Low-resistance fields in DC motors; application and testing

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Ground faults, short circuits and bad connections in **interpole coils, series coils and compensating windings** cause performance problems in DC machines, including brush sparking, flashover, stalling and catastrophic failure. Shunt coils have many turns of relatively small wire and are usually excited by a DC source independent of the armature. Series, interpole and compensating coils in the armature circuit usually are wound with a few turns of heavy wire as these coils carry armature current.

For accurate test results, make sure windings are clean and dry. Verify connections of low resistance fields by visual inspection. Apply DC voltage to an assembled field frame and perform a thermography scan to detect problems including uneven heating and loose or corroded connections. Verify that the terminal lead markings are correct. Lead marking should conform to the original equipment manufacturer (OEM) nameplate, NEMA MG1 or IEC 60034-8, whichever is applicable.

Straight series machines

Straight series field machines provide high starting torque for traction motors, mill motors, cranes and starter motors for gasoline and diesel engines. For these motors, series field strength increases and shaft speed slows with increasing load. A series motor with an open field coil will not start. See **Figure 1**.

Test for continuity in the series coil. Test series coil insulation resistance to ground using a 500V insulation resistance tester. Minimum coil resistance to ground should be temperature corrected to 40° C.

For straight series-wound machines with no shunt fields, apply approximate-rated armature current AC to each coil to test for shorted turns. Use an AC welder or other adjustable low-voltage AC power supply. Add resistance in series with the test circuit if you need to control the current. The current recorded for each coil should be within 10% of the average current. Reduce test current for series parallel connections.

For greater resolution in the test, a 400 Hz alternator can be useful for the AC drop test on series coils. Be sure to verify correct polarity of the coils. Be sure to hipot according to *ANSI/EASA AR100-2015: Recommended Practice for the Repair of Rotating Electrical Apparatus*, Section 4.

Interpole coils

Interpole coils help stabilize the effects of armature action that causes field distortion and associated brush sparking in DC machines. Properly functioning interpoles become magnetically stronger with increasing armature current. Test the integrity of interpole ground insulation and turn insulation, check for connection problems and inspect for correct polarity of the coils. Also verify air gap is uniform and shims are in the correct order, where applicable. See **Figure 2**.

> *"Validate the results of the AC voltage drop with a DC voltage drop test and compare results. The AC voltage drop should be within 10% of the average and the DC voltage drop should be within 5% of the average."*

Good ground insulation is the main concern for interpoles. Perform insulation resistance testing at 500V DC.

A surge comparison can be a good shorted turns test for interpole coils. The minimum surge test value should be 350V per turn. For maximum surge level, do not exceed (2E + 1000) VAC for new windings and 65% for reconditioned ones. Surge and compare result for each interpole to the coil on each side of it. The interpole surge test can be misleading since the impulse may dissipate too quickly in some applications. Verify results with the pole drop and impedance tests.

The AC pole drop test can also be a useful method to detect shorted turns in interpoles. Do not exceed armature current. Outside magnetic influences may distort the results of the surge test and AC drop test.

Validate the results of the AC voltage drop with a DC voltage drop test and compare results. The AC voltage

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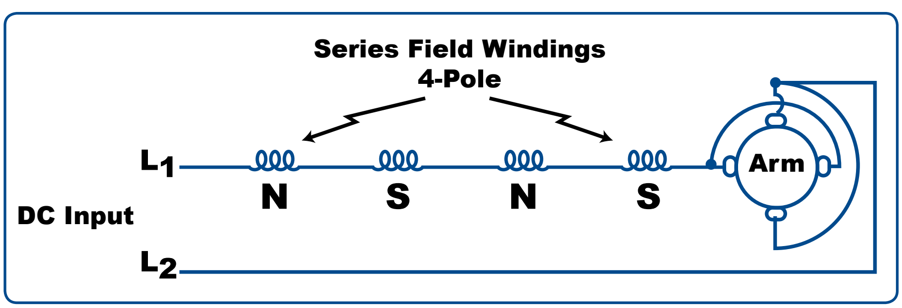

Figure 1. Series fields.

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drop should be within 10% of the average and the DC voltage drop should be within 5% of the average.

Use the AC impedance test to detect shorted turns in interpole coils. Separate the circuit and apply the same low voltage to each coil and compare current. The current recorded for each coil should be within 10% of the average current. Coils with shorted turns will draw higher current. Make sure the test current does not exceed nameplate rating.

After the interpole coils are reassembled into the frame, verify correct polarity of the poles in relation to the main fields and relative to the armature. Hipot interpole coils using test values in *ANSI/EASA AR100-2015*, Section 4.

Stabilized shunt and compound machines

Series fields work together with shunt coils in stabilized (stab) and compound machines. Stab and compound are very similar in appearance and connection but the purpose of the series coil and number of turns is different for each of these two types of motors. See **Figure 3**.

Compound machines combine the benefits of series and shunt motors with good torque and speed control. In compounded fields, the polarity of the series and the shunt may be the same (cumulative) or opposite (differential). Most compound machines are cumulative.

