DOI: 10.2478/ijasitels-2024-0016

Single Phase Induction Motor Electrical Performances

Alina Cristina Viorel[1], *Gabriela Crăciunaș*[2]

[1]*Computer Science and Electrical Engineering Department, "Lucian Blaga" University of Sibiu, Romania, E-Mail: alina.viorel@ulbsibiu.ro gabriela.craciunas@ulbsibiu.ro.*

Abstract

A **single-phase induction motor (SPIM)** is one of the most widely used types of electric motors for applications that require small to medium power even his features don't look very efficient energy parameters point of view. This motor runs on single-phase AC power, a real advantage for residential and light industrial applications and coupled with a DC permanent machine can emphasize its behavior in some specific situations.

Starting and running performance of single-phase induction motor depend on running torque requirements of the load. Some statements about power factor and efficiency will be done, also.

Keywords: SPIM, running torque, power factor, efficiency.

1. Introduction

1.1 Brief description of the SPIM

Most single-phase induction motor are two-phase motors with unsymmetrical windings and their axes have perpendicular positions. One of the stator windings, the main one, is in 2/3 slots distributed and is supplied straight on the source. The other one, considered secondary one, can be disconnected from the source after starting process or can remain connected through a serial impedance. The role of secondary windings is to create a create a phase shift to start the motor.

The rotor construction remains in conventional direction and the winding is a squirrel one which consists of conductive bars shorted at both ends.[1]

The construction of a single-phase induction motor is done to realize operating features more efficiently when a single-phase power supply is available.

1.2 Working Principle

To produce a starting torque a phase shift is necessary to create between the sinusoidal space distribution of magnetomotive force (mmf). Without shift phase the stator windings will produce an equal forward and backward- rotating mmf waves. By symmetry, such a motor inherently will produce no starting torque since at standstill, it will produce equal torque in both directions (figure 1).

The role of secondary stator winding is more than obvious to determine an interaction between the magnetic field produced by the stator and the magnetic field created by the induced current in the rotor. The torque created by this action causes the rotor to start.[2]

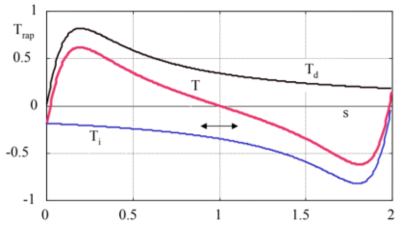

Figure 1. Torque-slip characteristic of a single-phase
induction motor on the basis of
constant forward and backward flux waves

The resultant torque-slip characteristic, which is the algebraic sum of the two components curves (direct torque Td and inverse torque Ti), shows if the motor were started by auxiliary means, it would produce torque in whatever direction it was started.

The type o impedance implemented could be resistive or capacity one. The expression of stator current from auxiliary winding is:

$$\underline{I}_{aux} = \frac{\underline{U}}{\underline{Z}_{sc\ aux} + \underline{Z}} \qquad (1)$$

Where: $\underline{I}_{aux}$ - the value of auxiliary stator winding

$\underline{U}$ - the supply voltage

$\underline{Z}_{sc\_aux}$ - the value of impedance placed on auxiliary winding

$\underline{Z}$ - the impedance of main winding

The maximum of starting torque is depending on the shift phase between phases (φ_{sc} - φ), due to the interaction of fields created when the currents pass the windings placed in 90-degree angle. The φ is the argument of $\underline{Z}$ impedance and φ_{sc} is the argument of main short circuit winding.

The expression of the maximum starting torque $T_{p\ max}$ is:

$$T_{p\ max} = K_T I_{pr} I_{aux} \tan\left(\frac{\varphi_{sc} - \varphi}{2}\right) \qquad (2)$$

Where: K_T – motor constant torque.

φ - the argument of main winding

φ_{sc} – the argument of main short circuit winding (for identical windings).[3]

The difference (φ_{sc} -φ) represents the shift phase between windings if the phases are identical. If $\underline{Z}$ is resistance, then φ =0. In this case the starting torque is not so significative.

