Interdisciplinary Journal of Engineering and Environmental Sciences
ISSN: 2994-2780 | Impact Factor: 6.68
Volume. 12, Number 1; January-March , 2025;
Published By: Scientific and Academic Development Institute (SADI)
8933 Willis Ave Los Angeles, California
https://sadijournals.org/index.php/ijees/index

INDUSTRIAL NODDLE PERMANENT MAGNET MOTOR TRANSIENT AND SPEED CONTROL ANALYSIS USING MATLAB

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DOI: https://doi.org/10.5281/zenodo.14739169

Abstract*—Industrial noddle permanent magnet motor transient and speed control analysis using Matlab is presented. The Permanent magnet (PM) is an AC machine whose excitation is provided by the permanent magnet, and is increasingly used in a variety of applications, which include machine tools, robotics, aerospace generators, actuators and electric vehicles. PM has a superior power density, torque to inertia ratio and efficiency. PM drives performances experimental were carried out and simulation results of the characteristics run-up of a PM has been presented graphically. The result show that as PM transient and speed varies is highly sensitive to rated voltage, stator resistance and equivalent field current value. This must be regulated during PM design and recommended for noddle industries and machines designers.*

Keywords*: Magnet, Noddle, Transient, Torque Excitation, Actuators, Permanent Magnet, Metering module.*

1.0 Introduction

Industrial noddle permanent magnet motor transient and speed control analysis using Matlab is presented. The Permanent magnet (PM) is an AC machine whose excitation is provided by the permanent magnet, and is increasingly used in a variety of applications, which include machine tools, robotics, aerospace generators, actuators and electric vehicles. PM has a superior power density, torque to inertia ratio and efficiency, when compared to conventional machines.

PM has no field windings on the stator frame but it relies on the magnets to provide the magnetic field where the rotor interacts to produce a torque. Commutation under load can be improve by introduction of compensating windings in series with the armature. Stator current of other conventional motor used in Industrial Noddle motor contains magnetizing as well as torque-producing components. The use of permanent magnet in the rotor of PM of Industrial Noddle makes it unnecessary to supply magnetizing current through the stator Industrial Noddle for constant air-gap flux, the stator current need only be torque producing. Hence the PM will operate at a high-power factor for Industrial Noddle plant because of the absent of magnetizing current and the noddle plant becomes more efficient than before.

2.0 Experimental Laboratory Research: The noddle plant consists of the following instruments and components: Permanent Magnet Motor, three phase wattmeter, Power supply unit (0-400V/ 0-220V), AC metering module (0.5/2.5A), AC metering module 250V, DC metering module (0.5/2.5V), Connection leads.

Laboratory Safety: Due to present of Laboratory high voltage, no connections should be made with the power 'ON'. PM motor power should be turn 'OFF' after completing each individual measurement. The circuit connection using PM motor, Power supply, Metering module, Figure 1:

