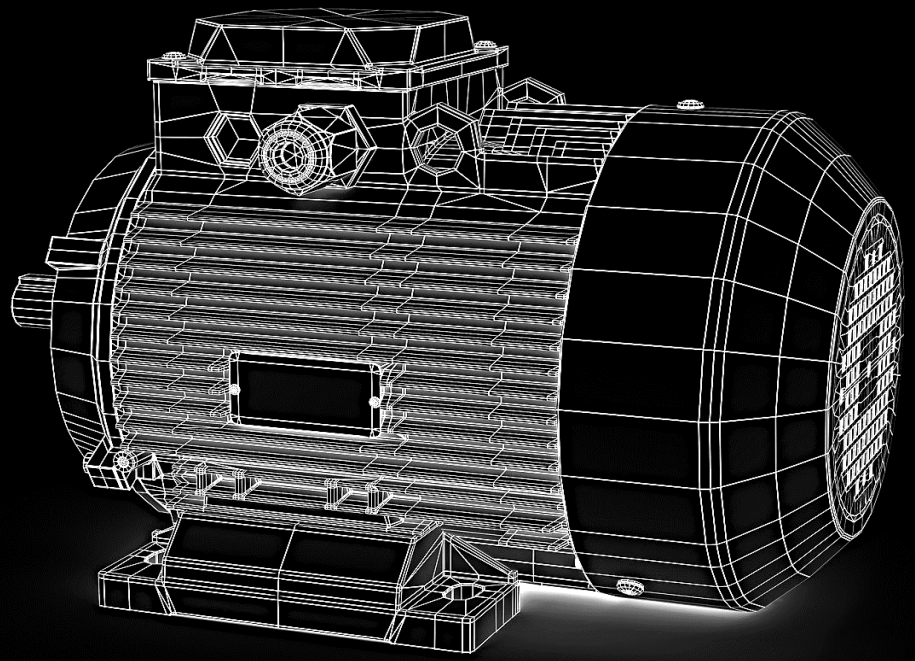

REDUCTION OF BEARING CURRENTS

CONDITION MONITORING

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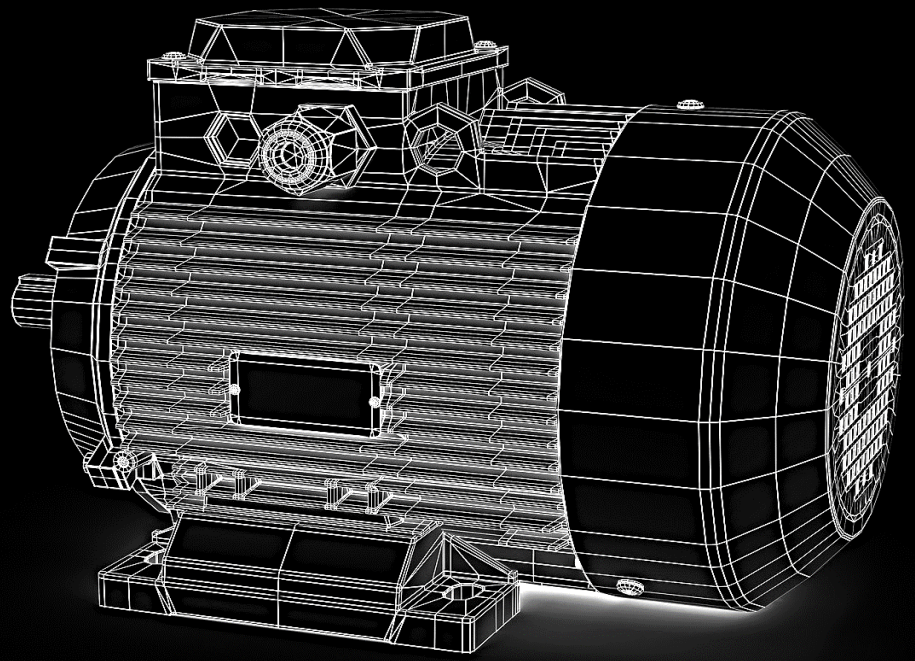
REDUCTION OF BEARING CURRENTS

INTRODUCTION

- Strategies for reduction of bearing currents can be divided into three major categories:
  - Insulating and conductive components (insulated bearings and shafts, conductive grease, grounding brushes),
  - Non-motorized measures (filters, ground, magnetic coupling, frequency converter parameters),
  - Motor reconstruction (Faraday shielding, increase of rotor impedance).