The value of starting torque is significative if the impedance contains a capacitor. The problem is for considered value of capacitors is that the shape of rotational magnetic field is circular for a certain load. If will be another motor load the capacitance of capacitor should be changed.

1.3 Starting and running performance of single-phase induction motor.

Classification of single-phase induction motor depends on the starting methods. Selection of the appropriate motor is based on the starting and running-torque requirements of the load, the duty cycle of the load, and the limitations on starting and running current from the supply line for the motor. The cost of single-phase motors increases with their rating and with their performance characteristics such as starting torque to current ratio. Typically, to minimize cost, an application engineer will select the motor with the lowest rating and performance that can meet the specifications on application.

This paper presents a typical single-phase induction motor, connected to dc permanents generator used as a load. More, at the end to armature of dc generator winding a resistance is connected. This assembly is typical laboratory essay in according to study the features of the SPIM. [4]

2 Simulation of a SPIM connected with a dc permanent magnet generator

The electric drive is realised with a single-phase induction motor as electric motor and a dc permanent magnet generator coupled to the shaft of the induction motor. As the motor turns, it drives the generator to rotate within its magnetic field. This rotation induces a DC voltage in the generator’s stator windings.

The electrical output from the generator is used to power a load, a resistance in this case.[4]

2.1 Performance of SPIM coupled with a dc permanent magnet generator

2.1.1 Description of the model

This simulation model realized in MATLAB using *Power Systems Blocks* shows the operation of a single-phase asynchronous motor with auxiliary phase operation modes.

This model uses single-phase asynchronous motor, a block existing in Matlab library, to compare their performance characteristics, such as torque, efficiency and power factor in different situations. The motor has 186.5 W, 220 V, 50 Hz, 1500 rpm. The system is fed by a 220V single phase power supply. It has identical stator windings (main and auxiliary) and rotor squirrel cage.

The working machine is a dc permanent magnet machine with no pre-set data.

The motor is first started at no load, at t=0. Then at t = 0.5 sec, a 0.3 Nm. torque is suddenly applied on the shaft (torque signal build with a signal generator). Also, the load machine (dc permanent magnet generator) is coupled with the second breaker.

At t= 1 sec. the first breaker is disconnected, and the system works with the main single-phase induction motor feeds by supply.

The entire process of simulation ended at t = 2 sec. when the system remains stationary.

2.1.2 The simulation model realised in Matlab/Simulink application

In the figure 2 the simulation model is presented. The model was realised in Matlab 2024 version. [5]

