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Maciej GWOŹDZIEWICZ*, Jan ZAWILAK*

INFLUENCE OF THE PERMANENT MAGNETS ARRANGEMENT ON THE SINGLE-PHASE LINE START PERMANENT MAGNET SYNCHRONOUS MOTOR PERFORMANCES

The paper deals with construction of single-phase line start permanent magnet synchronous motor. Circuit-field single-phase line start permanent magnet synchronous motor model based on the mass production single-phase induction motor was applied in Maxwell program. Various rotor constructions were taken into account. Influence of the rotor construction on the motor properties was examined. Running motor performances were examined.

1. INTRODUCTION

Among many of the literature and laboratory researches the trend towards the rapid development of permanent magnet synchronous motors and introduction them into mass production are plain noticeable. This motor type construction is similar to the induction motor construction [1–3]. The main difference between them is permanent magnets in the synchronous motor rotor. The rotor cage in the permanent magnet synchronous motor enables to self-starting and stabilizes the motor running. Line start permanent magnet synchronous motors have very good running properties and average starting properties [4, 5]. Nowadays, the medium power line start permanent magnet synchronous motors are built, tested and being introduced into production. The most recommended solution of the excitation of permanent magnet synchronous motor is NdFeB neodymium magnets, which are characterized by high energy density and high remanence induction. However the present policy of China (major global supplier

* Instytut Maszyn, Napędów i Pomiarów Elektrycznych, Politechnika Wrocławska, ul. Smoluchowskiego 19, 50-372 Wrocław, maciej.gwozdziewicz@pwr.wroc.pl, jan.zawilak@pwr.wroc.pl

of rare earth elements) results in rapid increase in the price of neodymium magnets, which forces manufacturers of synchronous motors with permanent magnets to reduce the volume of permanent magnets in the proposed motors.

Single-phase line start permanent magnet synchronous motor construction is quite similar to three-phase line start permanent magnet synchronous motor construction. The main problem in this type of motor is relatively narrow rotor yoke so the volume in the rotor for the permanent magnets installation is very limited. It causes additional difficulties in designing single-phase line start permanent magnet synchronous motors.

2. MODEL CONSTRUCTION

Two dimensional field-circuit models of the single-phase line start permanent magnet synchronous motor were applied in Maxwell ver. 14 program. The models are based on the mass production single-phase induction motor Seh 80-4B type with P_n = 750 W, U_n = 230 V, f_n = 50 Hz, n_n = 1370 rpm. Neodymium magnet N38SH type with B_r = 1,24 T and H_{cb} = 990 kA/m was chosen for the excitation of the synchronous motor. Single-phase induction motor was changed into single-phase line start permanent magnet synchronous motor by replacement standard squirrel-cage rotor with squirrel-cage permanent magnet rotor.

Permanent magnets shapes were changed saving their volume. Rotor bars were kept without change.

Circuit part of the motor model is shown in Fig. 1 and field parts of the motor models are shown in Fig. 2.

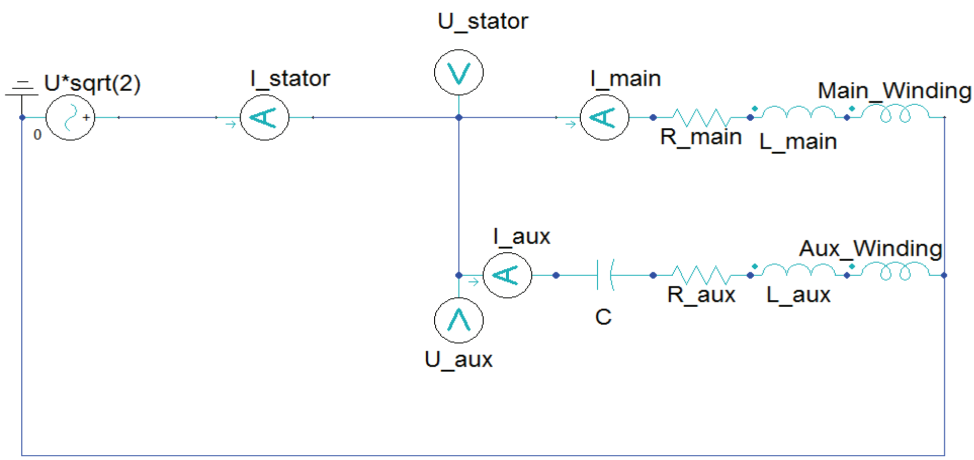

Fig. 1. Circuit part of the single-phase line start permanent magnet synchronous motor models

