International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

Obtaining Parameters from a Direct Current Motor of Permanent Magnets for Modeling with Evolutionary Algorithms

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Abstract: ***In this research we present the analysis of the mathematical model of the permanent magnet DC motor, Baldor brand, model AP7421 1/8 HP 1725 RPM TYPE 74AHPO, the evaluation of motor parameters has been a subject of great interest for several years. This interest is presented from the classification of engines, which is divided into: synchronous and asynchronous with different specifications in each of them. Obtaining electrical and mechanical parameters allows proposals to improve their efficiency; Differential equations and the analysis of the terms of the physical variables given by the motor manufacturer were applied against the data obtained in a normal operating environment. In the simulation, the Simulink software was used as a tool of the MATLAB program with which the behavior of the motor can be observed, applying the parameters obtained. They will be modeled with evolutionary algorithms that are widely used to solve real optimization and searching problems in electrical machine and algorithms. The algorithms of Differential Evolution (DE) and the Ant Colony Optimization (ACO) algorithm will be analyzed.***

Keywords: Analysis, Direct Current, Permanent Magnet, Motor, Parameters

1. Introduction

Nowadays permanent magnet DC motors are widely used in multiple industrial applications, due to their high efficiency, low maintenance and ease of control. [1]

The operation of DC motors is based on: converting electrical energy into mechanical energy inducing a rotating movement and generating a mechanical work.

The permanent magnet motors can be divided into two types: Synchronous motors with permanent external magnets (EPMSM), these have the permanent magnets mounted on the surface of the rotor, with a relatively large air gap; the second type are the internal permanent magnet motors (IPMSM) unlike the previous ones, this has permanent magnets inserted in the rotor, hidden and protected. [2]

In order to perform model analysis and obtaining engine parameters, it is necessary to understand and identify the operating variables through mathematical calculations, obtaining readings and data from it. [3]

The computational modulation in various investigations is carried out with the application of MATLAB's Simulink software, in which samplings are developed at a rapid speed, applying electrical and mechanical parameters and the visualization shows the operation of the engine based on the calculations obtained from the border variables. On the other hand, evolutionary algorithms are applied as optimization and search methods, which are based on evolution biological. Many optimization problems are difficult to solve only with the use of traditional techniques, which is why they use this type of algorithms, that are inspired by nature to obtain better results through their searching techniques. [4]

The application of algorithms allows us to look for the improvement in the performance of permanent magnet motors to achieve this application, it is essential to know the algorithms such as the optimization by colony of ants that is described as a tool for the solution of combinatorial problems, which is inspired by the collective behavior of the ants, also, this metaheuristic is considered as intelligence of swarms. [5]

Recently, several researchers have designed and applied new techniques and variations of the first ACO algorithm, in order to solve multi-objective problems. [6]

The algorithm of differential evolution multi-objective (DE) has been adopted by more than a decade by several researchers, which is used to address narrow problems of multi-objective optimization, which are used on a large scale in electrical machines. [7]

In Section II, the mathematical model of the DC motor of permanent magnets in its electrical and mechanical part, and the analysis for the obtaining of the parameters of the motor speed and current are presented. Section III describes the operation of the proposed evolutionary algorithms. In section IV the results obtained in the simulation are shown. Finally, section V details the conclusions of this research.

2. Mathematical Model

The direct current motor of permanent magnets is widely used this due to its performance, it is easy to control its speed and position [8], this device has mechanical and electrical characteristics that require the use of differential equations to be modeled.

In Figure 1, the diagram of the mathematical model of a direct current motor with its respective variables and symbols that represent its electrical and mechanical part is shown.

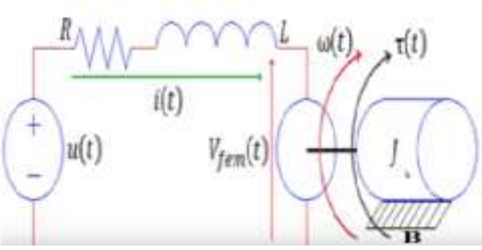

Figure 1: Model of a DC motor.

Where:
R =Ohmic resistance of rotor windings
L= inductance of rotor windings
J = moment of inertia of the rotor
B = Viscosity friction coefficient between rotor and stator

Variables that depend on time:

$u(t)$ = source of system excitation or voltage

$w(t)$ = angular speed of the rotor

$i(t)$ = system current

$fem(t)$ = Induced electrical voltage or induced electromotive force [9]

The electric part of the motor was analyzed applying the Kirchhoff voltage law, determining the voltage that enters the circuit, which will be equal to the resistance by the current passing through it, plus the voltage in the coil known as induced voltage, see Ec.1.