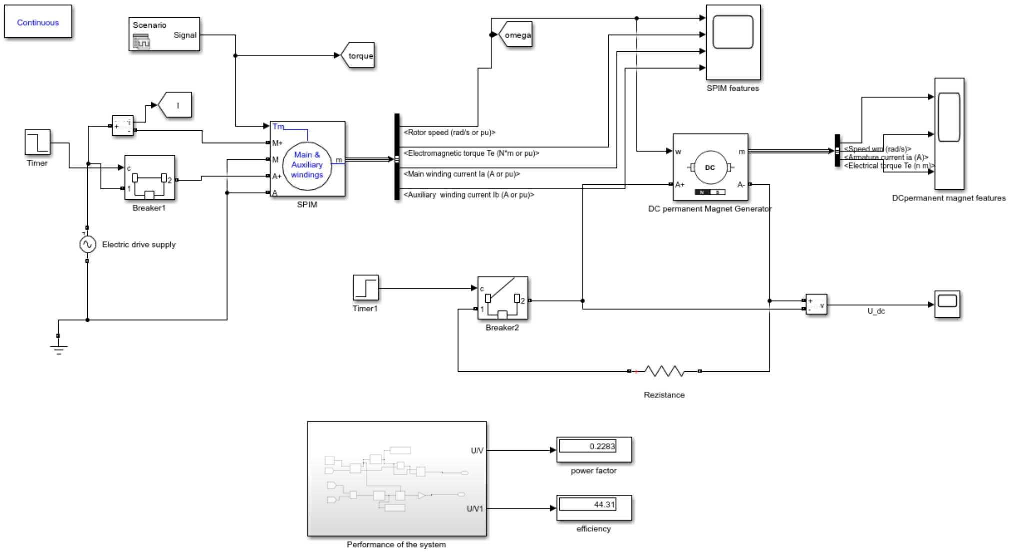

Figure 2. Electric drive simulation system

The model contains a subsystem for performance calculus: the power factor and the efficiency of the SPIM. To obtain these two parameters the usual equations were used. The equation for power factor is:[6]

$$\cos\varphi = \frac{P}{S} = \frac{P}{\sqrt{P^2 + Q^2}} \tag{3}$$

Where: P - active power
Q -reactive power
S- apparent power

For the calculus of efficiency, the equations used is:

$$\eta = \frac{P_{out}}{P_{in}} \tag{4}$$

Where: P_{out} –mechanical power
P_{in} – the power measured at the beginning of the system

The values are obtained using a specific block from library named *power* which compute active and reactive powers of voltage-current pair at fundamental frequency. In the subsystem a multimeter is used for making the connections easier.

2.1.3 Results obtained from simulations.

The Scope block displays the following signals for the model regarding SPIM: rotor speed (green trace) electromagnetic torque (blue trace), main winding current (magenta trace), auxiliary winding current, (brown trace), The mechanical power, power factor and efficiency of motor are computed inside the *Performance of the system* subsystem. Figure 3 describes the behavior of the system in the work sequence created.

