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Problems Encountered In Modern Synchronous Machines

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ABSTRACT: This article examines rotor and stator faults and common problems of synchronous machines. We investigated major and minor faults and failures in synchronous and asynchronous machines (SAASM) to avoid redundant downtime, maintain quality of service, and minimize revenue losses for smart grid (SG) operators and planners. In addition, state-of-the-art fault detection, fault diagnosis, root causes of faults and troubleshooting measures for (a) transformers, (b) stators and (c) rotors are discussed. Our work provides a detailed taxonomy of rotor and stator faults, electrical and mechanical stress, and fault diagnosis schemes for stable SG operation. We believe that our research contribution is more versatile than previous works, covering all aspects of SAASM failures and malfunctions.

KEYWORDS: Transformer, stator and rotor, synchronous machines, asynchronous machines.

INTRODUCTION

A synchronous machine consists of a stationary part - a stator and a rotating part - a rotor. The stator of a synchronous machine does not differ from the stator of an asynchronous machine, that is, it consists of a case (stamina), a magnetic core and a coil. According to the function and dimensions of the machine, the construction of the stator of the synchronous machine can be different. For example, in large-power, multi-pole machines, when the outer diameter of the stator magnetic core is 900 mm or more, the magnetic core plates are made of individual segments, and after assembly, they form a magnetic core cylinder. For the convenience of transportation and installation, the casings of the stator of large-sized machines are built in a prefabricated form.

The poles of synchronous machines have two types of constructions that are fundamentally different from each other: obvious poles and invisible poles. In power plants (power plants), three types of motors are mainly used in the primary motors driving the synchronous generator: steam turbines, hydraulic turbines or internal combustion engines (diesel). Each of them has a decisive effect on the construction of the generator, as it is the conduct of the generator. If the driving motor is a hydraulic turbine, the synchronous generator is called a hydrogenerator.

The core of the stator is made of mutually insulated electrical steel sheets, and three-phase alternating current coils are placed in the wedges in the inner part of the cylindrical housing. Synchronous machines are used as electric generators, engines and reactive power compensators. Like all electric machines, they have reversible properties. Synchronous machines are mainly installed in all power plants with generators with a capacity of 800 kVa (kilowatts) and more. The power of generators in hydroelectric power stations is somewhat less, it is 500-600 kVa. At nuclear power plants, the capacity of one block reaches 1.5 thousand MVA (Megavoltampere - transformer electric current power unit). Synchronous machine is an AC machine whose satisfactory operation depends upon the maintenance of the following relationship.

$$N_s = \frac{120f}{P} \dots\dots\dots (1) \quad \text{or}$$

$$f = \frac{PN_s}{120}$$

Where, Ns is the synchronous speed in revolution per minute (r.p.m), f is the supply frequency, P is the number of poles of the machine.

When connected to an electric power system, a synchronous machine always maintains the above relationship shown in equation. If the synchronous machine working as a motor fails to maintain the average speed (Ns) the machine will not develop sufficient torque to maintain its rotation and will stop. Then the motor is said to be Pulled Out of Step. In case, when the synchronous machine is operating as a generator, it has to run at a fixed speed called Synchronous speed to generate the power at a particular frequency. As all the appliances or machines are designed to operate at this frequency. In some countries, the value of the frequency is 50 hertz.

Both ends of the rotor are fixed to the contact rings fixed to the machine shaft, and the fixed current measuring brushes slide on the surface of the rings. As a source of direct current for the rotor, a constant current generator with a small power - an exciter is used. Usually, the power of the exciter is (1-3)% of the power of the synchronous machine. In some cases, direct current is generated by rectifying the current produced by a synchronous generator.

An alternating current machine in which the rotational speed (n) is constant and the frequency of the stator current depends on the ratio f = np/60 is called a synchronous machine. Synchronous machines are used as electric generators, motors and reactive power compensators. Like all Electric machines, they have a reversible feature. Synchronous machines are mainly used as three-phase electric generators in all power plants. Generators with a capacity of 800 kVa and more are installed in modern thermal power plants. The power of generators in hydraulic power stations is somewhat less, 500 - 600 kVA. In nuclear power plants, the power of one unit reaches 1.5 thousand MW.