$$u(t) = Ri(t) + L\frac{di(t)}{dt} + Vfem(t) \qquad (1)$$

Electrical part of the engine

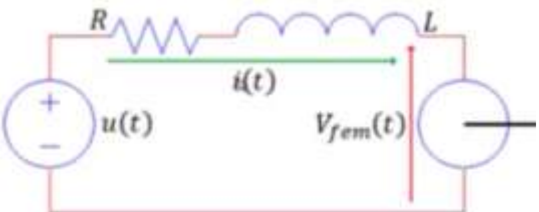

Figure 2: Electrical part of the engine

In order to find the value of the dynamic variable it is necessary to obtain the derivative of the current through the Ec.2

$$L\frac{di(t)}{dt} = u(t) - Ri(t) - Vfem(t) \qquad (2)$$

Mechanical part of the engine

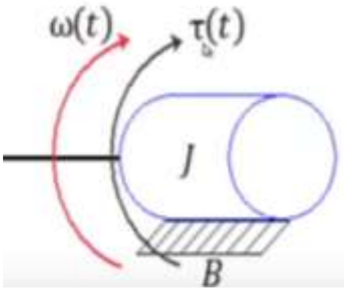

Figure 3: Mechanical part of the engine

Figure 3 shows the model of the mechanical part of the rotor, where the sum of the forces that rotates the axis is equal to the sum of the opposing forces. Represented in Ec.3.

$$r(t) = Bw(t) + j\frac{dw(t)}{dt} + Ti \qquad (3)$$

Where we clear the variable of interest and obtain the characteristic equation of the forces. Ec.4

$$J\frac{dw(t)}{dt} = r(t) - Bw(t) - Ti \qquad (4)$$

Where Ti is the friction torque, or initial torque.

It is worth mentioning that there are two constants that relate both the electrical part and the mechanical part, these expressions are represented by K_t that is in the torque Ec.5 and K_E that is in the electromotive force induced Ec.6

$$r(t) = K_t i(t) \qquad (5)$$

$$Vfem(t) = K_E w(t) \qquad (6)$$

The four most significant expressions for the model of a direct current motor are theformula to find the current, where yes, the inductance is passed to divide, we obtain the derivative of the current. Ec.2, in the same way we obtain the angular velocity, Ec.4. The Ec.5 torque and the induced electromotive force. Ec.6. So, we can emphasize that all of them are directly related.

3. Evolutive Algorithms

A) Algorithm multi-objective differential evolution CMODE

The multi-objective differential evolution algorithm is a stochastic direct search algorithm, based on a population P, that uses a set of the initial population Q, which is chosen at random and comprises the candidate solutions. This set is made up of vector individuals NP, while each vector includes the decision variables VD, in a decision space S, which must be optimized, through its operations of mutation, crossing and for the selection process the methodology is implemented of dominance and all this is repeated by iteration to improve the initial candidate solution, until the maximum number of Gmax generations is reached or the required fitness value is achieved. [10] [11]

In each generation of the differential evolution algorithm maintains:

1.- a population consisting of N_p vectors

$P_g = \{\vec{x}_1, \vec{x}_2 \ldots \vec{x}_{Np}\}$ where g denotes the number of generations;

2.- Objective function values $F(\vec{x}_1)$, $F(\vec{x}_2)$, …$F(\vec{x}_{Np})$, and it restriction level $R(\vec{x}_1)$, $R(\vec{x}_2)$, ………..$R(\vec{x}_{Np})$.

The algorithm starts from a population $P_{(g)}$ generated randomly within the decision space defined by $[L_i, U_i]$, $1 \le i \le n$. later a group of individuals (Q) are chosen randomly from the population $P_{(g)}$ to produce an offspring (C) to apply the mutation, crossing and selection (DE) operations and are eliminated from $P_{(g)}$ Thereafter, the non-dominated individuals (R) are identified from (C) and replace the individuals dominated in Q, (if they exist), the Q set is updated and subsequently Q is updated in $P_{(g)}$

It should be mentioned that, if R contains only infeasible solutions, C will also be composed entirely of infeasible solutions, so the solution not feasible with the lowest degree of restriction violation in R is stored in file A. Each g generation, all the unfeasible individuals in A are used to replace the same number of individuals in $P_{(g)}$. It should be noted that the previous substitution is executed based on an unfeasible solution, replacing mechanisms inspired by multi-objective improvement. The procedure is repeated until the maximum number of iterations is achieved. [12]

B) Ant Colony Optimization Algorithm

The algorithm ACO is denominated as intelligence of swarms of insects, which use a set of optimization techniques inspired by the collective behavior of the ants, in the simulation of the algorithm it is by means of artificial ants, that are able to learn a space of search during their execution, so they get experience to build better solutions. [13] [14]

Inicialization

In this phase, the problem data are introduced, and the parameters of the algorithm are initialized, which is why it is dependent on the problem to be solved

You must define the number of ants (h) that will form the colony and initialize it, taking in. Note that increasing its size means increasing the exploration of the solution space, but also the cost of memory and computing time. The information related to the pheromones T_{ij}, is also initialized, with an initial value T_0 homogeneous so as not to decant the search; the evaporation parameter(ρ), which has the function of reducing the intensity of pheromone traces; and the parameters that weigh the influence of pheromones (α) and heuristic information (β).