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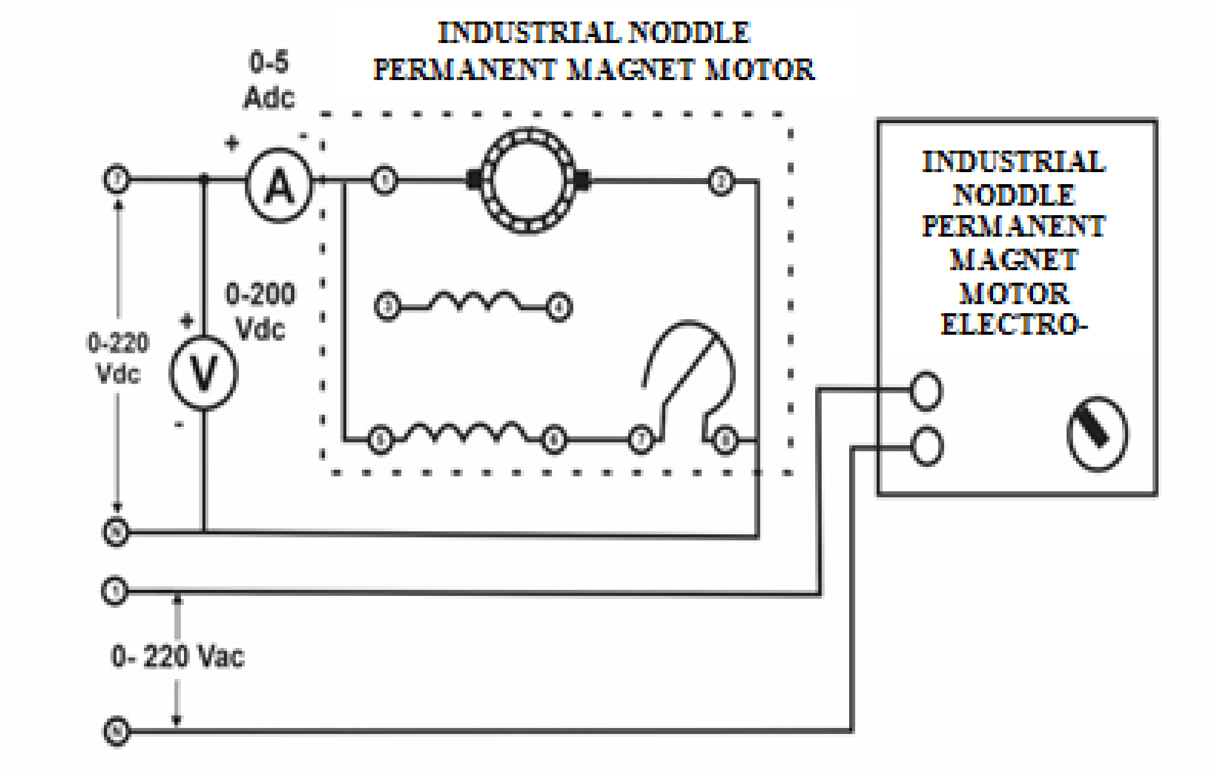

Figure2: Industrial noddle permanent magnet motor DC Motor Speed Control Test [2, 9, 12]

The figure 2 Industrial noddle permanent magnet motor DC Motor Speed Control Test. The system was control by (1).Setting the desire speed (2) The speed was control by controller (3) the actual speed was Compares from tacho-generator (4) The current controller control the current from over current (5) The input current was from the measuring device (6) The output from the current controller was converted to digital pulse (7)Converter driver (8)The converter output drives the motor (9) The field converter is a simple rectifier that provide a constant field current (10) Received Constant field current.

The results are: I_1 = 1.43Aac, I_2 = 2.23Aac, E_1 = 400-V, the PM motor toque was 15.8 1bf.in and apparent power =522 VA. The results of no-load characteristic of industrial noddle PM motor are, Average current = 0.62, Apparent power = 223VA, Real power72w, Reactive power = 211var, Power factor = 0.323. The results of characteristic of industrial noddle PM motor when the resistance was set at zero ohms and at the torque of 91bf.in are: Average current = 1.08Aac, Apparent power = 378 VA, real power = 290w, reactive power = 242var, power factor = 0.772, horse power = 0.220, efficiency = 56.6%. The results of characteristic of industrial noddle PM motor when the resistance was set at 16Ω and at the torque of 91bf.in are: Average current = 1.03Aac, apparent power = 377 VA, real power = 283w, reactive power = 240var, power factor = 0.768, horse power = 0.117, efficiency = 30.8%. The results of no-load and full load characteristic ratio of industrial noddle PM motor when the torque is at 91bf.in are: Average starting current to full load current = 1.42Aac, starting torque to full load torque = 1.76, full load current to no load current = 1.70.