The stator and rotor are the main parts of the synchronous machine. The core of the stator is assembled from mutually insulated electrical steel sheets and is fixed to the inner surface of the cylindrical integral cord. Three-phase alternating current windings are placed in the slots in the inner part of the stator axis-1. Both ends of the rotor winding are fixed to the contact rings fixed to the machine axis. #39, on the surface of the rings fixed brushes slide. As a source of direct current for the rotor, a constant current generator with a small power - a wake-up is used. Usually, the power of the exciter is (1-3) % of the power of the synchronous machine. In some cases, the current generated by the synchronous generator; Direct current is generated by rectification. In order to ensure the manufacturing technology of synchronous machines with clearly visible poles and to ensure the mechanical strength of their construction, it is recommended to use them in cases where the speed of rotation is less than 1000 rpm. A hydraulic turbine is often used as the primary engine of a fixed-pole generator. Therefore, such generators are called hydrogen generators, their rotation speed is in the range of 60 to 750 rpm. The change in speed over such a wide range is due to the difference in water pressure and waste in the hydrogens.

Structure and types of synchronous machines: The stator (fixed part) and rotor (rotating part) are the main parts of synchronous machines.

The structure of the stator of a synchronous machine is similar to the structure of the stator of an asynchronous machine. The stator consists of the body of the machine, the base (stanini) and the iron core inside the body, and the armature coils located in its wedges. The iron core of the stator is assembled from some plates (made of special steel) with a thickness of 0.35-0.5 mm (1-1.5 mm in high-power machines). The stator coil is wound with copper wire. Usually, stator coils consist of several pieces. The stator windings of a synchronous machine are often connected in a star manner.

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The ends of the winding of the stator, like the ends of the winding of the asynchronous motor stator, are denoted by the letters AVS and XYZ at the end. Synchronous machines are of two types depending on the structure of the rotor.

- a rotor with clearly visible magnetic poles, that is, a rotor with a clear pole;
- rotor with invisible magnetic poles.

Magnetic poles or pole iron core are assembled from some plates made of special steel. A coil is wound on the magnetic poles of the rotor. The coils wound on individual poles are connected in series. This coil is called the rotor coil or the excitation coil of the generator. The coil wrapped around the magnetic poles creates the main magnetic field of the synchronous generator. The two ends of the rotor coil are connected to two copper or brass rings fixed to the shaft of the machine. The rings are well insulated from each other and from the shaft, the brushes slide on the rings and the brushes are connected to the terminals of the machine.

The rotor winding, which creates the main magnetic field of the machine, is connected to a constant current source. An overview of the open-pole rotor is given. A fixed-pole rotor consists of a shaft and a cylindrical (solid or composite) rotor body made of special steel. The entire rotor body has slots where the rotor shaft is located. Wedges are formed only in 2/3 of the rotor body. The winding of the rotor is wound with an insulated copper wire. the ends of the coil are removed to the terminal box of the machine through rings and brushes. This device is connected to a constant current source.

In addition to the main parts mentioned above, synchronous machines have additional parts such as covers with bearings, a brush device and, in medium-power machines, a fan mounted on the rotor shaft. Generally, AC machines are simpler than DC machines because they do not have a collector. The absence of a collector of the machine allows to install the armature on a fixed part of the machine. So, the main magnetic field of a synchronous machine is created when a constant current passes through its rotor coil. In general, the part that creates the main magnetic field in electric machines is called an inductor. Variable e.yu.k. The chulgama part that forms is called yakorg.

LITERATURE REVIEW AND METHODOLOGY

Synchronous is a Greek terminology which means operating at the same time. Electric rotating machinery is an apparatus which consists of a rotating and stationery member that generates, converts, transforms or modifies electric power. Faraday's Law of Electromagnetic Induction, Ampere Biot-Savart's Law of Electromagnetic Induced Forces and Lenz's Law of Action and Reaction, with the law of energy conservation, all together constitute the basic theoretical bricks on which the operation of any electrical machine can be explained. The Synchronous Machine is an alternating current machine whose rotation under steady state condition is equal to the integral number of alternating current cycles in its stator.