Construction of Solutions

Probability is a function that depends on the artificial trail of pheromones and simulates the behavior of ants in nature for the choice of routes

$$P_{ij}^{h} = \{ \frac{[T_{ij}]^{\alpha}}{\sum I \in N_i^h [T_{il}]^{\alpha}} \quad (7)$$

Where P_{ij}^{h} is the probability that the ant h chooses the component j in the decision i, T_{ij} represents the intensity of the trace of pheromones in the option j of the decision i, α is a parameter

Pheromone Evaporation

The evaporation of pheromones is carried out in all elements of the trace, simulating the process that occurs in nature.

$$T_{ij} \leftarrow (1-\rho) * T_{ij} \quad (8)$$

Pheromones Update

Each artificial ant deposits a quantity of pheromones in each of the elements of the trace that form the solution, thus increasing the intensity of the trace.

$$T_{ij} \leftarrow + \sum_{h=1}^{h} \Delta T_{ij}^{h} \quad (9)$$

Increasing ΔT_{ij}^{h} it is a function of quality, so better solutions deposit more, so that in later iterations of the search it tends towards the areas where those solutions have been found.

4. Simulation & Results

A) Simulink of Matlab.

Simulink provides a graphical user interface (GUI) to model the system in physical form, which allowed us to analyze the systemdynamic from models with block diagrams. The Simulink is widely used in different areas of engineering such as: biomedical, telecommunications, electronics, control engineering and robotics.

B) Parameters

The simulated model of the permanent magnet DC motor consists of the following parameters, which were calculated, measured and compared with the manufacturer's technical data:

Table 1: Parameters

Motor DC Parameters	
Inductance (L)	96.2 mH
Resistance (R)	31.15 Ω
Inertiamoment (J)	17.54 OI^2
Coefficient of viscous friction(B)	7 µ
Constantelectromotive(ke)	1.408
Electric time constant(te)	3.088
Torque constant(kt)	13.44
Current (I)	0.65 amp
Revolutions per minute(RPM)	1725 rpm
Angular speed (w)	180.64 r/s
Torque (Hp)	0.536 Nm
Potence (HP)	0.13= 96.94 Watts
Voltage(Volts)	180 volts

5. Results

With the simulation, the behavior of the velocity and angular current parameters can be observed.

In fig. 4, the diagram of a CD motor that is composed of two subsystems, current and angular velocity is observed.

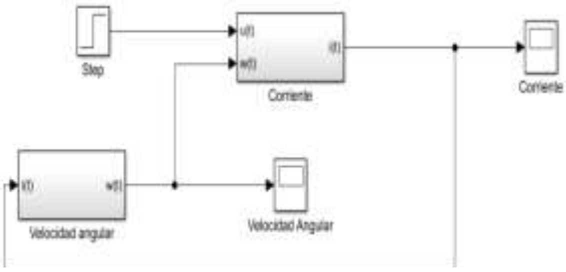

Figure 4. Schematic of the dc motor

In fig. 5 the simulation of the angular velocity subsystem is shown

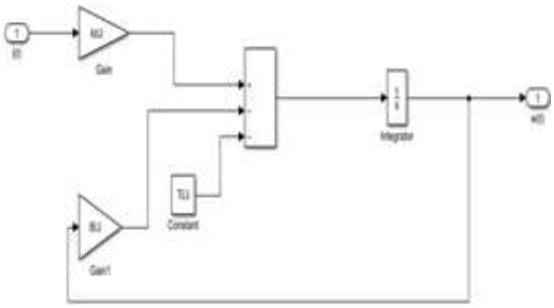

Figure 5: Angular Speed Simulation

In fig. 6 shows the simulation of the current subsystem.