3.0 Mathematical Modeling of PM Motor

The stator of the PM Motor and the wound rotor synchronous machines (SM) are similar. The permanent magnets used in the PM motor are of a rare-earth variety with high resistively, hence the induced current in the rotor is negligible. [1, 3, 8]

There is no difference between the back electro-motive-force produced by a permanent magnet motor and that produced by an excitation coil. Mathematical model of PM Motor is similar to that of wound rotor SM. [1, 6, 11] The following assumption were made for the derivative equation, (i) Saturation current is neglected and may be taken into account by parameter changes, (ii)The induced EMF is sinusoidal, (iii)Eddy current and hysteresis loss are negligible, (iv)There are no dynamics field current, there is no cage on the rotor. With these assumptions, the stator d, q equations of the PM in the rotor reference frame are [2, 5, 10]

$$V_q = R\, i_q + p\lambda_q + \omega_s \lambda_d \quad (1)$$

$$V_d = R\, i_d + p\lambda_d + \omega_s \lambda_q \quad (2)$$

Where

$$\lambda_q = L_q i_q \quad (3)$$

And

$$\lambda_d = L_d i_d + \lambda_{df} \quad (4)$$

V_d and V_q are the d, q, axis voltages, i_d and i_q are the d, q axis stator current, L_d and L_q are the d, q axis inductance, λ_d and λ_q are the d, q axis stator flux linkages. While R and ω_s are the stator resistance and inverter frequency, respectively. λ_{df} is the flux linkage due to the rotor magnet linking in stator. The electric torque is

$$T_e = 3p[\lambda_{df} i_q + (L_d - L_q) i_d\, i_q] / 2 \quad (5)$$

And the equation for the motor dynamic is

$$T_e = T_L + B\omega_r + J p\omega_r . \quad (6)$$

P is the PM motor number of pole pairs, T_L is the load torque, B is he damping coefficient, ω_r is the rotor speed, and J is the moment of the inertia. The inverter frequency is related to the rotor speed as follows: $\omega_s = p\omega$. **(7)**

PM motor model is nonlinear as it contains product terms such as speed with i_d and i_q. Note that ω_r i_q and i_d as state variables.

Dynamic equation of the PM motor is presented in (1) - (6) and (8) - (10) expressed it in state-space form as: [4, 5, 7]

$$p\, i_d = (V_d - R\, i_d + \omega_s L_q\, i_q) / L_d \quad (8)$$

$$p\, i_q = (V_q - R\, i_q - \omega_s L_d\, i_d - \omega_s \lambda_{df}) / L_q \quad (9)$$

$$p\omega_r . = (T_r - T_L - B\omega_r) / J. \quad (10)$$

PM motor, d, q variable obtained from a, b, c

Park transformations are:

$$\begin{bmatrix} v_q \\ v_d \\ v_o \end{bmatrix} = 2/3 \begin{bmatrix} \cos(\theta) & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\ \sin(\theta) & \sin(\theta - 2\pi/3) & \sin(\theta + 2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \quad (11)$$

Inverse of PM motor, d, q, Park transformations

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 1 \\ \cos(\theta - 2\pi/3) & \sin(\theta - 2\pi/3) & 1 \\ \cos(\theta + 2\pi/3) & \sin(\theta + 2\pi/3) & 1 \end{bmatrix} \begin{bmatrix} v_q \\ v_d \\ v_o \end{bmatrix} \quad (12)$$

PM motor total input power to the noddle machine in term of the, b, c variables is:

$$\text{Power} = v_a\, i_a + v_b i_b + v_c i_c \quad (13)$$

PM motor d, q balance power system is:

$$\text{Power} = 3\,(v_d i_d = v_q i_q)\,/\,2 \quad (14)$$

Table1: Experimental Result Record of Industrial noddle permanent magnet motor DC Motor Speed Control Test.