The rotor with permanent magnets or electromagnets rotates in synchronism with the Rotating Magnetic Field (RMF) created by the stator. Synchronous Machines can be classified as Generators, Motors and Compensators according to their uses. Generator action is observed when the rotor runs faster than the synchronous speed of the machine which is possible by means of a prime mover, motoring action is observed when the rotor is dragged behind the air-gap flux by retarding torque of a shaft-load. A Synchronous Compensator is a Synchronous Motor whose shaft is allowed to rotate freely without any load. Its field winding excitation is controlled by a voltage regulator to either generate or absorb reactive power as needed to adjust the grid's voltage, or to improve power factor [5]. This work discusses the basic principles of the Synchronous Machine and its uses as Motor, Generator and Compensator; it further explain in details the advantages and applications of the synchronous machine as a compensator in power system networks.

Three phase SAASMs are workhorse of all industries due to its versatility and robustness. However, such machines cause limitations on exceeding that cause premature failure of the stator, rotor, and shaft. Main short-comings in SAAMs includes:
(a) stator winding fault failures, (b) shaft eccentricity failure, and (c) rotor faults.

Damages in SAASMs are due to the following reasons: • Duetodefective bearings, rotor starts vibration and results in damage of the machine. • Turns of stator winding are insulated from each other by a di-electric medium when insulation failure or a short circuit occurs and the machine stops working. This type of fault results in cracks or damage to rotor bars where it touches end rings. Numerous literature reports and reviews exist on SAASMs, for example, Zhang et al. discussed fault detection and diagnosis systems that can detect different types of faults in.

Stator current and time are used as inputs to the system and direct torque control technology (DTC) is used as technical control in the drive system. Time is the factor that plays an important role for both the detection of fault and the selection of the most appropriate corrective action per type of fault. Benefits of DTC include:
(a) relatively simple construction, and
(b) very good flow and torque control performance.

There is no transformation in power modulation block and no current control loops. Although discussed technology has some drawbacks such as:
(a) variable switching frequency,
(b) operating at low speed, and
(c) high torque ripples.

Vijayakumar et al. presented a simulation of the most common faults in three-phase squirrel cage machines with a finite element method in [5]. Finite elements software is used to graphically record:
(a) electric and magnetic fields, and
(b) the waveform of flux density distribution in the air gap and electromagnet core.

RESULTS AND DISCUSSION

Mainly there are three types of faults mechanical faults electrical faults and magnetic faults in synchronous machines. Electrical faults are related to stator winding, whereas mechanical faults are related to bearing, air gap and rotor-stator alignment. Magnetic fault is related to the generation and distribution of magnetic field lines. Electrical fault is further subdivided into stator faults and external faults (drive-related faults). The stator consists of winding is an area for most insulation-based faults. These faults generally occur due to the failure of insulation. Mechanical faults consist of bearing faults and eccentricity faults. This fault can be further subdivided into static eccentricity (SE), dynamic eccentricity (DE) and mixed eccentricity.

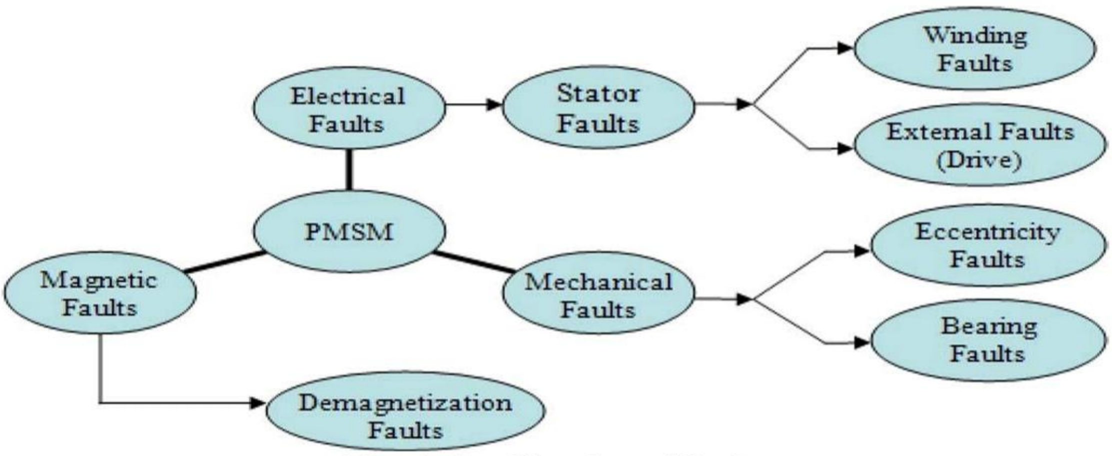

Fig. 1 classification of faults

Fig. 1 shows the schematic classification of all faults in PMSM. To increase PMSM performance, raise their lifetime, and lower their high Costs, fault prediction in PMSMs is necessary. Faults in PMSMs are classified into three parts: electrical, magnetic, and mechanical faults. Due to having access to the stator of the motor, the detection of electrical faults in faulty PMSM is much easier in magnetic or mechanical faults. Vibrations and noise in PMSM are directly related to air gap