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INSULATED BEARINGS

REDUCTION OF BEARING CURRENTS

INSULATED BEARINGS

- In motors controlled by frequency converters, shaft currents have the greatest effect on the motor bearings, where the bearing surfaces are damaged quickly and irreversibly by spark discharges.
- In this case, the lifespan of the bearing is determined by the number of spark solutions and their intensity.
- As a result, bearing can deteriorate tens of times faster. bearing can deteriorate tens of times faster.
- The larger the device, the more complicated and expensive it is to replace the motor bearings.

REDUCTION OF BEARING CURRENTS

INSULATED BEARINGS

- In the case of motors with a power of more than 100 kW, to reduce bearing currents, there are recommended following solutions in priority order:
  - Insulated bearings,
  - Insulated shaft,
  - Insulated housing of the bearing,
  - Insulated rings,
  - Hybrid bearings,
  - Ceramic bearings,
  - Magnetic bearings.

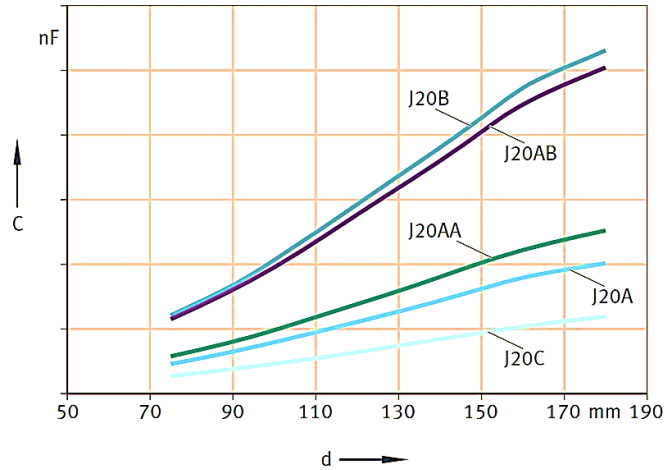
REDUCTION OF BEARING CURRENTS

INSULATED BEARINGS

- The most common method to eliminate the bearing currents is to use insulated bearing(s). An insulated bearing is a completely ordinary steel bearing, which inner and/or outer rings are covered with a ceramic material.
- Usually, this material consists largely of alumina (Al_2O_3). An insulated bearing is 5…10 times more expensive than a common bearing. Since the usage of an insulated bearing increases the price of the electrical machine by ~15%, insulated bearings are usually not included in the standard equipment of smaller motors.
- Many of motor manufacturers provide solutions for the reduction of bearing currents with the usage of only one insulated bearing. This solution can help to reduce the high-frequency shaft currents circulating in the motor.
- In the case of motor failure, it is also advisable to replace the insulated bearing in order to reduce the risks associated with the dismantling and installation.

REDUCTION OF BEARING CURRENTS
INSULATED BEARINGS

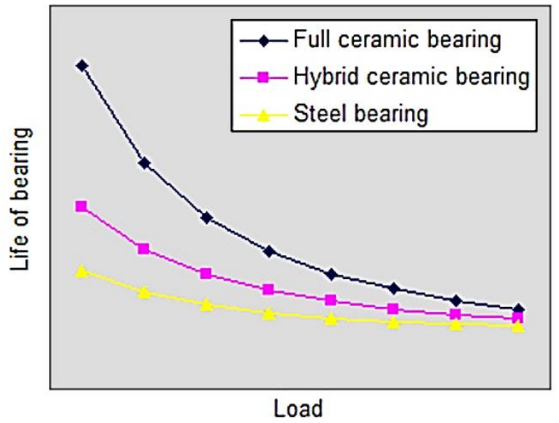
- If the motor has two insulated bearings, the following should be considered:
  - There is a potential difference between the motor shaft and the housing, which can be up to 10% of the motor supply voltage, or in some cases even greater, as shown in graph.
  - Shaft voltage can be dangerous to people and to motor-related equipment (such as a tachometer or equipment connected to the motor shaft).
- Purchasing a new motor controlled by a frequency converter, it can be reasonable to choose a motor with an insulated shaft instead.