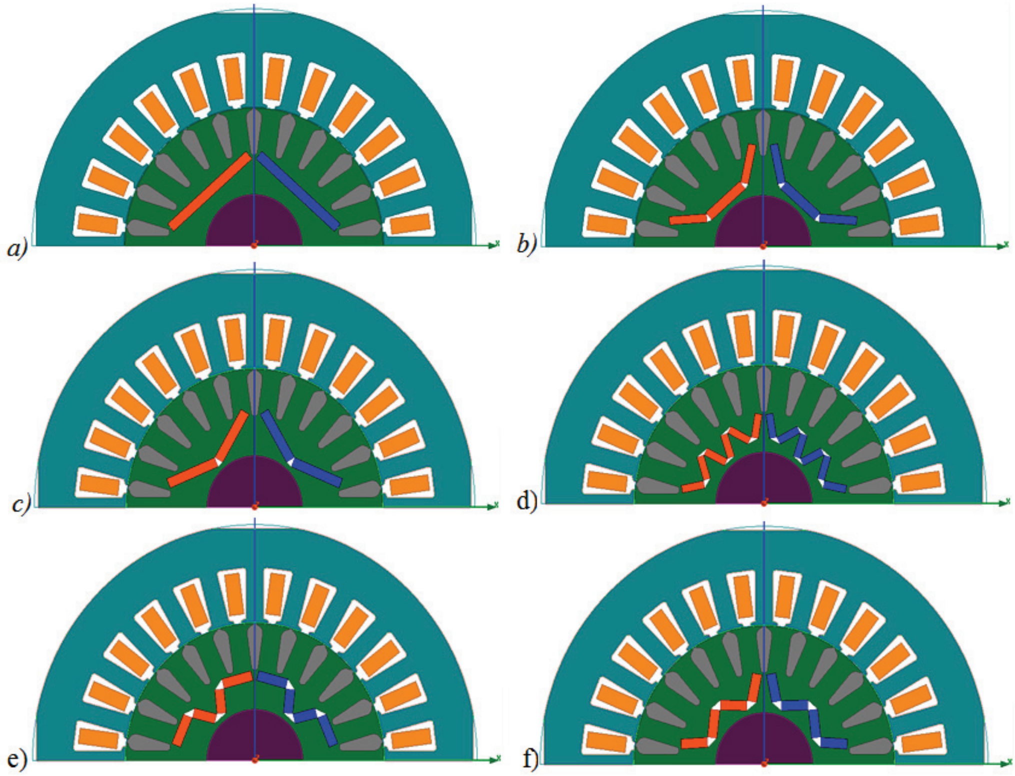

Fig. 2. Field circuit parts of the single-phase line start permanent magnet synchronous motor models with different permanent magnet shapes: a) —, b) ***U***, c) ***V***, d) ***VVV***, e) □, f) ***W***

3. EMF INVESTIGATION

Influence of the permanent magnets assembly in the single-phase line start permanent magnet synchronous motor on the EMF magnitude was examined. EMF THD coefficient was calculated according to the formula (1):

$$THD_E = \frac{\sqrt{\sum_2^{40} (E_h)^2}}{E_1}. \tag{1}$$

Cogging torque was assessed according to the formula (2):

$$T_{cogging} = T_{peak_{MAX}} - T_{peak_{MIN}}. \tag{2}$$

Obtained results are shown in Fig. 3.

