CLAIMS

1. A method of detecting winding fault during online operation of an electrical machine, said method comprising,

acquiring a set of signals from the electrical machine over a period, said set of signals comprising two or more magnetic flux signals, each flux signal obtained from a respective flux sensor positioned on an external surface of the electrical machine;

extracting an internal winding fault indicator from the set of signals;

comparing the internal winding fault indicator with a baseline indicator;

determining an internal winding fault when the internal winding fault indicator deviates from the baseline indicator by a threshold; and

further comprising detecting an external fault prior to the step of extracting the internal fault indicator.

2. The method of claim 1, wherein the electrical machine is a transformer comprising a magnetic core, said magnetic core comprising,

a centre limb, a first outer limb positioned on one side of the centre limb and a second outer limb positioned on another opposite side of the centre limb, wherein the three limbs are spaced apart and arranged substantially parallel to one another, each limb having a primary winding and a secondary winding;

a top yoke member connected to a respective first end of the centre, first and second outer limbs,

a bottom yoke member connected to a respective second end of the centre, first and second outer limbs;

the method further comprising energising the transformer, prior to the acquiring of the set of signals;

wherein energising the transformer comprises passing a varying electric current through the primary winding to produce varying magnetic fluxes, said varying magnetic fluxes capable of inducing an electro motive force in the secondary winding.

3. The method of claim 2, wherein

acquiring the set of signals from the transformer over a period comprises acquiring a first flux signal and a second flux signal,

wherein the first flux signal is acquired from a first flux sensor positioned proximate the first outer limb and the second flux signal is acquired from a second flux sensor positioned proximate the second outer limb.

4. The method of claim 3, wherein extracting the internal winding fault indicator comprises acquiring a line-voltage signal of the transformer;

summing the first and second flux signals to obtain a total flux signal;

obtaining the difference between phase angles of the line-voltage of the transformer and the total flux signal, as the internal winding fault indicator;

or obtaining a combination of (i) the difference between phase angles of the line-voltage of the transformer and the total flux signal and (ii) magnitude value of the total flux signal, as the internal winding fault indicator.

5. The method of claim 4, wherein the threshold is 110%, 115%, 120%, 125%, 130%, 135%, 140%, 145%, 150%, or 155% of the phase angles obtained during initial calibration.

6. The method of any one of claims 4 or 5, wherein detecting the external fault comprises extracting an external fault indicator by

obtaining a first difference between phase angles of the line-voltage of the transformer and the first flux signal; and

obtaining a second difference between phase angles of the line-voltage of the transformer and the second flux signal;

wherein the external fault indicator is the absolute value of a difference between the first difference and second difference;

and

detecting the external fault in the transformer when the external fault indicator is within a faulty range.

7. The method of claim 6, wherein the faulty range is a phase angle value which is more than 0º and less than 90º.

8. The method of claim 6 or 7, further comprising detecting an inrush current condition to the transformer prior to detecting the external fault in the transformer, wherein detecting the inrush current condition comprises

extracting respective first and second magnitude values of second harmonic components of the first and second flux signals;

comparing magnitude values of first and second flux signals against respective acceptable magnitude values; and

detecting the inrush current condition if the magnitude values of a core-leakage/-linkage flux signals at the first and second outer limbs are greater than the respective acceptable magnitude values.

9. The method of claim 8, wherein the acceptable magnitude values are not more than 140%, not more than 145% or not more than 150% of the magnitudes obtained during initial calibration.

10. The method of claim 8 or 9, further comprising re-acquiring a new set of signals from the transformer when the inrush current condition is detected.