E_A (volts)	I_A (amps)	Speed (rev/min)	Torque (Ibft.in)
200	0.34	1495	0
200	1.02	1424	3
200	1.73	1264	6
200	2.34	1219	9
200	2.93	1384	12
200	3.14	1414	15

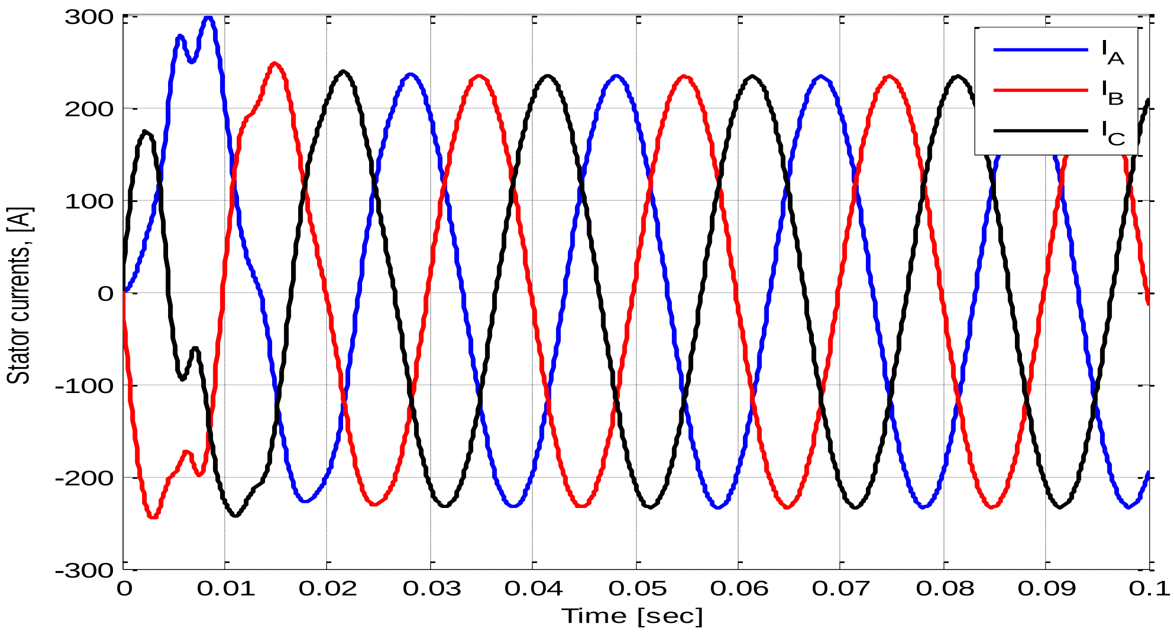

Figure 3: Graph of Industrial Noddle PM Motor Stator phase currents versus time function at run-up condition