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and air gap flux density. Air gap itself depends upon the mechanical installation of the machine and mechanical faults. Flux density in the machine is directly related to stator winding, number of poles and slots, type of winding and stator faults.

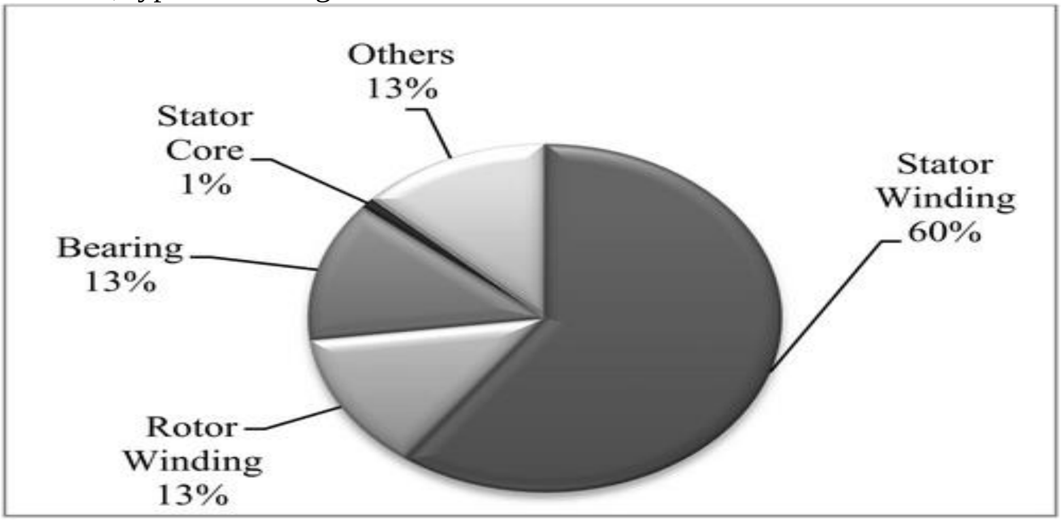

Figure 2

According to Figure 2, 60% of the faults are dedicated to the stator winding. The most probable causes for winding faults are high temperature, short circuits, electrical discharge, mechanical stress, magnetic force and insulation deterioration. Generally, stator winding fault diagnosis methods use magnetic flux, current and voltage or a combination of them.

Although the phase-to-phase and phase-to-ground faults are more severe than the inter-turn winding faults, they can be detected more easily by protection relays in a fraction of a second. Detection of the inter-turn fault is difficult at the incipient stage because it does not significantly influence the terminal currents. Therefore, condition monitoring is essential for inter-turn faults to diagnose the fault at the starting point and prevent the following problems. There is a widespread belief that many phase-to-ground or phase-to-phase faults started as undetected TTF, which grew and propagated until disaster finally occurred. Here, the stator winding fault detection methods are briefly reviewed in transformers and induction motors, and then the methods are extended to the SGs.

In the incipient stage, the insulation failure is not dangerous, but if it is not detected earlier, it may lead to a severe fault. The TTF in the winding induces a high-induced current, which flows in the shorted loops and causes the winding failure [29]. Detecting the fault early decreases the machine damage, and the machine can be put back into service by rewinding the stator [30].

Differential relays cannot detect the TTF due to instrumental transformer saturation, which reduces its sensitivity. Hence, other methods such as negative or zero sequence-based methods should be used for the TTF diagnosis, beside the differential relay. To detect the stator-winding fault in the SGs, various quantities such as current, voltage, and magnetic flux can be utilised. The following techniques can be applied for stator fault detection.

