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**Abstract.** An inverter can be used to supply a voltage waveform containing more than one frequency component to an induction machine in order to cause full-load currents to flow in the conductors of both the rotor and stator. Unlike the usual mixed-frequency test where (typically) a 0.1 p.u. sinusoidal voltage at 40 Hz is superimposed on a 1.0 p.u. sinusoidal voltage at 50 Hz to supply the machine, the use of an inverter allows the machine tester to have relatively comprehensive control over various quantities which determine the rate at which power is dissipated inside the induction machine. In particular, though conventional practice can cause the correct r.m.s. currents to flow in the stator conductors, it is not generally possible to also ensure that other losses are the same in the mixed-frequency test as they would be during full-load operation of the machine.

This paper reports the use of a digital simulation of the induction machine and inverter system to investigate the effects of different possible forms of the mixed-frequency test using an inverter supply. The model used for the induction machine simulation is a phase equation model which has been accelerated by a method developed by the authors.

**Keywords.** Induction machine, inverter, mixed-frequency.

## 1. INTRODUCTION

The testing of induction machines to determine the power dissipated as heat and the associated temperature rise is a matter of interest to both customers and manufacturers alike. High temperatures cause deterioration of insulation materials and high rates of power dissipation necessarily mean low efficiency values. The power losses of induction motors are categorised as electrical and mechanical losses. Some of the electrical losses can be predicted reliably from the machine design but some components are less predictable (particularly the stray load losses). Similarly, there is still a substantial amount of uncertainty attached to the prediction of the cooling properties of a machine.

The only heat run which is completely accurate involves loading the shaft of the induction machine by mechanically connecting it to another machine of the correct rating. This ensures that the correct power losses occur inside the machine and also ensures that the airflow will match that obtained when the machine is in service. Unfortunately, this is a very expensive form of test for several reasons known to every manufacturer of large electrical machines. Not least among these is that a large load machine fitted with the correct half-coupling must be available for the test.

To avoid this expense, other approximate forms of the tests have been devised. With synchronous machines and DC machines, it is common practice to perform "back-to-back" tests using two identical machines when such a pair exists. For induction machines (particularly cage-rotor machines), back-to-back testing is much

more difficult because the load machine has to be fed with a lower-frequency supply than the driving machine if the two shafts are directly coupled. Some methods have been developed (for example Morris [1]) whereby a gearbox is fitted between the shafts of the two machines to accommodate the difference in speeds but this re-introduces the potential problem of having matching half-couplings.

Other approximate forms of the test involve two machines which are connected together electrically. The "phantom loading" test is one example (Fong [2] and Ho [3]) which involves the introduction of a DC voltage source in the connections between the terminals of the two machines. With only one degree of freedom under control, it is clear that, at best, one match may be made between the power losses in the machine on full load and the power losses in the machine on phantom loading test. Ho [3] effectively employs the assumption that overall losses will be correct if rated stator current is produced.

For slip-ring induction machines, a method exists called the "superimposed frequency test" which involves feeding harmonic currents into the rotor from an auxiliary supply. Romeira [4] expounds such a test. Unfortunately, the vast majority of induction machines are cage machines and the proportion is rising.

Plevin [5] reports that, for the testing of standard frequency large output cage-type induction machines, a method called "the forward short circuit test" has been developed by GEC Large Machines Ltd and has been applied for more than 40 years to wide range of machine designs up to 21 MW. This test involves