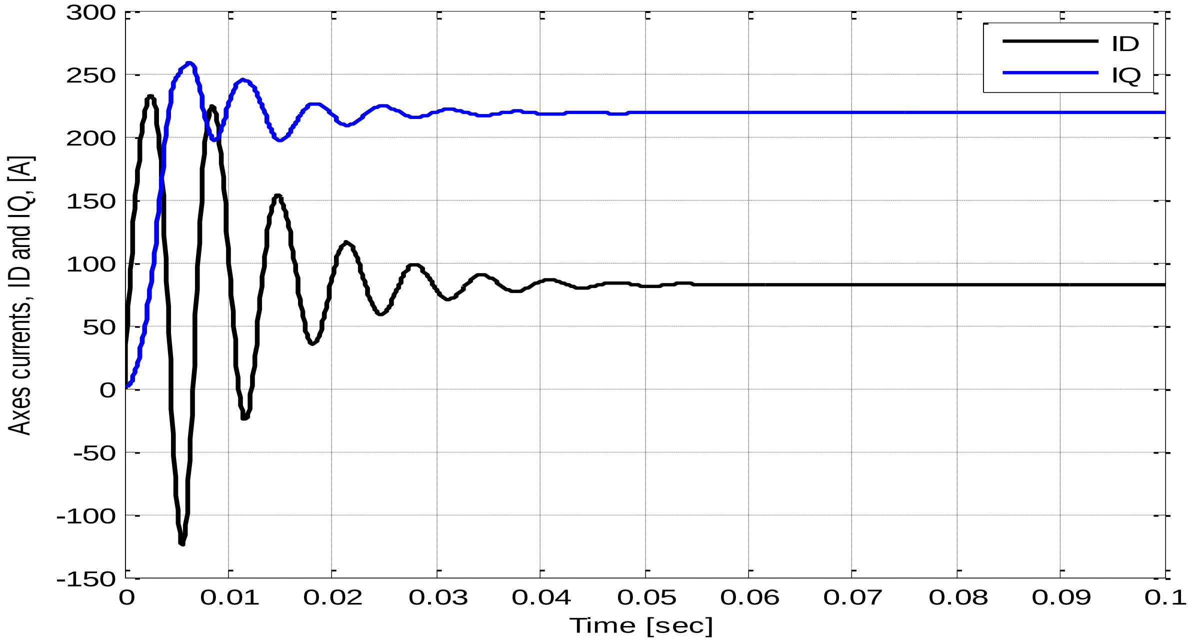

Figure 4: Graph of Industrial Noddle PM Motor axis current ID and IQ against time at run up condition

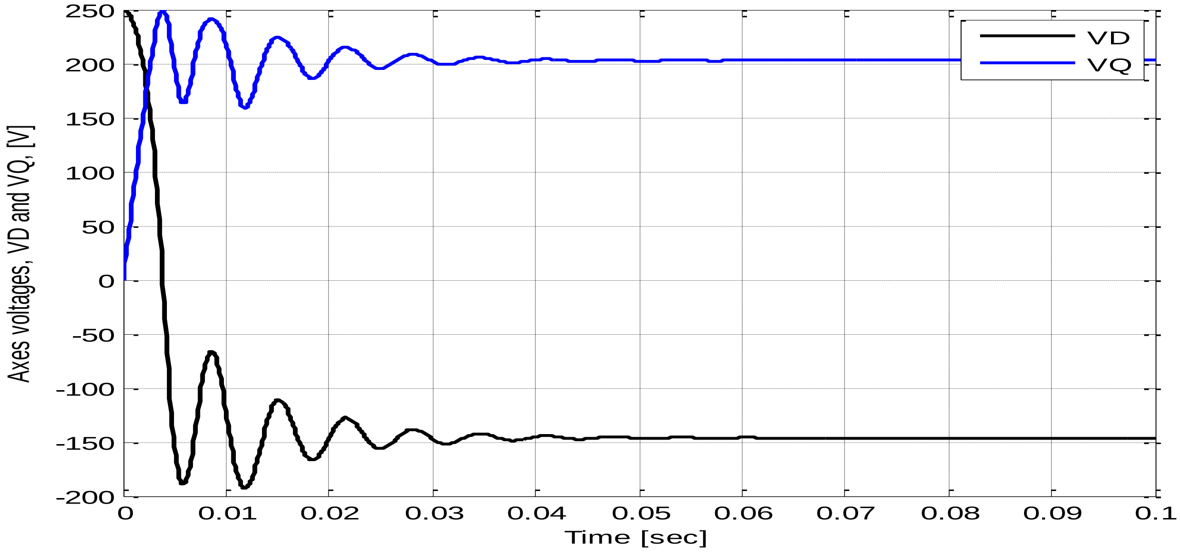

Figure 5: Graph of Industrial Noddle PM Motor axes voltages VD and VQ against Time at run up condition

