Detection of rotor winding asymmetries

Science, Physics

Because of its robustness, simplicity and reliability, induction motors (IM) have been widely used as electromechanical devices for energy conversion. Among the types of induction motor most used are the squirrel-cage and wound-rotor, the latter being less employed, but with advantageous characteristics over other types of motors, among others, its capability to develop high start torques at lower start-up currents, making them adequate for industrial applications such as ball and sag mills, cranes, pumps, fans and blowers, conveyors, chippers or hoists, and even in recent years they have been used massively as generators in wind turbine units.

In spite of its robustness and the fact that this type of motors is usually subjected to continuous work under corrosive environments, high temperatures, electrical and mechanical stresses, inevitable failures occur, inter alia, rotor winding asymmetries, stator short-circuits, eccentricities, bearing faults, slip-rings and brushes damages, that can lead to machine failures over the process or application in which it operates, being the most usual those related to the stator and rotor by holding 45% of the total. Such faults occur as resistance variations or short circuits, producing a phase asymmetry by changing the phase impedances causing electrical disturbances, the possibility of other defects and interruption in the process where they are installed generating high economical loses. Hence, an early detection of faults is essential in order to avoid or minimize the effects of the upcoming failure.

The most common approach to perform the detection of faults in induction motors (including wound-rotor motors) is based on methodologies that use electrical signals due to its simple implementation, low cost and non-invasive nature. In this regard, there are many published works that detail the different variables and techniques used for diagnosis, among the most recurrent is the use of currents, with a technique that is based on a spectral analysis in steady state using the Fourier transform (MCSA) to evaluate the amplitude of the amplified components in case of failure. Other works in the literature have proposed alternative methodologies by analyzing vibration signals, or other quantities such as speed an current to diagnose failures in WRIM. Even though these techniques have shown prominent results, they fail indicating false diagnosis, mainly due to the presence of load torque oscillations and supply voltage fluctuations, and in the case of MCSA to the fact that the main idea of this approach is to detect isolated frequency peaks in the FFT spectrum that may easily be produced by other phenomenon. Focusing on that issue, several works have emerged proposing to combine physical variables such as vibration and torque or stray magnetic field and vibration, since the occurrence of the fault gives rise to a range of pulsating torque frequencies that are transmitted to the machine frame.

Recently, some researchers have developed some techniques to avoid false diagnosis problems using more sophisticated Time-Frequency Decomposition (TFD) tools that detect evolutions of fault-related evolving frequency components that occur during the start-up such as the discrete wavelet transform (DWT), the Wigner-Ville Distribution to sense the high-frequency failure harmonics and a combination of procedures, first the Empirical Mode Decomposition (EMD) method to track the low frequency fault-related components and then the Wigner-Ville Distribution at the startup of the motor. These approaches improve the reliability of the diagnosis advantaged by the ability of these techniques to detect evolutions of fault-related evolving frequency components occurring during transient since the machine is subjected to stresses above normal operation which may highlight defects that are difficult to observe during steady state operation being more reliable indicators than a single peak in the FFT spectrum.

For this purpose, the signal processing tools for the detection of faults during startup are excellent to overcome conventional problems. On the other hand, although a large number of techniques for monitoring and detecting faults in induction motors have been developed, they are focused, used and validated mainly in squirrel-cage induction motors which, despite being the most widely used, are not the only ones existing, situation that has left aside other types of motors with great importance and usefulness, such as WRIM. Moreover, current methodologies still have some drawbacks, such as its complicated portability to other induction motors, forcing researchers to opt for inclusive alternatives as the use of magnetic flux sensors, which represent an excellent option as source of information to perform the detection of faults having special features, among others, its inexpensiveness, easy installation and non-invasive nature.

In this regard, there are few works that use this type of sensors during start-up conditions, and even more, it is very little explored its use in WRIM, so the present work proposes a novel methodology for the detection, monitoring and quantification of fault components appearing in the presence of asymmetry defects in WRIM by means of appropriate signal processing techniques used during transient: Short-time Fourier Transform (STFT) and

DWT demonstrating that the presence of asymmetry faults leads to the appearance of characteristic patterns in the time-frequency analysis of the start-up flux signals. Three different flux sensors positions are considered in the study. Moreover, given the importance of the classification of the failure in the automation of the diagnosis process, a fault level indicator is defined based on the flux transient time-frequency obtained results.