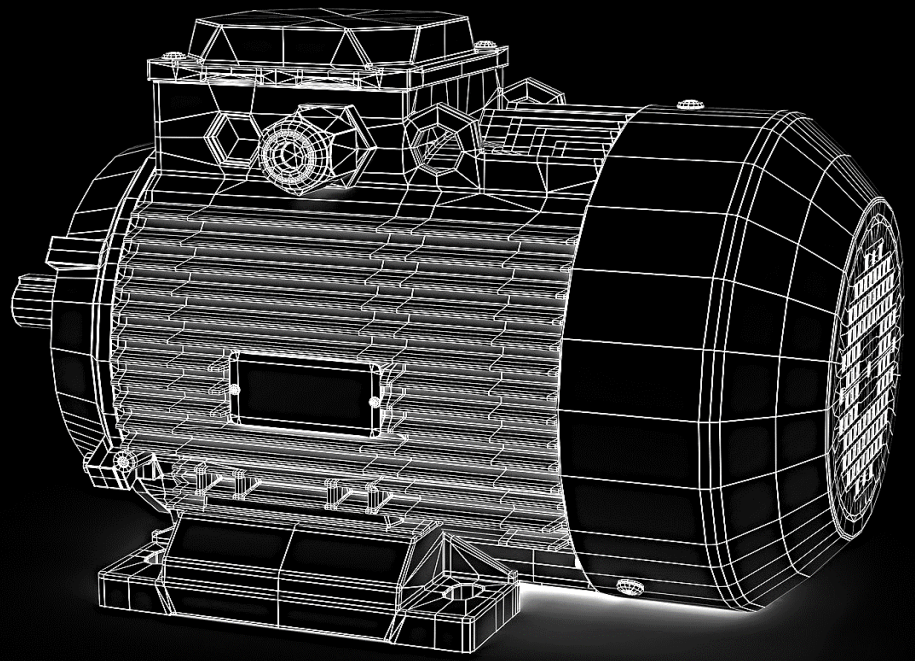


REDUCTION OF BEARING CURRENTS

INSULATED BEARINGS

- Only in case of ceramic, hybrid or magnetic bearings, shaft currents can be completely avoided.
- As common metal bearings, the housings of hybrid bearings are made of metal. However, the rolling elements are usually made of ceramic.
- The housing of hybrid bearing is made of metal, while the housing of ceramic bearing is made of ceramics.
- Magnetic bearings have many advantages over the common bearings, some of them are as follows:
  - No vibration,
  - Lubrication is not required,
  - No friction,
  - Can be used at high speeds (up to 40 000 rpm),
  - Extended lifespan.





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CONDUCTIVE GREASES

REDUCTION OF BEARING CURRENTS

CONDUCTIVE GREASES

- The generation of bearing currents and their magnitude in motor bearings are directly related to the dielectric properties of the lubricant used. Generally, bearing lubricants can be conditionally classified as follows:
  - Conductive greases, which have electrical resistivity in the range $10^2 \ldots 10^5$ Ω·cm,
  - Non-conductive greases, which have electrical resistivity in the range $10^7 \ldots 10^8$ Ω·cm.
- If there are used lubricants with low electrical resistivity, the bearing capacity is relatively small and their electrical conductivity is generally sufficient to direct the currents to flow them from the rotor to the motor housing safely and without damaging the bearings.
- To increase the electrical conductivity, metallic dust is added to the lubricant, which reduces the relative dielectric constant of the lubricant by 1000 times.