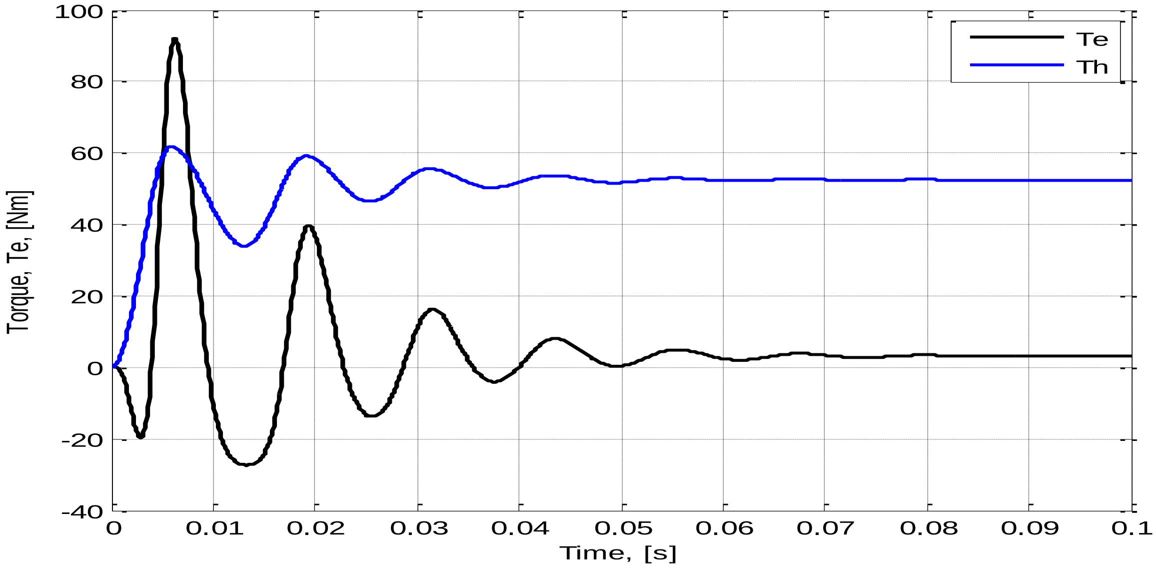

Figure 6: Graph of Industrial Noddle PM Motor Torque versus Time function at run up condition

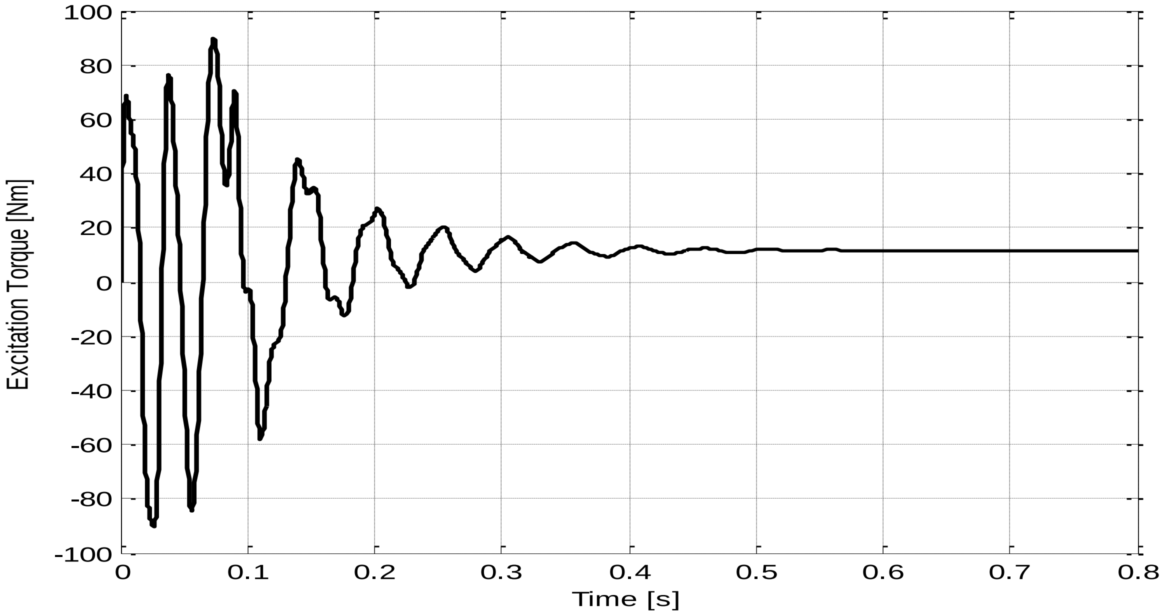

Figure7: Graph of Industrial Noddle PM Motor Excitation Torque against time at run-up Condition

