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Imbalance faults constitute a significant portion of all faults in wind turbine generators (WTGs). WTG imbalance fault detection using generator current measurements has advantages over traditional vibration-based methods in terms of cost, implementation, and system reliability. However, there are challenges in using current signals for imbalance fault detection due to low signal-to-noise ratio (SNR) of the useful information in current signals and nonstationary characteristic frequencies of imbalance faults. This paper proposes a method of using generator stator currents for imbalance fault detection of direct-drive WTGs. In the proposed method, the variable shaft rotating frequency of a WTG is estimated from one phase stator current measured from the generator terminal by using a phase lock loop (PLL) method. The estimated shaft rotating frequency is then processed by using appropriate up-sampling and variable-rate down-sampling algorithms. Consequently, the variable characteristic frequencies of imbalance faults in the spectrum of the estimated shaft rotating frequency are converted to constant values. Therefore, the signatures of wind turbine imbalance faults can be clearly identified from power spectral density (PSD) analysis of the converted shaft rotating frequency signal. Simulation and experimental results show that the proposed method is effective to detect various imbalance faults in direct-drive WTGs.