REDUCTION OF BEARING CURRENTS

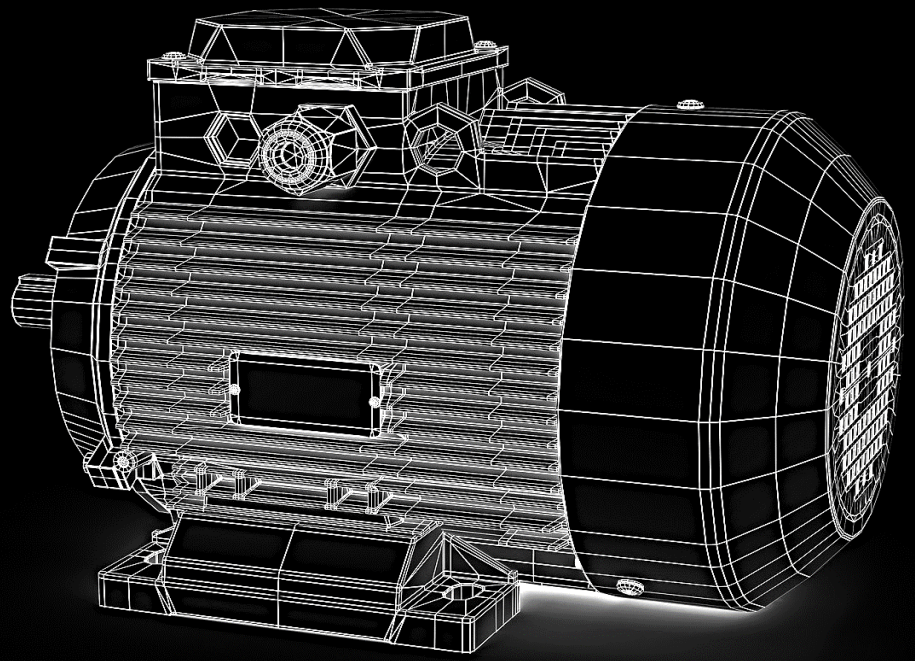
CONDUCTIVE GREASES

- Using conductive greases, it must be considered these greases shorten the lifespan of the bearing by about three times.
- Because of the extremely abrasive conductor debris contained in the grease, microcracks are to be created on the bearing surface, especially in case of high rotational speed.
- Besides, electrical conductivity of the lubricant is not constant and depends on the operating conditions changing over the time.

REDUCTION OF BEARING CURRENTS

CONDUCTIVE GREASES

- Although the use of a conductive lubricant is the cheapest and fastest way to solve the problem of bearing currents, this method may be recommended rather than a temporary solution.
- Due to the spark solutions, metal debris is released from the bearing surface, which gets into the lubricant and significantly increases the electrical conductor properties of the lubricant.
- During sparking, the lubricant and impurities oxidize, causing the grease to darkening, shorten the life of the lubricant and degrade lubrication properties.



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SHAFT GROUNDING CONTACTS AND RINGS

REDUCTION OF BEARING CURRENTS

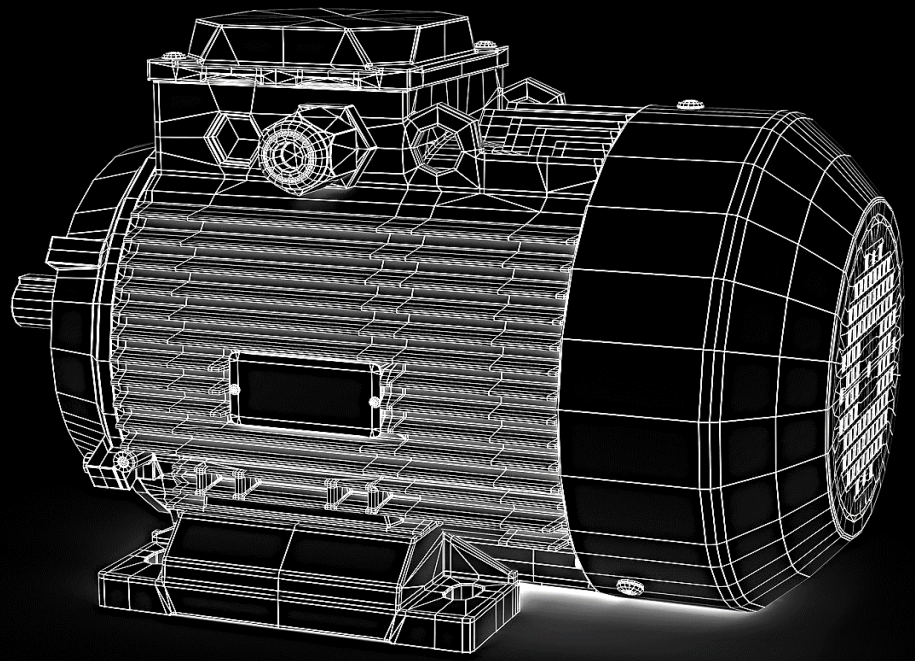
SHAFT GROUNDING CONTACTS AND RINGS

- Basically, there are two methods to protect the motor controlled by frequency converters from shaft currents and spark solutions are:
  - Dielectric separation between the motor shaft and the housing so that the bearings cannot pass through the bearings,
  - Creation of electrical connection between the motor shaft and the housing, for which the shaft grounding contacts and rings are well suited.
- The operating principle of grounding contacts is identical to the brushes used to feed the windings of the DC motor. The lifespan of the brushes is mostly determined by the compressive force of the electrical transmission with which the brush is pressed against contact. The higher the pressure, the faster the brush wears.
- Grounding rings are made from hundreds of thousands to millions of carbon fibers, which are only a few microns in diameter and about ten millimeters in length.