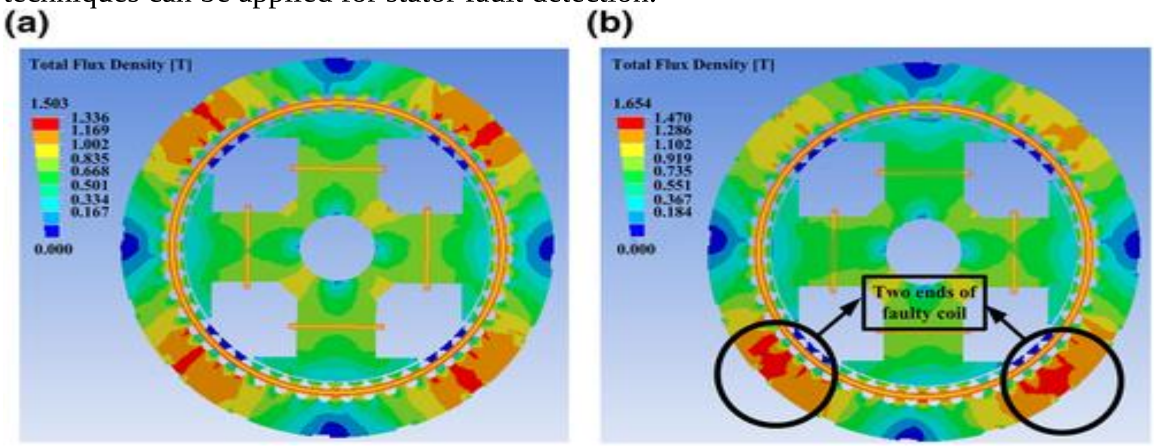

Figure 3

The magnetic flux sensors are used for TTF detection in transformers by measuring the leakage flux and flux-linkage with high sensitivity. Besides, the air-gap and stray magnetic flux monitoring are enthusiastic methods in induction motors, which are used for stator TTF detection. Four different search coils mounted in various parts of the induction motor have been introduced in Ref. [39] to measure the magnetic flux. The MMF near the shorted turns has been decreased in the TTF case. In the healthy case, the MMF is sinusoidal in space and time, but in the faulty case, the air-gap MMF is distorted as shown in Figure 3.

The search coil can measure the total harmonic distortion (THD) of the air-gap magnetic flux; the THD of the flux increases the fault in the stator winding; the saturation and loading conditions can be also taken into account. In addition, the fault location is identified using the ANN and wavelet transform. Although the magnetic flux sensor is mostly inexpensive, reliable, and sensitive, its main drawback is practical limitations during installation. The stray flux sensors are non-invasive and inside/in the vicinity of the SG stator housing, but the stray flux is so small even in the faulty case and decreases the condition monitoring sensitivity.

In the large SGs, the stator winding fault is mostly severe, and the TTF is more probable in small ones. Therefore, conventional protection devices can detect the stator fault in a large SG without any problems, but the TTF in a small SG can be diagnosed by novel methods like air-gap flux or stray flux monitoring. Although the mentioned methods are sensitive and accurate, the current/voltage-based methods are more popular because they do not need additional sensors.

Owing to the rotor rotation, both mechanical and electrical faults can take place in the rotors. Detection of the electrical failure in the rotor, that is the SG short-circuit.

Winding is quite different from the stator because the DC flows in the rotor winding and the faults cannot be detected by sinusoidal waveform-based approaches. To discriminate rotor electrical and mechanical faults, symmetrical component monitoring can be considered an appropriate method. In the proposed method, the current spectrum and voltage have been analysed to discriminate against the rotor faults. The results show that the rotor TTF increases the positive, negative, and zero sequences of the rotational frequency of the first right sideband, while the mechanical fault increases only the positive sequence of the rotational frequency. Furthermore, vibration can be used to diagnose both winding and eccentricity faults.

The TTF in the rotor winding is caused by insulation failure due to ageing, thermal, and mechanical stresses [67]. As a result of short-circuit turns, the total ampere-turn is reduced in the affected pole, and consequently, the air-gap magnetic flux density distribution becomes asymmetrical. Magnetic flux and vibration are two major quantities, measured by sensors, which can be used for the rotor winding fault diagnosis. For this purpose, magnetic flux probes were used in the 1970s for the first time and developed up to now. Some methods focus on the stray flux or leakage flux measured by stator wedge-mounted sensors; however, its magnitude is small and not recommended for condition monitoring. A new flux probe was introduced in Ref. It has been mounted on the stator core tooth to measure the main magnetic flux passing through the core tooth. These probes can be removed more easily than the conventional flux probes. A non-invasive method has been proposed in Refs., which uses the external search coil to sense the stray magnetic flux in the SGs. Analysing both the stray flux and frame vibrations can detect the rotor TTF in SGs.