11. The method of claim 1, wherein the electrical machine is a motor or generator comprising,

a stator having a cylindrical frame, the cylindrical frame comprising a plurality of electrically conductive windings arranged therein;

a rotor having a cylindrical body concentrically mounted and rotatable within the cylindrical frame of the stator, said rotor having a drive end and a non-drive end; and

an elongated shaft member coaxially mounted to the rotor, said shaft member protruding from the rotor at the drive end;

the method further comprising energising the motor or generator, prior to the acquiring of the set of signals;

wherein energising the motor comprises passing a varying electric current through the windings of the stator to produce varying magnetic fluxes, said varying magnetic fluxes capable of inducing the rotor and shaft member to rotate about respective longitudinal axis of the rotor and shaft member; and

wherein energising the generator comprises driving the rotor and shaft member of the generator to rotate about respective longitudinal axis of the rotor and shaft member to produce varying magnetic fluxes linked with the windings of the stator, said varying magnetic fluxes capable of inducing an electro motive force in the windings of the stator.

12. The method of claim 11, wherein

acquiring the set of signals from the motor or generator over a period comprises acquiring a set of *P* flux signals from *P* flux sensors positioned proximate the stator along the circumference of the cylindrical frame of the stator, such that any two adjacent flux sensors along the circumference of the cylindrical frame has an angular separation of $\frac{360}{P}$ degrees with

respect to the longitudinal axis of the cylindrical frame, wherein *P* represents the total number of poles of the motor or generator.

13. The method of claim 12, wherein extracting the internal winding fault indicator comprises

summing the set of *P* flux signals to obtain a total flux signal; and

performing a Fourier transform on the total flux signal to obtain a magnitude of the total flux signal as the internal winding fault indicator.

14. The method of claim 13, wherein the threshold is 120%, 130%, or 140% of the magnitude of the total flux signal obtained during initial calibration.

15. The method of any one of claims 12 to 14, wherein detecting the external fault comprises

performing a Fourier transform on each of the *P* flux signals to obtain respective magnitudes of the *P* flux signals;

summing the respective magnitudes of the *P* flux signals to obtain a summed value as an external fault indicator; and

detecting the external fault in the motor or generator when the summed value is within acceptable threshold.

16. The method of claim 15, wherein the acceptable threshold is 90%, 85%, or 80% of a baseline load indicator of a lowest loading condition, said baseline load indicator obtained during an initial calibration.

17. The method of claim 16, wherein the baseline load indicator is obtained based on a sum of the respective magnitudes of the *P* flux signals, or either one of a phase current magnitude or line-current magnitude of the motor or generator, obtained during the initial calibration.

18. The method of claim 17, wherein prior to the detecting an external fault, the method comprises identifying a loading condition by

comparing the summed magnitudes of *P* flux signals or phase-current magnitude or line-current magnitude with corresponding pre-calibrated values.

19. The method of any one of claims 1 to 18, further comprising triggering a trip signal when the internal winding fault is detected.

20. The method of any one of claims 1 to 19, wherein the two or more flux sensors are either Hall-effect based flux sensors or passive coils.

21. The method of any one of claims 1 to 20, further comprising acquiring flux signals for at least one fundamental cycle of the flux signals.

22. A system for detecting winding fault during online operation of an electrical machine, said system comprising,

a power supply unit,

a receiver unit for receiving a set of signals acquired from the electrical machine over a period, said set of signals comprising two or more magnetic flux signals, each flux signal obtained from a respective flux sensor positioned on an external surface of the electrical machine;

a signal pre-processing unit for pre-processing the set of signals; and

a DSP or FPGA or microcontroller or microprocessor for extracting an internal winding fault indicator from the set of signals, comparing the internal winding fault indicator with a baseline indicator, determining an internal winding fault when the internal winding fault indicator deviates from the baseline indicator by a threshold, and detecting an external fault prior to the step of extracting the internal fault indicator.

23. A non-transitory computer readable storage medium having stored thereon instructions for instructing a processing unit of a system to execute a method of detecting winding fault during online operation of an electrical machine, said method comprising,

acquiring a set of signals from the electrical machine over a period, said set of signals comprising two or more magnetic flux signals, each flux signal obtained from a respective flux sensor positioned on an external surface of the electrical machine;

extracting an internal winding fault indicator from the set of signals;

comparing the internal winding fault indicator with a baseline indicator;

determining an internal winding fault when the internal winding fault indicator deviates from the baseline indicator by a threshold; and

detecting an external fault prior to the step of extracting the internal fault indicator.