REDUCTION OF BEARING CURRENTS

SHAFT GROUNDING CONTACTS AND RINGS

- Grounding contacts can have an uneven electrical contact. In this case, brushes are to be changed and monitored constantly.
- The installation of the grounding ring is not more complicated than the grounding contact.
- However, since the microfibers of the grounding ring are in minimal contact with the shaft (or there is no direct contact), it is recommended to cover the fibrous part of the motor shaft under the grounding ring with a special conductive silver paint.



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CHARACTERISTICS REGULATION OF FREQUENCY CONVERTERS

REDUCTION OF BEARING CURRENTS

REGULATION OF FREQUENCY CONVERTER

- Basically, bearing currents can be caused by the following non-adjustable technical characteristics of the frequency converter:
  - Frequency converter power electronics (design and components),
  - Presence of built-in filters,
  - PWM topology,
  - Frequency converter power supply type.
  - Operating principle of frequency converter (frequency control or vector control).
- The number of power electronics output stages in the frequency converter has the largest and most decisive effect on the generation of bearing currents.
- The vast majority of frequency converters used in industry are two-level, but already at the output of a three-level frequency converter, which minimize or even eliminate the risk of spark discharges in motor bearings.

REDUCTION OF BEARING CURRENTS

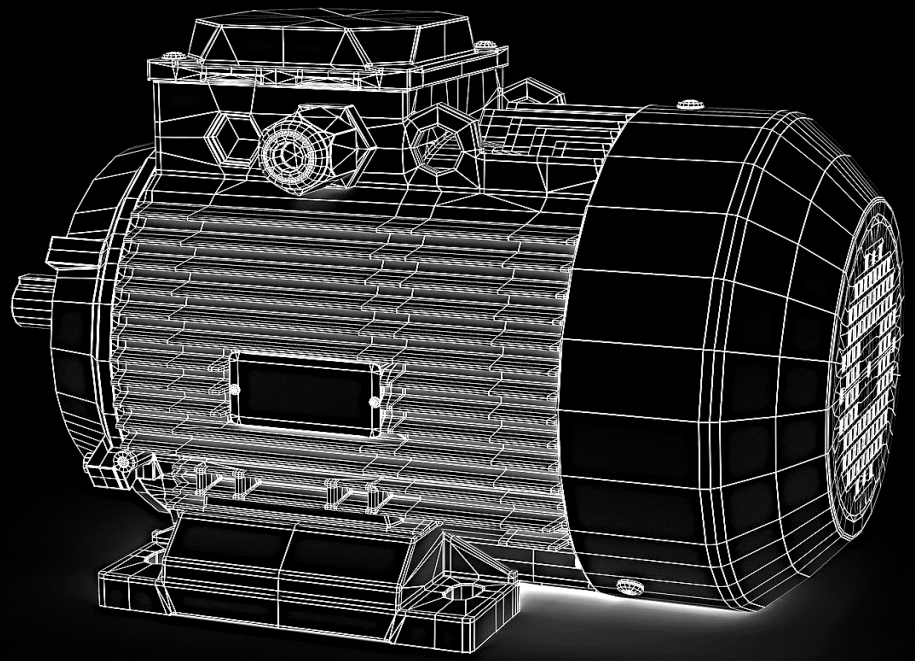
REGULATION OF FREQUENCY CONVERTER

- Although multilevel frequency converters significantly reduce motor leakage currents, multilevel inverters are very expensive, so it may still be more economical to choose a two-level inverter with integrated filters to reduce shaft currents and interference.
  - Standardly, there are used the following filters:
  - dU/dt filter,
  - Sine wave filter,
  - Filter for reduction of higher harmonics,
  - EMC filter.

