RESEARCH NOTE

MODIFICATION FACTOR FOR SIZING EQUATION OF ELECTRICAL MACHINES - SINGLE - AND THREE PHASE INDUCTION MOTORS

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Abstract Comparison between the results from the design procedure based upon the value of D^2L (volume of iron) and IEC standard used by manufacturers indicates that the basic design equation of electrical machines must be modified by a proper modification factor. This modification factor is evaluated for single- and three-phase induction motors and its variation with motor rating and poles number is obtained and compared.

Key Words Induction Machines, Design, Electrical Machines Equation

چکیده مقایسه بین نتایج حاصل از طراحی بر اساس مقدار D^2L (حجم آهن) و استاندارد IEC بکار رفته توسط سازندگان نشان می دهد که معادله اساسی طراحی ماشین های الکتریکی باید توسط ضریب اصلاح مناسبی، اصلاح گردید. این ضریب اصلاح در موتورهای القایی تکفاز و سه فاز محاسبه شده و تغییرات آن نسبت به مقادیر توان نامی و مقدار قطب ها، بدست آمده و مقایسه شده است.

INTRODUCTION

Electrical machine output power is generally expressed as a function of product of diameter and core length of the machine. Application of the conventional output equation for industrial motors, in a wide range of ratings, reveals that it is a common practice to obtain a significantly larger volume than that normally manufactured motors have. Therefore, the need for a modified output equation for electrical machines design is strongly felt.

In electrical machines design, first the basic dimensions (stator core diameter and length) used for punching design are estimated. Then other major parameters are estimated. And finally the design is completed by performance prediction of the machine [1-3]. If a designer employs a larger iron volume, the designed machine normally gives a satisfactory performance without taking into account the economical aspects. The estimated principal dimensions depend on the rated voltage, output power, speed and frequency of the machine.

The main purpose of the present study is to introduce a modification factor for output equation of induction motor which can be used for design of induction motor with an optimum iron volume.

OUTPUT EQUATION

The major part of an induction motor in the design process is its stator. The rotor can, on the whole, be accomodated in a properly designed stator. Of course, in the stator design, certain features of the rotor design must be taken into account.

Most induction motors are designed and manufactured as part of a coherent range. The output equation expresses the output power of the motor as a function of stator diameter (D_0), core length (L_{fe}), average airgap flux density (B_g), specific electric airgap flux loading (q) and the synchronous speed (n_s):

$$S = C_0 . D_0^2 . B_g . n_s . L_{fe} . q \quad (1)$$

Other output equations have been deduced in which an influence of the rotor diameter on the motor rating may be investigated. In such output equations, the power of D_0 is changed from 2 to 2.5 and 3. Bone [4] has assumed a constant current density and related the permissible conductor current with D_0^3. Further assumptions taken in Reference 5 lead to a new sizing equation which has a number of new features.

In the beginning of motor design, some of motor proportions are not known for the designer and some empirical coefficients are employed in the design process. The coventional output equation for estimation of D_0 and L_{fe}, used by many designers, is as follows:

$$D_0^2 L_{fe} = 16.39\times10^6 \ C_0 . hp / n_s \quad (2)$$

where:

$$C_0 = C_1 \ C_f \ C_t \quad (3)$$

is the output constant. D_0 and L_{fe} are in centimeters. C_1, C_f and C_t depend on the rating, frequency and type of the motor respectively.

The size of motor also influences many other factors. For instance, a single-phase motor is usually larger than a corresponding poly-phase motor. Further, the size of a general purpose, high efficiency motor is bigger than that of the short hour motor, where in the latter case efficiency is of secondary importance.

If Equation 2 is used to design a motor, the obtained dimensions are usually larger compared with the existing motor in the market. Then economical aspects may be taken into account and therefore Equation 2 can be used with a suitable modification factor. The recent work by the authors [6] lead to a better design using such a modification factor.

The modification factors K_m are evaluated for capacitor-run and capacitor-start single-phase, as well as three-phase squirrel-cage induction motors. The calculated $D_0^2 L_{fe}$ using the conventional output Equation 2, called $D_0^2 L_{fe\,(old)}$, is compared with that given by IEC standard [7], $D_0^2 L_{fe\,(new)}$. Then the modification factor K_m is determined as follows:

$$D_0^2 L_{fe\,(new)} = D_0^2 L_{fe\,(old)} / K_m \quad (4)$$

DEPENDENCY OF K_m ON DIFFERENT FACTORS

Examination of the modification factors K_m indicates that in general it is not possible to obtain a single value for the whole range of the induction motors, but various values depending on the type and poles number can be determined. On the other hand, as the output power increases, K_m values for a single-phase motor vary almost linearly and this trend remains more or less the same for three-phase fractional horse power induction motors. For integral three-phase induction motors, K_m variation differs from those given above.

Table 1 Shows typical mean values of the modification factors due to single- and three-phase induction motors with different poles number.

The modification factor versus output power for capacitor-start single-phase induction motors is shown

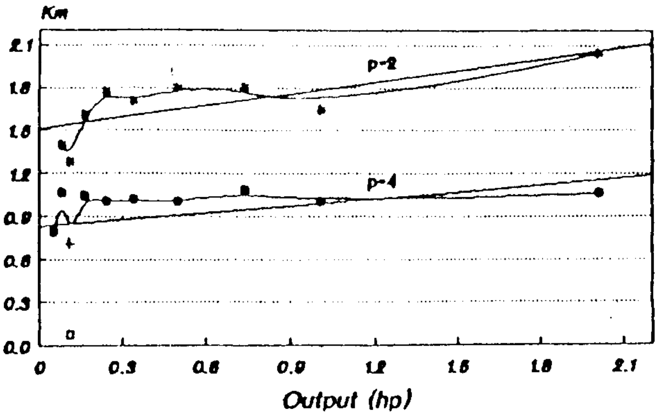

Figure 1. K_m versus output power of single-phase capacitor-start induction motors.