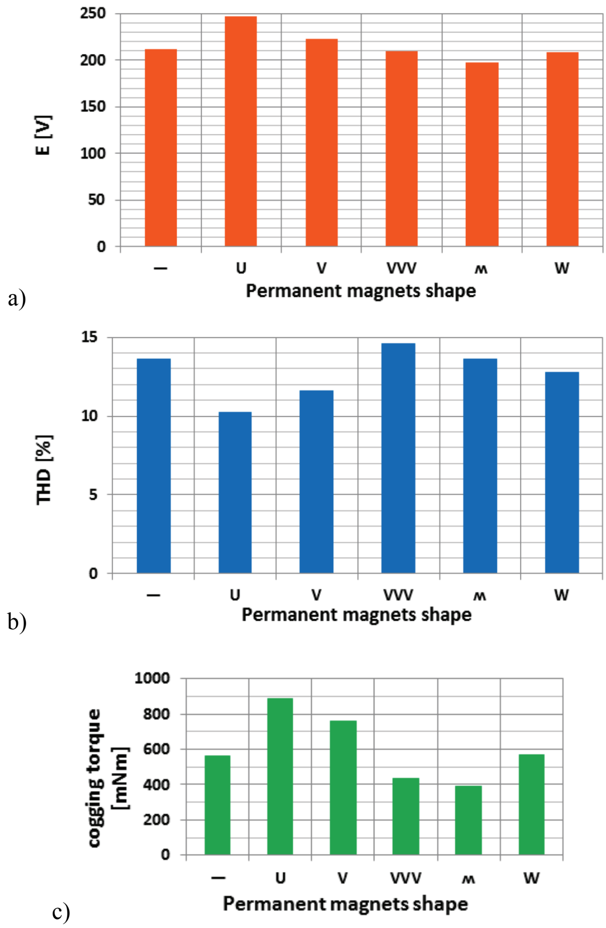

Fig. 3. Influence of the permanent magnets shape: a) on the 1st EMF harmonic magnitude, b) on the THD coefficient, c) on the cogging torque

According to the results shown in the Fig. 3 permanent magnets assembly in single-phase line start permanent magnet synchronous motor has significant influence on the EMF magnitude, its THD coefficient and cogging torque.

For further investigation only ***U*** shape was taken into account due to the highest magnitude of the EMF and the lowest magnitude of the EMF THD coefficient.

4. AUXILIARY WINDING PARAMETERS

In Maxwell program single-phase line start permanent magnet synchronous motor with permanent magnets assembled in ***U*** shape was examined. Running capacitor capacitance C_{run} and number of the auxiliary winding turns z_{aux} were changed. The criterion was to obtain the highest motor efficiency for load power P_n = 1100 W. P_n = 1100 W is next step in this motor classification relative to P_{IM} = 750W. Low power line start permanent magnet synchronous motors have higher rated power than induction motors with the same size [8]. Due to that assumption the single-phase line start permanent magnet synchronous motor P_n = 1100 W seems to be reasonable. An example of obtained results is show in Fig. 6.

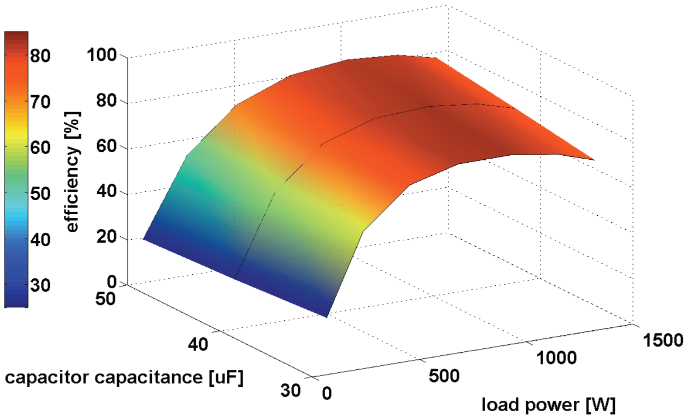

Fig. 6. Influence of the running capacitor capacitance on the single-phase line start permanent magnet synchronous motor efficiency curve for number of the auxiliary winding turns z_{aux} = 40 turns

According to the obtained results the highest motor efficiency was obtained for the C_{run} = 50 μF and for z_{aux} = 40 turns. The single-phase line start permanent magnet synchronous motor performances were compared with the induction motor performances in Tab. 1.

Table 1. Comparison of single-phase line start permanent magnet synchronous motor and single-phase induction motor

		IM	PMSM
P	kW	0.75	1.1
η	%	73	84
$cos\varphi$	–	0.92	0.95
I	A	4.9	6.1
j_{main}	A/mm^2	8.1	8.1
j_{aux}	A/mm^2	6.4	4.6

Obtained results presented in tab. 1 show clearly advantages of single-phase line start permanent magnet synchronous motor. These results put single-phase line start permanent magnet synchronous motors construction in good position for the further development.

Current densities in the main and auxiliary winding of the single-phase line start permanent magnet synchronous motor do not exceed the corresponding current densities of the induction motor so there is no hazard of overheating during motor running.

4. CONCLUSIONS

Permanent magnets assembly in the single-phase line start permanent magnet synchronous motor rotor has significant influence on the motor properties. The goals of this type of electric motor designing are limitation of the permanent magnets volume and simultaneously achieving high motor performances. The main problem during single-phase line start permanent magnet synchronous motor is relatively narrow rotor yoke what is restriction in permanent magnets assembly.

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