The stab coil helps guard against instability of the motor in a field-weakened state and usually has fewer series turns than the compound. Also, there may be fewer stabilizing fields than shunt fields. For example, a four-pole motor may have only two stabilizing fields. The polarity of the stabilizing field is always the same polarity as the shunt field below. In rare cases, the designer might decide the series fields are too strong. To weaken them, a shorting jumper is sometimes used across two diagonally opposite series fields. That usually takes the form of a rectangular wire curled and connected to partially bypass the series. When performing an AC voltage drop test, the jumper must be disconnected to avoid false indications of a shorted coil.

For compound and stab coils, first check continuity to verify no open circuits are present. Use 500V megger to verify acceptable insulation resistance (IR) between the series fields and the shunt coil. If a series field is shorted, the AC voltage drop across the shunt field will be greatly skewed. A compound or stab motor with an open series field will not start. Verify the polarity of the series vs shunt matches the original. Refer to the May 2004 *Currents* article "Simple Tests to Assure Proper DC Performance."

When shunt fields are present **DO NOT** apply AC voltage to series coils. A very high voltage can be induced into the shunt by transformer action. Drop test the shunt field with AC and measure the voltage induced across the series.

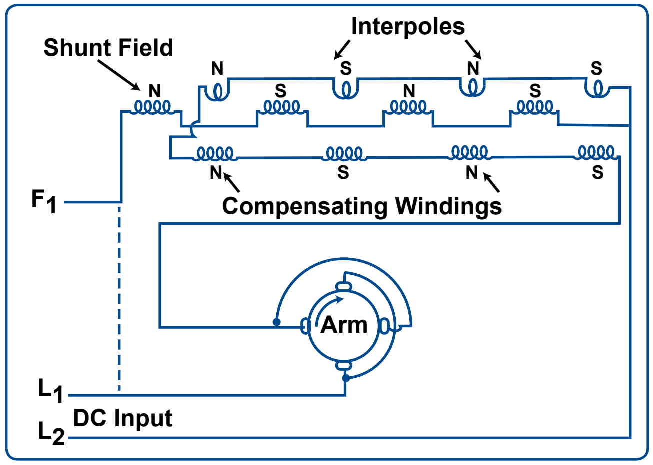

Figure 2. Interpole circuit.

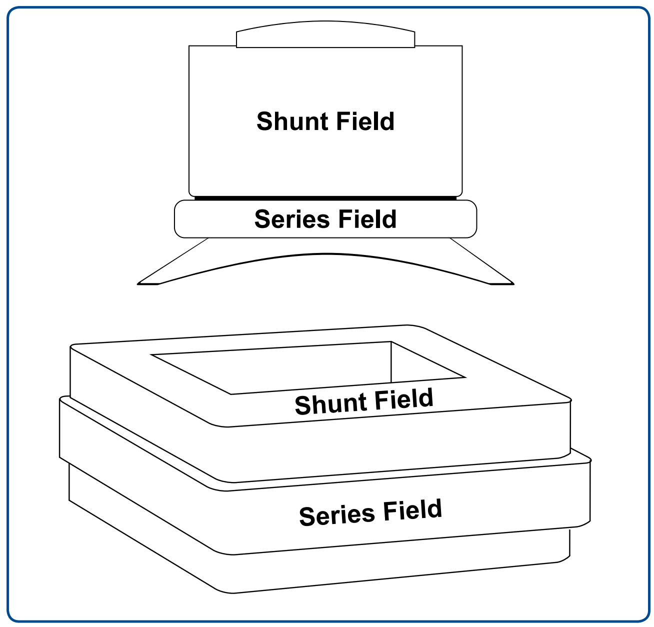

Figure 3. Stab shunt and compound coils.

Compensating windings

The compensating (comp) or pole-face winding is an extension of the interpole coil and helps mitigate brush sparking under severe loading such as large mill motors and reversing applications. Comp coils may be copper bar one-turn coils or there may be two or more turns in the slot. Comp windings can also be made with random coils.

The compensating winding is embedded in the face of the main pole. The pole face winding reduces bar-to-bar peak voltage and risk of ring fire and flash over. These windings are particularly prone to low IR readings due to the presence of carbon and other contaminants.

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Test compensating windings with a 500V insulation resistance test to ground. Expect low IR readings when performing the comp bar megger test with bars fully connected. The number of poles times the number of bars per pole gives a DC circuit with (bars x poles) parallel branches. For example, an 8-pole DC machine with 10-pole face bars per pole = 80 parallel legs. Consider 80 comp bars fully connected in parallel and each bar individually megs 500 MΩ. The total connected resistance-to-ground would measure 6.25 MΩ. The only way to know the IR for sure is to separate the connection.

Discover shorted turns in comp windings with thermography. The AC drop test would also work.

High potential test the comp winding according to *ANSI/EASA AR100-2015*, Section 4. ●