). Various algorithms/ techniques for the detection, classification and location of faulty bearings, stator winding and broken rotor bar faults are detailed below.

Bearing Faults: Defect in the bearing is detected based on the Total Harmonic Distortion by computing the spectral content of the three-phase stator current signals. Subsequent to fault detection, current signals are decomposed with Stockwell Transform to extract the features related to magnitude and phase angle. Features are fed to SVM classifier which are selected optimally using fisher score and correlation-based feature selection methods. Two binary SVMs have been used for the three faults under consideration. Post to fault classification, the fault indices based on maximum of magnitude and phase angle of ST matrix have been formed which is compared with the pre-set threshold to locate the faulty bearing. To establish the algorithm, the defective bearings have been collected from the industry and the experimental investigation has been carried out to validate the proposed algorithm.

Stator winding faults: The standard deviation of the ST matrix for selected frequency bands has been evaluated for the detection of stator winding faults. These faults are classified into turn-faults and ground faults using the standard deviation of zero sequence current. Subsequent to fault classification, the location of the fault i.e. faulty phase is classified using features of the ST matrix computed over selected frequency range with two SVM classifiers. The proposed algorithm has been validated using the experimentally collected stator current signals of the motor with customised windings to carry out emulation of various stator faults.

Broken rotor bar faults: Broken rotor bar faults with different levels of severity have been emulated by drilling holes in the bars to a different number of broken bars. The stator current

signals recorded in the experimental investigation have been decomposed using ST matrix. Mean absolute deviation of energy over a selected frequency range of ST matrix has been evaluated and compared with a threshold value (of the healthy rotor) for detection of fault. The severity of the fault has been estimated by the standard deviation of entropy of ST matrix over a selected frequency range.

Thus, the proposed algorithm can be utilised in condition monitoring equipment to carry out predictive maintenance.