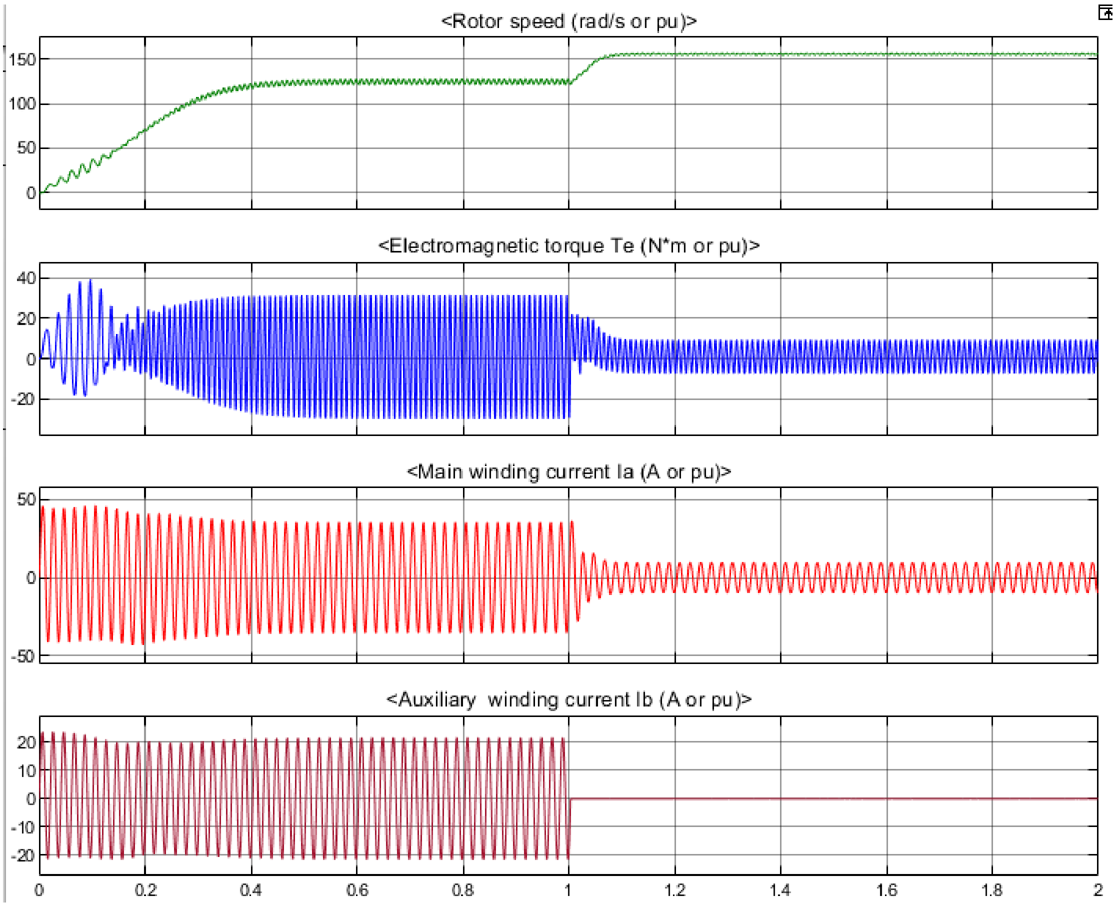

Figure 3. The behaviour of SPIM in total time considered.

All three moments of simulations are well represented on the features. The major aspect is when the auxiliar stator winding is disconnected and the SPIM continues to run but with other values. The generator doesn’t have any major influence on the motor parameters.

2.1.4 DC permanent magnet generator

The parameters monitored on it are: speed wm[rpm], electromagnetic torque Te [Nm], armature current ia [A] and armature voltage U_dc [V]. The values obtained in the considered moments are presented in figure 4.

As it described before, the electric drive is running in no-load conditions till t = 0.5 sec. The moment when the resistance is coupled at the armature winding is very well emphasized on the simulations.

The system running at the same rotor speed at 150 [rad/s].
The output voltage of a DC permanent magnet generator is directly proportional to the speed of the rotor. At higher rotational speeds, more magnetic flux is cut by the stator windings, resulting in a higher voltage.
For small-scale applications, DC permanent magnet generators can be more cost-effective due to their simple construction.