Pole No.	Single-phase		Three-phase
	Capacitor-start	Capacitor-run	
2	1.66	2.01	1.55
4	0.95	1.23	1.77
6	____	____	2.18

in Figure 1. The straight line sketched across each curve presents the trend of the curve. As the speed of the motor increases, the amount of the required iron volume is reduced.

Figure 2 illustrates K_m for capacitor-run single-phase induction motors.

Figures 3 and 4 show K_m for three-phase squirrel-cage fractional-and integral type induction motors.

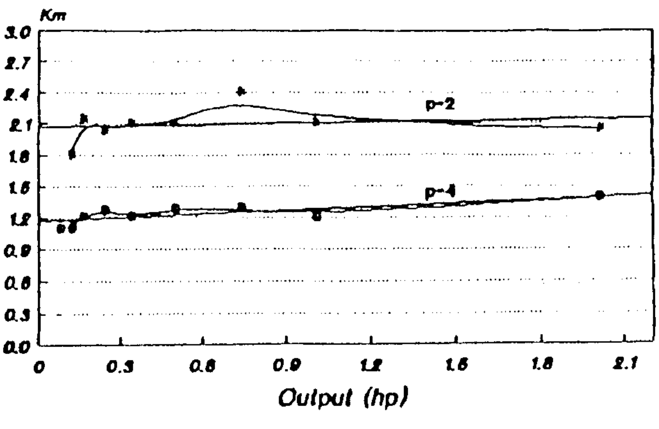

Figure 2. K_m versus output power of single-phase capacitor-run induction motors.

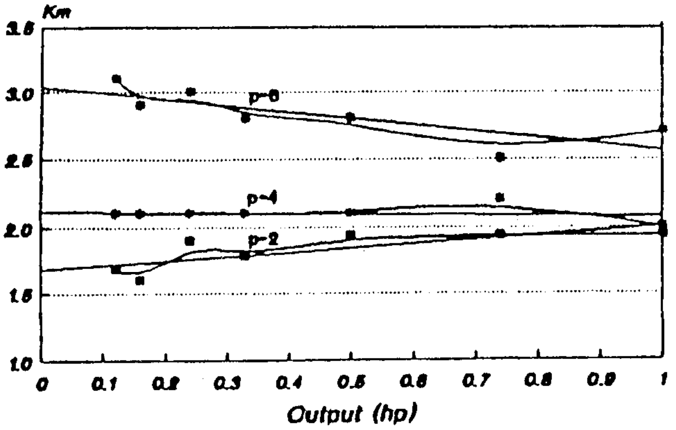

Figure 3. K_m versus output power of three-phase squirrel-cage fractional-type induction motors.

CONCLUSIONS

The following results are abtained:

1. In general, if the modification factor K_m is used, a capacitor-run induction motor requires about 17% less iron than a capacitor-start induction motor, for the same rating.

2. The value of modification factor for the single-phase induction motor is decreased by the increase of the poles number.

3. On the contrary to the single-phase induction motors, the value of the modification factor for three-phase induction motors is reduced by increaseing its speed.

4. The modification factor is necessary for design and optimisation of single- and three-phase induction

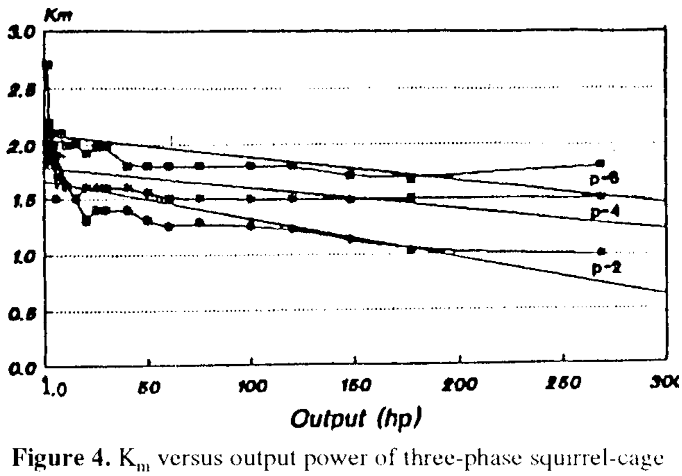

Figure 4. K_m versus output power of three-phase squirrel-cage integral-type induction motors.

motors using high quality core materials.

REFERENCES

1. B. Schwarz, "Geometrical Approach to the Economical Design of Rotating Electrical Machines", *IEE Proc.*, Vol. 113, No. 3, (1966).
2. P. H. Trickey, "Output of Induction Motors Depends on total Active Materials, "*Product Eng.*, (1946).
3. C. G. Veinott, "Theory and Design of Small Induction Motors", New-York, McGraw-Hill.
4. J. C. H. Bone, "Influence of Rotor Diameter and Length on the Rating of Induction Motors", *IEE Proceeding*, Electric Power Applications, Vol. 1, No. 1, (1978).
5. V. B. Honsinger, "Sizing Equation for Electrical Machinery", *IEEE Trans. on Energy Conversion*, Vol. EC2, No. 1, (1987).
6. J. Faiz and Sh. Honarparvar, "CAD of Single-phase Induction Motors Based on a New Geometrical Approach", Proc. of 3rd International Conference of Modelling and Simulation of Electrical Machines and Static Converters, IMACS-TCI' 90, Nancy, France, (1990).
7. IEC Publication, (1988).