

CLAIMS

1. A method of fault detection in synchronous machines; the method comprising:
- 5 using at least one sensor to determine parameters linked to the magnetic field generated within the synchronous machine including parameters based on one or more of magnetic field strength, rotor current or voltage, stator current or voltage, and vibration; processing the sensor measurements to identify data artefacts linked to the magnetic field, wherein the processing includes one or more signal processing techniques
- 10 based on time, frequency, and both time and frequency; and analysing the output of the signal processing in order to identify and categorise irregularities in the magnetic field that are indicative of a fault in the synchronous machine, wherein the analysing includes recognising patterns in the processed sensor measurements, via use of computer aided pattern recognition techniques such as via
- 15 machine learning algorithms.
2. A method as claimed in claim 1, wherein the method is for detecting faults linked with one or more of eccentricity faults, damper winding faults, and short circuit faults.
- 20 3. A method as claimed in claim 1 or 2, wherein the method is for fault detection in large synchronous machines such as hydropower generators.
4. A method as claimed in claim 1, 2 or 3, wherein the method is carried out
- 25 during a time period in which there is a transient magnetic field of the type that arises during start-up or shut-down of the machine.
5. A method as claimed in any preceding claim, wherein the sensor(s) include at least one existing sensor or at least one non-invasive sensor.
- 30 6. A method as claimed in any preceding claim, comprising using one or more existing sensor(s) comprising one or more voltage or current sensor(s) configured for use during operation of the synchronous machine for monitoring and/or control of the machine.

7. A method as claimed in any preceding claim, wherein at least one non-invasive sensor provided as a part of a fault detection system, where this sensor is temporarily placed with the machine for performing the fault detection method.

5 8. A method as claimed in any preceding claim, wherein the method does not require any physical modification to the synchronous machine to place or attach a new sensor.

9. A method as claimed in any preceding claim, wherein the sensor
10 measurements do not include any data transferred from the moving parts of the rotor.

10. A method as claimed in any preceding claim, comprising using a sensor provided for the synchronous machine at a potential transformer thereof.

15 11. A method as claimed in any preceding claim, including determining a radius of gyration for the rotor of the synchronous machine and using the radius of gyration to identify and categorise irregularities in the magnetic field.

12. A method as claimed in claim 11, including obtaining the radius of gyration
20 data obtained via time series data mining and using the radius of gyration data for detecting a damper winding fault or an eccentricity fault.

13. A method as claimed in claim 11 or 12, including mapping the phase space
25 for induced voltage in the field winding of the synchronous machine.

14. A method as claimed in claim 13, wherein the induced voltage is determined or measured via a sensor at the potential transformer.

15. A method as claimed in any of claims 11 to 14, including seeking to identify
30 a damper winding fault in the form of a broken damper bar, wherein the analysing step includes a comparison of the measured radius of gyration compared to equivalent measurements of radius of gyration for a healthy synchronous machine.

16. A method as claimed in any of claims 11 to 15, including seeking to identify
35 an eccentricity fault, wherein the step of analysing the output of the signal processing includes determining a normalised radius of gyration with reference to a radius of gyration

for a machine that is known to be healthy, with the normalised radius of gyration being defined as the difference between a radius of gyration for a healthy synchronous machine and the measured radius of gyration, with this difference being divided by the healthy radius of gyration.

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17. A method as claimed in claim 16, comprising automated identification and categorisation of possible eccentricity faults by assessing the value of the normalised radius of gyration compared to a threshold value.

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18. A method as claimed in any preceding claim, wherein the computer aided pattern recognition techniques are based on a machine learning algorithm trained with a plurality of processed sensor measurements that are known to relate to fault free machines as well as a plurality of processed sensor measurements that are known to relate to machines with a fault.

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19. A fault detection system for fault detection in synchronous machines, the fault detection system comprising: a data processing apparatus for connection to at least one sensor in order to receive parameters linked to the magnetic field generated within the synchronous machine including parameters based on one or more of magnetic field strength, rotor current or voltage, stator current or voltage, and vibration;

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wherein the data processing apparatus is configured to:

process the sensor measurements to identify data artefacts linked to the magnetic field, wherein the processing includes one or more signal processing techniques based on time, frequency, and both time and frequency; and

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analyse the output of the signal processing in order to identify and categorise irregularities in the magnetic field that are indicative of a fault in the synchronous machine, wherein the analysing includes recognising patterns in the processed sensor measurements, via use of computer aided pattern recognition techniques such as via machine learning algorithms.

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20. A fault detection system as claimed in claim 19, wherein the data processing apparatus configured to perform the method of any of claims 1 to 18.

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21. A fault detection system as claimed in claim 19 or 20, comprising at least one existing sensor and/or at least one non-invasive sensor.

22. A fault detection system as claimed in claim 19, 20 or 21, wherein the fault detection system uses sensors without any data transfer from the moving parts of the rotor.

5 23. A large synchronous machine acting as a hydropower generator, the synchronous machine including the fault detection system of any of claims 19 to 22.

24. A computer programme product comprising instructions that, when executed within a fault detection system as in any of claims 19 to 23, will configure the
10 data processing apparatus thereof to:
process the sensor measurements to identify data artefacts linked to the magnetic field, wherein the processing includes one or more signal processing techniques based on time, frequency, and both time and frequency; and
analyse the output of the signal processing in order to identify and categorise
15 irregularities in the magnetic field that are indicative of a fault in the synchronous machine, wherein the analysing includes recognising patterns in the processed sensor measurements, via use of computer aided pattern recognition techniques such as via machine learning algorithms.

20 25. A computer programme product as claimed in claim 24, comprising instructions arranged to configure the data processing apparatus to perform other steps as claimed in any of claims to 1 to 18.