The search coil near the frame is first applied to induction motors for fault detection. A similar search coil can be also used in the SGs. The frequencies in the magnetic flux spectrum and signal spectrum of vibration define the healthy and faulty SGs. In the faulty condition, the magnitude of some frequencies increases compared with the healthy case. It is noted that although there are amplitude changes every 25 Hz in the vibration spectrum, the most significant modification appears at low frequencies, especially at 225 Hz, but the healthy frequencies remain unchanged.

As shown in Figure 4, to diagnose the rotor-winding fault in turbo- and hydro-SGs, the flux probe is installed in the stator slot. The flux probe is sensitive to of the air-gap radial flux change. As each rotor slot passes the flux probe, a difference in the induced voltage waveform in a search coil caused by magnetic poles is detectable. An inter-turn fault in a coil reduces the peaks associated with the two opposite slots containing the faulted coil, thus, the presence of shorted turns could be detected.

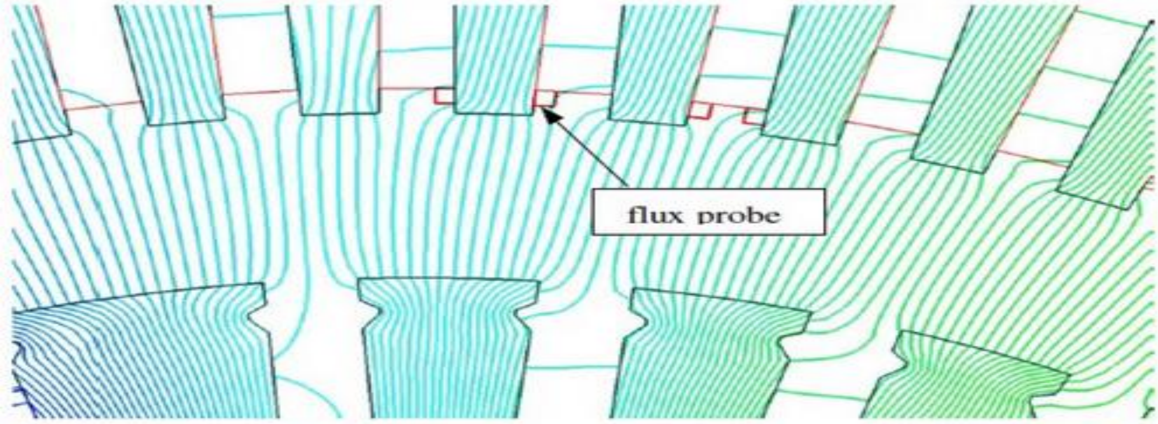

Figure 4

Rotor eccentricity is a mechanical fault in rotational machines related to the rotor. Generally, the air gap is distributed homogeneously, but the rotor eccentricity is defined as the asymmetric air-gap that exists between the stator and rotor. Large synchronous motors tend to be well-built and sturdy. They are often overbuilt with material to withstand the severe loads that are applied. The most common failures for industrial synchronous machines, in order, are:

- Bearings due to general wear and contamination
- Rotor fields – due to high temperatures, these will often burn up from the inside out
- Amortisseur windings – mostly in reciprocating loads. Because of the amount of energy absorbed, the winding bars will often crack. In particular, if the rotor fields are beginning to fail and are short, it is easier for the rotor to fall out of the 'synch.'
- Stator windings – general wear and contamination. Stator windings in synchronous machines tend to be 'form wound' and heavily insulated.

Figure 5 shows the static eccentricities (SE) and dynamic eccentricity (DE) faults. In the case of the SE fault, the position of the minimal radial air-gap length is fixed in space. The DE occurs when the centre of the rotor is not at the centre of the rotation, and the position of the minimum air gap rotates with the rotor. These faults are critical for electrical machines and must be detected in the early stage. Different methods have been presented for the eccentricity fault detection in induction motors but less in SGs. Therefore, the detection methods for induction motors are presented firstly, and then some proposed approaches in SGs are discussed.

