UNDER LOADED MACHINES

A machine is underloaded when it works below its normal rating.

If the machine works in cycles of normal load, separated by periods of variable duration at no load, the underloading is temporary, but if the machine never attains normal load it is under loaded permanently; it is too big for its job.

Of all the components of an electrical rotating machine, the brushes and the commutator are perhaps the only items that suffer and sometimes dangerously so when underload is prolonged.

CAUSE AND EFFECT

In normal conditions of use a brush wears by mechanical and electrical effects.

When a machine rotates at no load the current is nearly zero and the electrical wear of the brushes is also nearly zero; the skin is starved of graphite; the friction between brush and commutator increases strongly and quickly due to glazing of the contact surfaces. The brushes become noisy and vibration develops with increasing severity to the point of brush destruction and in the extreme the destruction of the pressure fingers and springs on which the brushed rely to maintain contact.

ESTIMATION OF UNDER LOAD

As the current density is found from the current (in A) in the brush divided by its cross section (in cm^2) then for a machine having p poles and b brushes per pole each of section s (cm^2) and a total machine current I (A) the density is given by:

$$J_B = \frac{2\,I}{b\,p\,s}$$

At the nominal load the density is $\frac{2\,I_n}{b\,p\,s}$ where I_n is the nominal current as indicated on the machine name plate.

With a variable load it is necessary to consider the extreme values I max and I min and also the average value I_{av} of the current in the machine so giving three characteristic values for current density to compare with the normal density: I_{av} can be easily assessed from the graph of a current recorder especially if the load cycle is repetitive.

Underload exists when $I_{av} < I_n$ and the degree of underload is deduced from I_{av} / I_n.

The degree of underload must not be confused with the load factor.

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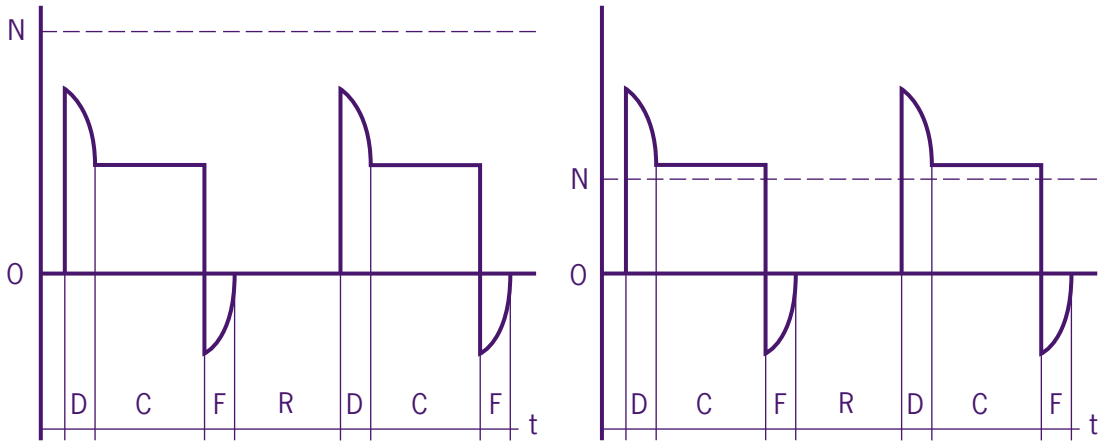
Where a cyclic load operation requires a period of no load between successive cycles, the load factor is the ratio of the on-load time to the total running time as indicated in the diagrams of *fig. 1*.

The two parameters, degree of underload and load factor have values less than 1 for machines having both a cyclic load and a permanent under load.



N: nominal current

$$\text{Load factor} \quad \frac{D + C + F}{D + C + F + R}$$

D: starting period

C: constant load period

F: braking period

R: no load period

Fig. 1

REMARKS

It must be noted that the aptitude of a brush to support prolonged underload depends greatly on the characteristics of the material from which it is made.

