A GRAPHICAL TREATMENT OF THE INDUCTION MOTOR

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A graphical treatment of the induction motor by Alexander Heyland

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ALEXANDER HEYLAND

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BY

ALEXANDER HEYLAND

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G. H. ROWE and R. E. HELLMUND

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A GRAPHICAL TREATMENT OF THE INDUCTION MOTOR.

The object of the method described in the following pages is the experimental determination of the characteristic properties of induction motors. It consists essentially in the practical application of the circle diagram, first described by the writer in 1894.* It is based on two simple and quickly performed experimental tests on the finished motor.

The method shows at a glance the main properties of a motor and its commercial excellence. The writer has used the circle diagram several years in the testing room for comparing calculated values with results obtained from tests, and it has well served its purpose.

Before describing the method and its applications, perhaps I may be allowed to present briefly the theory of the induction motor, and the derivation of the diagram.

GENERAL THEORY OF THE INDUCTION MOTOR.

The induction motor is in principle a transformer. The exciting member *A* (Fig. 1) represents the inducing or primary circuit; the short-circuited member *B* repre-

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*Elektrotechnische Zeitschrift, Oct. 11, 1894, p. 561.

sents the induced or secondary circuit. The alternating fields produced by the current in the exciting coils combine in the well known manner to form a rotating field. The motor is, therefore, a *transformer with a rotating field*, and the load of the system is determined at any time by the difference between the constant speed of rotation of the field produced in the stationary member A, and that of the rotating short-circuited member B. The turning of the rotor is due

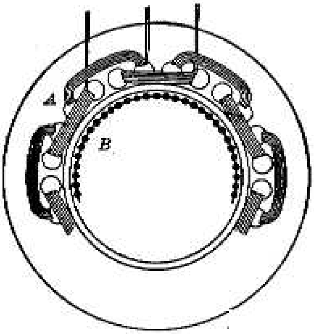

FIG. 1.

to the torque existing between the rotating field and the currents produced in the short-circuited member by rotation in the field. These currents, and therefore also the torque, vary directly with the product of the slip and the field interlinked with the secondary conductors.

The slip is defined as the difference between the speed of rotation of the exciting field, and that of the short-circuited secondary. The variation of the slip in the induction motor has the same significance as the variation of load of the ordinary transformer, due to a change of its external resistance.

With constant impressed electromotive force, the field produced by the current in the primary winding is constant for all loads, as in the transformer. This, however, is not true in the short-circuited member, which is the real work transmitting element. Herein lies the essential difference between the induction motor and the transformer without leakage, in which, as is well known, the total primary field passes through the secondary. Since there must, of necessity, be an air-gap between the short circuited windings and the primary windings, not all of the magnetic lines ϕ induced in the primary member pass through into the secondary. But a part ϕ_s passes directly through the space between the two windings back into the primary member, and only the *difference $\phi_A = \phi - \phi_s$ passes into the short-circuited member. This field ϕ_A produces, in the latter, currents which lag, according to the law of induction, a quarter period behind the field, *i.e.*, they are in quadrature with the inducing field, and therefore the torque produced is proportional to the product of induced currents and primary field.

The lines ϕ_s are called leakage lines or leakage field, and since they are caused by the primary current I_1

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*In fact there is not only a primary leakage, but also a secondary leakage that is a flux which is interlinked with the secondary conductors only. It is however admirable, and simplifies further considerations, to assume that the primary and secondary leakage fluxes are combined to form one single leakage flux—i. e. the primary leakage flux ϕ_s. The inexactness introduced thereby is of no practical importance in the results obtained from the following derivation.—ROWE HELLMUND.

only, they must be proportional to it. If we designate the reluctance of the leakage path by ρ_s, then we have

$$\phi_s \propto \frac{I_1}{\rho_s}$$

The main field, as in the transformer, is of constant amplitude $= \phi$. Therefore, the armature field ϕ_A is given by the difference between the main field and the leakage field $\phi_A = \phi - \phi_s$ (Fig. 2), and is produced by the difference between the ampere turns of the primary and secondary circuits. If we call the resulting magnetizing current, I, and the reluctance of the path of the secondary field ρ, then

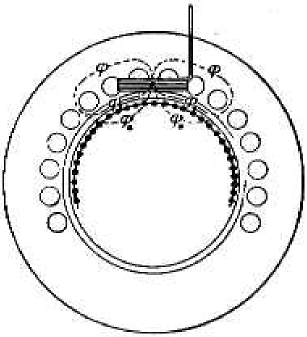

FIG. 2.

$$\phi_A \propto \frac{I}{\rho}$$

This magnetizing current is thus not constant, as in the transformer, but decreases with increasing load since with increasing load the current I_1 and therefore ϕ_s increases. ϕ_A will therefore decrease.