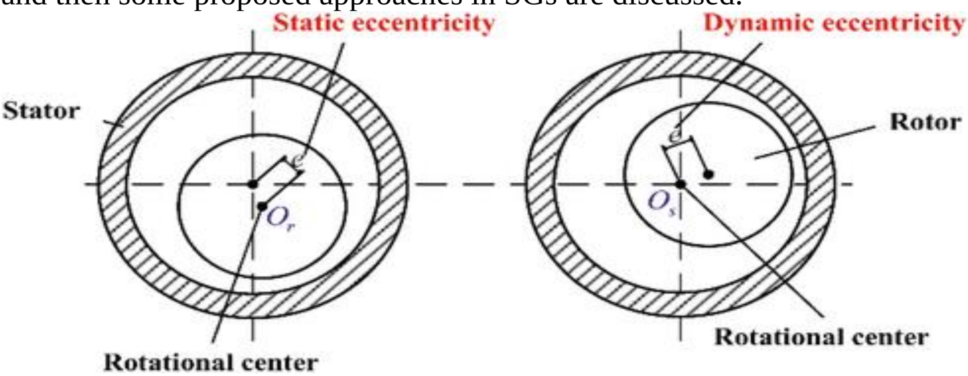

Figure 5

The eccentricity fault can be detected in large induction motors using line current and motor frame vibration. Besides, based on a new theoretical analysis has presented to diagnose SE and DE faults simultaneously. Search coil installation in stator slots is another approach for detecting the SE fault, which is not practical because the sensors must be fixed in the machine during the manufacturing process.

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The current harmonic analysis has been presented in Refs. The volunteer harmonic components are the 17th and 19th. However, the mentioned harmonics depend on the structure and geometry of the SGs. Moreover, these harmonics are similar to power network harmonics. Rotor current double-frequency ripple can be used for SE fault detection, where the impact of the regulator has been ignored.

The mixed eccentricity (ME) fault may occur in electrical machines, where both symmetrical and rotor rotation axes are displaced concerning the stator rotation axis. All stator, rotor, and rotational symmetrical axes are displaced concerning each other. The SE, DE, and ME faults in SGs are discussed in Ref. The ME fault diagnosis method has been also introduced for permanent magnet synchronous motors in Refs.

Damper bars are used in large SGs. These bars are located axially into the pole face slots, and two ends are connected. At starting, the rotor speed and synchronous speed differ, and currents are induced in the damper bars and develop the torque, which is called the asynchronous operation of the SG. Damper bars in SG are used to counteract an asynchronous air-gap flux caused by electrical and mechanical transients. Moreover, they are used in direct-online applications to bring the SG to synchronous speed. The damper bars damp the transient power and torque oscillations. The rotor speed oscillates around the synchronous speed in transition, and this oscillation should be damped by the damper bars. The damper bars in a steady-state mode are quite different from the fault condition. Hence, the damper bar fault detection methods in SGs is proposed here. The correlation of the broken bars fault in induction motors and the damper bars in SGs has been considered in Ref.

Although the current and thermal stress are considered for designing the damper bars, failure is possible due to the deficient construction of the damper cage or frequent and hard duty cycle. This kind of fault is not common in SGs, but it occurs in some SGs and leads to severe damage. Due to the similarity of the damper bars and induction motors cage bars and the probability of the broken damper bars fault, proposing the novel detection methods was not enthusiastic for researchers, and a few methods have been presented for fault detection. An online diagnosis method for damper bars breakage is presented in Ref. It uses a flux probe to measure the air-gap flux from the starting to the rated speed. Another method for diagnosing the broken damper bars in Ref. Hilbert–Huang Transform (HHT) based on the Empirical Mode Decomposition (EMD) method reported in Refs.

Temperature is a key parameter for broken damper bars fault detection, and temperature sensors are mounted on the rotor to measure the temperature rise during the fault. A resistance temperature detector (RTD) is one of the sensors used to sense the temperature. Besides, the temperature sensors have been reported in Ref. Therefore, temperature monitoring can be an easy and economical method for broken damper bar fault detection, but some believe that the mounted RTD is an invasive method. Some techniques such as the artificial intelligence (AI) approach help to improve diagnosis methods and their sensitivities. The AI application in electrical machines and drives is proposed in Refs. It also focuses on the stator winding fault diagnosis of induction motors.