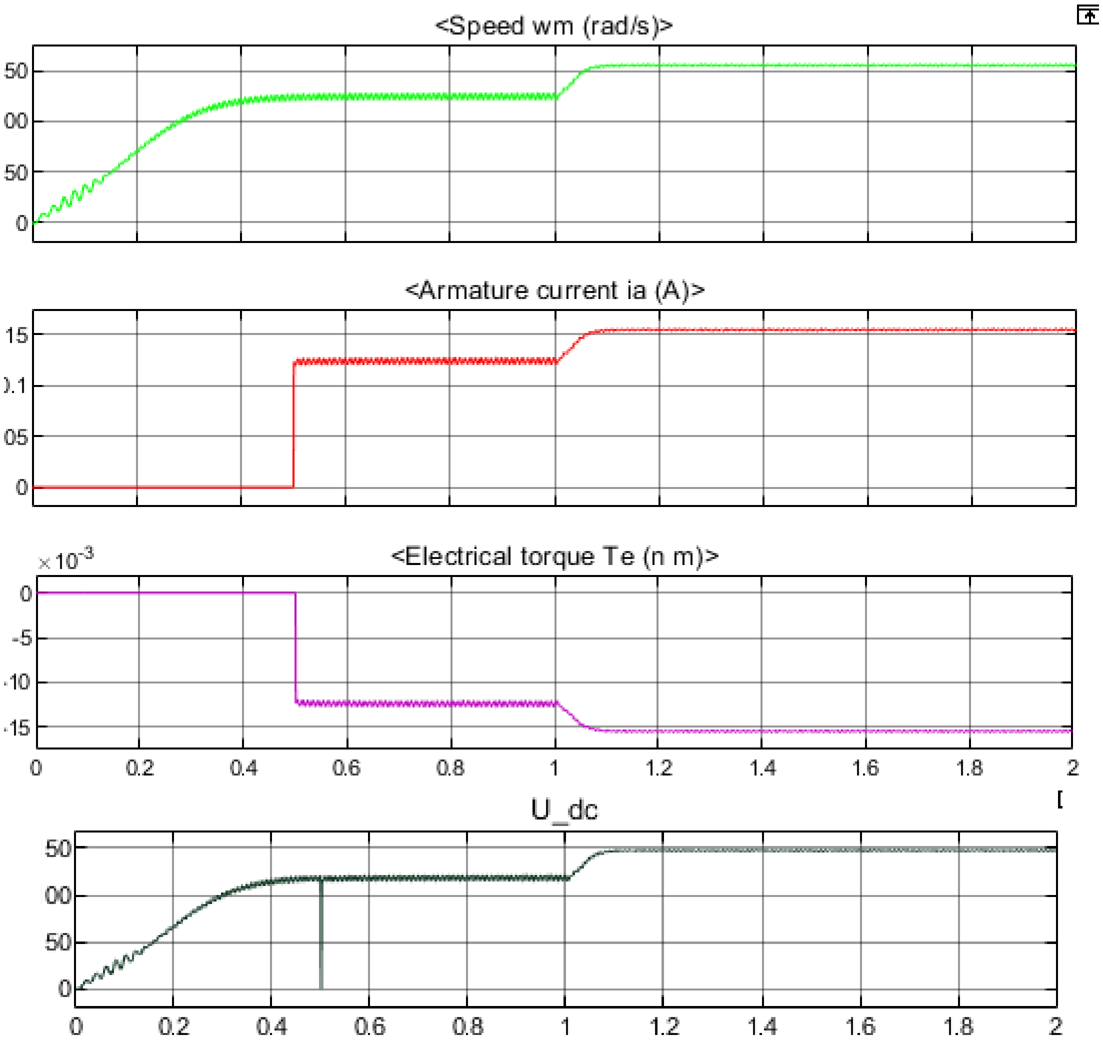

Figure 4 The dc permanent magnet output characteristics

The energetic parameters, power factors and efficiency are presented in Table 1.

Table 1. Table example

Moment of time	**T_p [Nm]**	**Power factor**	**Efficiency [%]**
t = 0.4 sec	20.5	0.96	2.21
t = 0.8 sec	21.5	0.96	2.4
t = 2 sec	6.05	0.23	43.33

If in the first two situations (before and after the connected DC permanent magnet generator) are quite similar, the third situation (when the stator auxiliar winding is disconnected) introduces a big difference between parameters. If the power factor and starting torque is reduced, the efficiency is increased.

3 Conclusions

The application could extend to power other electrical loads, charge batteries, or be fed back into the grid. The generated DC can also be converted to AC if necessary, using an inverter.

The advantages of this electric drive are simplicity and the low cost of single-phase induction motors. Using a structure with permanent magnet develops a process of reliability and low maintenance costs. The system emphasizes the possibility to generate DC power which is easier to store in batteries.

But the system is less efficient than a three-phase motors drive and it is possible to require additional regulation for stable power delivery. Moreover, the power factor and efficiency are not feasible for higher power applications.

Integrating such a system can be a practical solution for specific applications, especially in small-scale power generation and motor-driven systems. To increase efficiency a specific design and control strategies should be implemented.

References

[1] Biro K.A., Viorel I.A., Szabo L., Hennerberger G. *Mașini electrice speciale*, Editura Mediamira, Cluj Napoca, 2005.
[2] Fitzgerald A.E., Kingsley Ch., Jr, Umans S. *Electric Machinery, Sixth Edition,* McGraw-Hill Higher Education, ISBN 0-07-123010-6, Singapore, 2003.
[3] Viorel I.A., Iancu V., Biro K.A., *Determinarea impedanței optime de pornire în monofazata motorului de inducție,* Volumul celui al VI-a Simp.de inf. Și cond., Cluj, 1980, pp. 23-28.
[4] Nica C., Enache S., Enache Monica-Adela – *Mașini Electrice Speciale – Îndrumar de laborator,* Reprografia Universității din Craiova, 2001.
[5] www.mathworks.com
[6] www.mathworks.com - H. Ouquelle and Louis-A.Dessaint (Ecole de technologie superieure, Montreal)