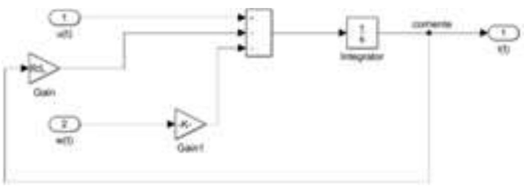

Figure 6: Current Simulation

The following figures show the outputs obtained with respect to the simulation of the DC motor

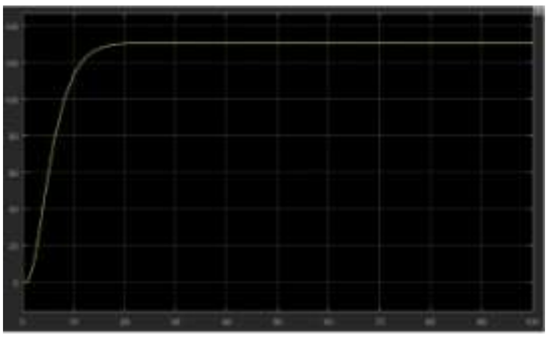

Figure 7: Angular Speed Behavior as a Function of Time

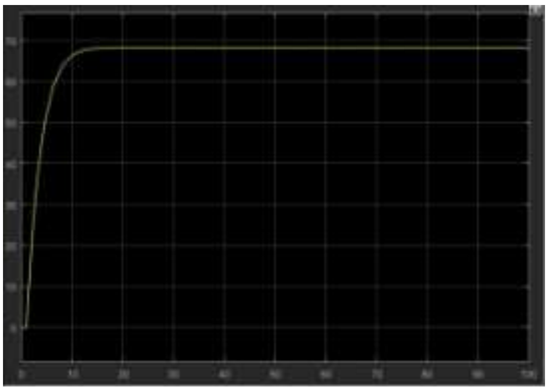

Figure 8: Current-Time Behavior

6. Conclusion

With the application of the mathematical model, the obtaining of electrical parameters of the dc motor of permanent magnets and through the simulation can be observed the behavior of the motor both in the speed and the current

.

In order to model a direct current motor with permanent magnets, different differential equations are used to identify the parameters that allow us to obtain an exact electrical and mechanical model of the motor.

The simulation was carried out with the MATLAB Simulink tool, applying the real values of the machine to develop experimental tests and thus obtain results where the efficiency of the engine can be observed under the operating regimes.

These results allow us to continue with an investigation, with a theoretical-practical foundation to propose improvements that propitiate a performance of said engine.

References

[1] A. V. Deepti Yadav, «Performance Analysis of PMSM Drive using MPSO and MOGA Technique,» Lucknow, India, 2016.

[2] M. A. J. A. M. K. Liu Qinghua, «Desing Optimization of Interior Permanent Magnet Synchronous Motors for Wide-Speed Operation,» Indonesia, 2001.

[3] M. S. A. Alvarado, «Modelo Matematico de un Motor de Corriente Continua Separadamente Exitado: Control de Velocidad por Corriente de Armadura,» vol. 6, nº 1, pp. 155-161, 2012.

[4] A. E. S. J. E. Eiben, «Introduction to Evolutionary Computing,» Springer Verlag, pp. 71-87, 2003.

[5] M. Dorigo, «Optimization, learning and natural algoritms,» Milan, 1992.

[6] J. L. Z. Y. C. Q. Ying Xie, «Optimization Desing of Line-Start Permanent Magnet Synchronous Motor Based on Ant Colony Algorithm,» de International Conference on Electrical Machines and Systems, Hangzhou, China, 2014.

[7] K. P. Rainer Storm, «Differential Evolution - A Simple and Efficient Adaptative Scheme for Global Optimization over Continuous Spaces,» de International Computer Science Institute, 1995.

[8] A. M. O. K. K. M. A. J. H. W. P. M. A. Rahman, «Advanced on Single-Phase Line-Start High Efficiency Interior Permanent Magnet Motors,» IEEE Trans. Ind Electron, vol. 59, nº 3, pp. 1333-1345, 2012.

[9] S. J. Chapman, Maquinas Electricas, Mexico, D.F: McGraw Hill, 2012.

[10] Z. C. Yong Wang, «Combinig Multiobjetive Opt imization whit Differential Evolution to Solve Constrained Optimization Problems,» IEEE Transaction on Evolutionary Computation, vol. 16, nº 1, pp. 117-133, 2012.

[11] L. L. Gustavo Caravaggi Tenaglia, «A multiobjetive Approach of Differential evolution Optimization Applied to Electromagnetic Problems,» IEEE Transactions on Magnetics , vol. 50, nº 2, 2014.

[12] D. M. I. N. A. O. T. W. N. Alireza Fatemi, «Fast Multiobjetive CMODE Type Optimization of PM Machines Using Multicore Desktop Computers,» IEEE Trasactions on Industry Aplications , vol. 52, nº 4, pp. 2941-2950, 2016.
[13] M. B. S. G. A. L. Sofiane Mendaci, «Ant Colony for Optimal Design of PM Synchronous Generator for Direct-Drive Wind Turbines,» 2014.
[14] W. S. Y. P. Daniel Soto, «Algortimo de Optimizacion de Colonia de Hormigas Multiobjetivo Aplicado al Problema de la mochila Multidimensional,» Programacion Matematica y Software, vol. 3, nº 2, pp. 20-30, 2012.

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