In AI-based systems, several quantities such as stator currents and voltages, magnetic fluxes, and frame vibration are utilised as input signals. Generally, an expert system, an artificial neural network (ANN), a fuzzy neural network, and their combinations are the well-known methods in AI. ANN has been widely studied during the last 2 decades and successfully applied to dynamic system modelling as well as fault diagnosis.

Vibration monitoring has a long history in condition monitoring and is used in various electrical equipment. Recently, many have focused on thermal condition monitoring using infrared thermography. This apparatus identifies temperatures and hotspots of different locations. Thermography is used in induction motors and SGs for condition monitoring. The high cost of an infrared device is the main disadvantage of thermal monitoring methods. The above-mentioned methods can be combined to present a comprehensive approach which has the advantages of both for fault diagnosis. One of these methods uses air-gap flux, stray flux, and vibration to detect the rotor-winding fault in the hydro-generator precisely.

There are two key advantages of the presented algorithm for realising the monitoring system. The first advantage is the integration of the two methods for the measurement of magnetic flux. The applied measuring procedure includes a comparative analysis of the results of magnetic flux measurements with the results obtained by the system for measuring mechanical vibrations to approach fault detection comprehensively. The second advantage is the mobility of the monitoring system and its application without interrupting the generator operation (the case when the leakage stator flux is measured or when the system is connected with the previously built-in sensors in the air gap of the generator).

Capacitive sensors are installed on the surface of the stator, while the inductive sensors are fixed in the ventilation ducts of the stator. As shown, mounted sensors must measure the air-gap and stray flux first, and then the signal processing method is applied to determine the THD of stray flux. Any change in magnetic flux may be a sign of a fault in the SG. Therefore, vibration measurement can complete the fault detection process. The unbalanced magnetic flux and increased vibration show the rotor-winding fault, and the SG must be shut down immediately.

CONCLUSION

The current- and voltage-based methods are generally more useful than the flux-based ones, because these parameters can be measured as easily as possible by instrumental transformers. For this purpose, analysing harmonics in various conditions and using signal-processing techniques such as Wavelet and Fourier transform. Nowadays, vibration analysis is used for various fault detection in electrical machines and this processed vibration data can present much information about the SG condition, especially under mechanical faults. Apart from the mentioned parameters, the frequency spectrum of SG offers invaluable data about condition monitoring. In transformers, frequency-based methods are popular and it can be used in SGs.

All proposed methods can be combined by AI techniques (as a hybrid method) to increase their sensitivities. Moreover, AI can help researchers to reduce errors and prevent some catastrophic problems that can occur because of CT, VT or other sensor mal-operation.

This paper has tried to investigate why the aerospace industry still favours the classical WFSG as the main source of electrical power generation on board aircraft. Following a detailed but wide review of existing materials, this paper has shown how the direct controllability of the field for a WFSG, its robustness and the inherent reliability bottleneck of more advanced machine (PM, SR) drive families have all contributed to this trend. Following this, the paper then focused on highlighting the main challenge of such systems, their inherent low, system-level power density. The traditionally low operating speeds associated with WFSGs need to be increased by significant orders, even when considering the mechanical challenges associated with such rotating field systems.

The current state-of-the-art WFSG that exceeds all other systems is the generator developed and demonstrated by Honeywell that can achieve 7.9kW/kg at a rotor speed of 19,000 rpm. This demonstrator has shown that by overcoming the mechanical challenges associated with higher speeds, then a WFSG can achieve comparable power density levels to those coming from more advanced technologies such as PM and SR drives. Combining this improvement in power density with the traditional benefits of wound field systems (controllability, reliability and robustness), then it can be perceived that the WFSG still has a lot to offer even in such harsh and demanding environments as that of the aerospace industry.

The faults we have seen in this paper are uncertain and opportunistic; they may arise in any course of time irrespective of on-time and in-time operations. When they arise they should be diagnosed and eliminated to keep the system running efficiently and smoothly. Otherwise, they may cause severe damage to other systems and the persons working in that environment. By this study, we can draw some conclusions that are.

- All faults lead to distortion of stator current (Is). So by analysis of „Is" we can detect the presence of fault.

- Air gap is an important parameter in a motor, it should be uniform. The motor should be well installed.
- Conductance of the winding conductor should be high. So that heat generated H= I2R is minimum.

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