REDUCTION OF BEARING CURRENTS

REGULATION OF FREQUENCY CONVERTER

- Purchasing a new frequency converter, it is recommended to choose the PWM topology, which allows to reduce the generation of shaft currents (switching frequency is supposed to be low).
- For example, Soft-Switching PWM is suitable, which allows the motor to be operated at a relatively low switching frequency.
- In theory, there are also proposed many different PWD methods have been proposed, such as Zero Common-Mode PWM (ZCM), Zero Common-Mode Subharmonic PWM (ZCM-SPWM), Active-Zero-State (AZS), Remote-Three-State (RTS), Nearest-Three-State (NTS).
- However, different strategies can degrade the efficiency of the frequency converter or increase the higher harmonic generation. Due to what these algorithms have not found practical usage.



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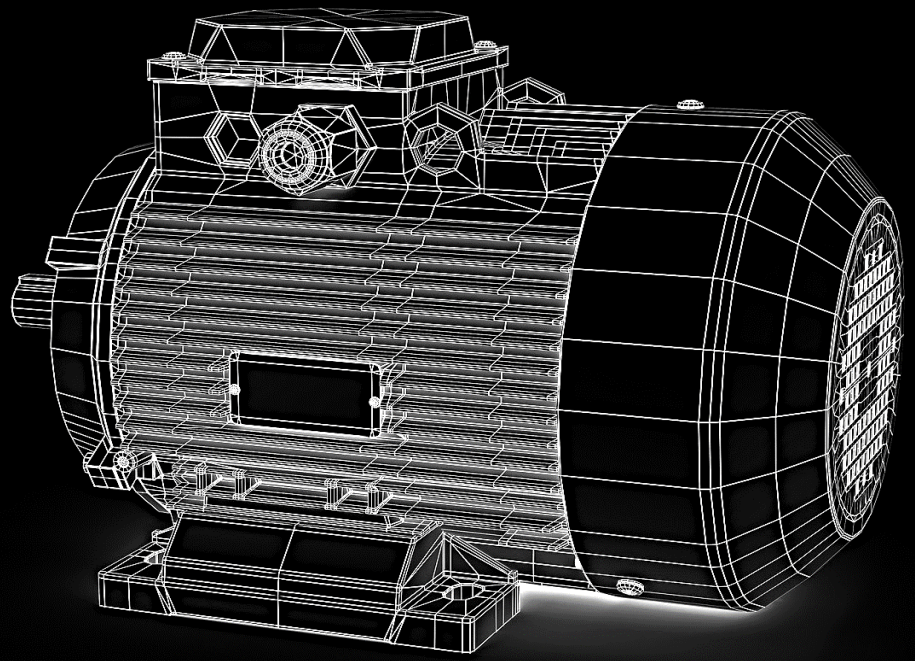
COMPARISON

REDUCTION OF BEARING CURRENTS

COMPARISON

Method	Effect	Comment
One insulated bearing	Ineffective	The circulating currents are reduced in the motor, but the lifespan of an uninsulated bearing is likely to be shortened.
One insulated bearing and grounding contact	Effective	The ground brush or ring must be on the non-insulated bearing side. Additionally, there can be used a common mode filter.
Two insulated bearing and grounding contact	Very effective	Very efficient solution with the usage of common mode filter.
Hybrid or ceramic bearings	No spark solutions	Very effective. Most likely the best solution for small motors.
Conductive grease	Effective if bearing currents are low	This is recommended as temporary solution only for smaller motors. Bearing currents increase and the lifespan of the bearing is reduced in several times due to the composition of the lubricant.
One grounding contact or ring	Effective	Regular maintenance is required for the grounding brush. The solution is suitable for smaller motors. There can be used a common mode filter.
Two grounding contacts or rings	Very effective	The solution is better suited for smaller motors. Regular maintenance is required for the ground brush. For larger motors, it is also recommended to install insulated bearings.
Correct ground and cabling	Longer cables can reduce currents	Proper grounding and cabling is a prerequisite for solving the problem. The main circulating leakage currents are reduced, as is the risk of motor insulation failures and disturbances.
Common mode filter (passive)	Relatively effective	The cheapest and most efficient of the filters. Reduces high frequency currents. In the case of large motors, additional measures are definitely needed.
dU/dt filter (active)	Decreases a bit in case of larger motors	To be used for the highest output voltage (from 690 VAC).
Sine wave filter	Decreases	The reduction depends on the filter, but in any case only the circulating shaft currents are reduced. The most expensive of the filters. Significant heat losses must also be considered.



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THANK YOU!