To speak only of electrographitics (EG group) it must be remembered that the "grey" low resistance grades form thick glossy skins and support no load conditions better than "black" higher resistance brushes which deposit little graphite and form light transparent skins.

This superiority of the "grey" over the "black" grades is limited to low load applications. For high or overload conditions the inverse is true i. e. "black" grades commutate better than "grey" grades and can better support high peak currents.

By example and as an approximation it can be said that the "grey" grade EG 389 P can handle without difficulty current densities as low as to 3-4 A/cm^2 for prolonged periods (on a skin previously formed) and overloads, of short duration, up to 13 or 14 A/cm^2, whilst the black grade EG 319 P in otherwise same conditions can support temporary peaks of 18 to 20 A/cm^2, but does not much care for currents below 7 or 8 A/cm^2, if it has had no special treatment previously.

REMEDIES FOR THE PROBLEMS DUE TO PROLONGED UNDERLOADING

When the characteristic symptons appear it is necessary to modify the brushes to prevent deterioration of the machine.

The situation is the result of a poor patina or its complete disappearance; it can be restored by the following action:

– reduce the number of brushes. This is a simple and rapid solution.

Under conditions of continuous load (phase C *fig. 1*) sufficient brushes must be retained to ensure that the current density does not exceed 12 A/cm^2 . By contrast, for short duration (phases D and F) a current density between 14 to 20 A/cm^2 can be sustained by the same grade.

In addition, it is desirable to reduce to a minimum the number of brush tracks on the commutator to obtain the maximum lubricating benefit from the brushes by reducing the surface area on which the patina is to be developed.

– change the brush grade

It is necessary to make this change when the above expedient does not solve the problem because the number of brushes remaining restricts the range of the machine when taking account of the underload running that is too low for the grade of brush in service.

Usually using brushes of lower resistivity provides a better commutator patina but the level of commutation is not quite so good.

Often the use of a resin or wax in a brush will make the brush less sensitive to underload running whilst not affecting its commutating ability.

Because of the foregoing the choice of a grade is always a compromise between the machine problems on load and when running under loaded.

OBSERVATIONS

1) When reducing the number of brush tracks with brushes staggered circumferentially (Technical note STA BE 16-23) it is necessary to ensure that the same arc of contact is retained with the remaining brushes.

With such brush staggering especially with 3 tracks of brushes having 2 brushes on the neutral line (positions 1 and 3) and one brush advanced (position 2) as shown on *figure 2*, the reduction must be made by removing a brush from either position 1 or 3 but not from position 2.

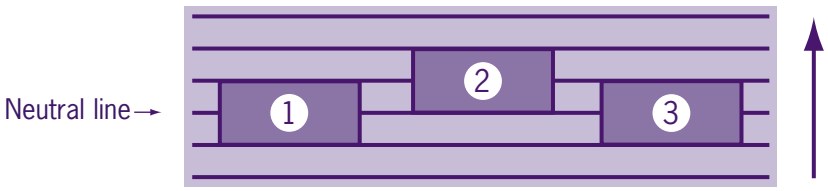


Fig. 2

2) In practice, quite often in modern machines a powerful flow of cooling air is used, drawn from outside the factory etc., or from a water cooled heat exchanger designed for water at a temperature of 25°C but often this water is at a temperature of only 10-12°C resulting is excessive cooling.

Also, an underloaded machine operates at low temperatures.

Because of these factors the commutators of these machines are at low temperatures.

Generally, a patina will not develop when the temperature of copper of the commutator is less than 40°C.

3) On machines where the power does not exceed 150/200 kW and operating under stable conditions without interruptions or overloads (10-12 A/cm^2 maximum in the brush) good results can be obtained with grade BG 469 (BG group). Under these conditions and provided the commutator temperature is adequate, satisfactory performance can be obtained at current densities of only 1 A/cm^2.

This grade should not be used on shunt excited generators if the voltage is less that 100 V because of difficulties of excitation.

Imprimé en France - S.I.C. - CHATEAUNEUF sur LOIRE - 02 38 58 63 63

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