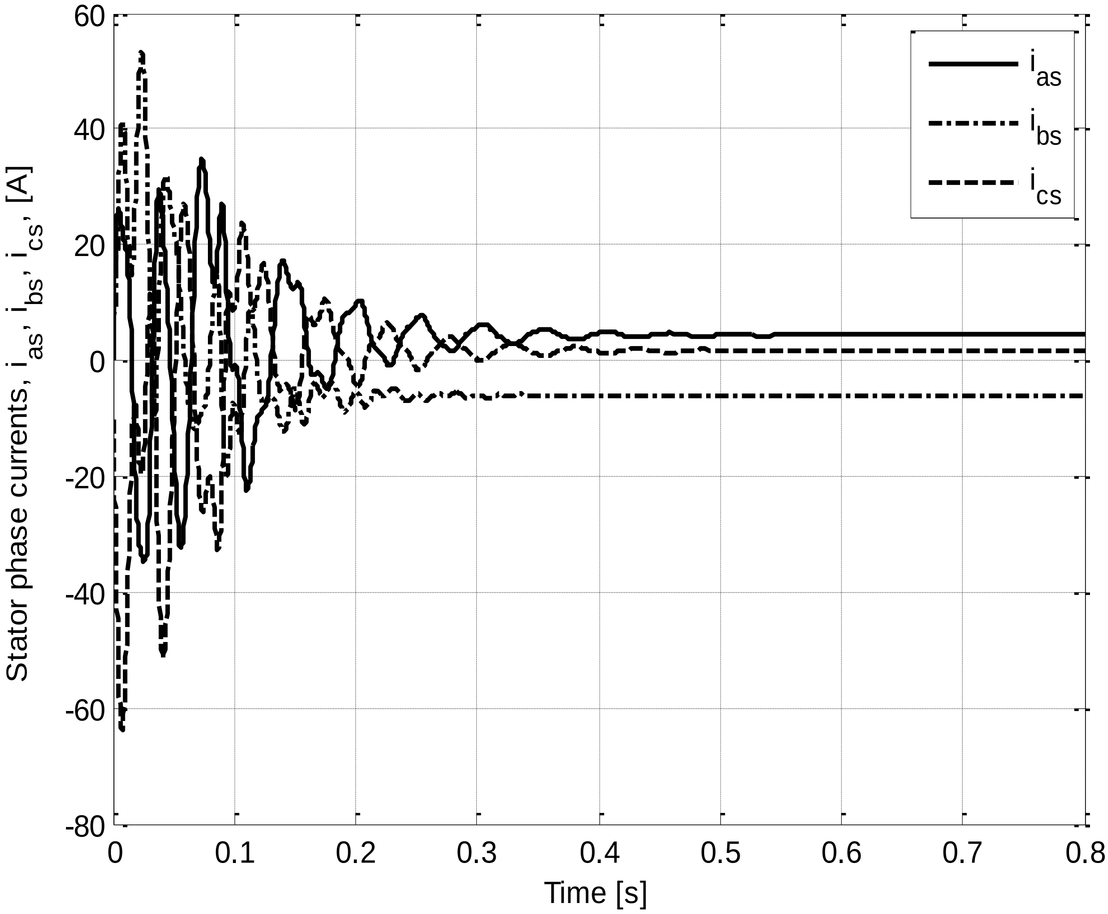

Figure8: Graph of Industrial Noddle PM Motor Stator Phase Currents against time at run-up Condition.

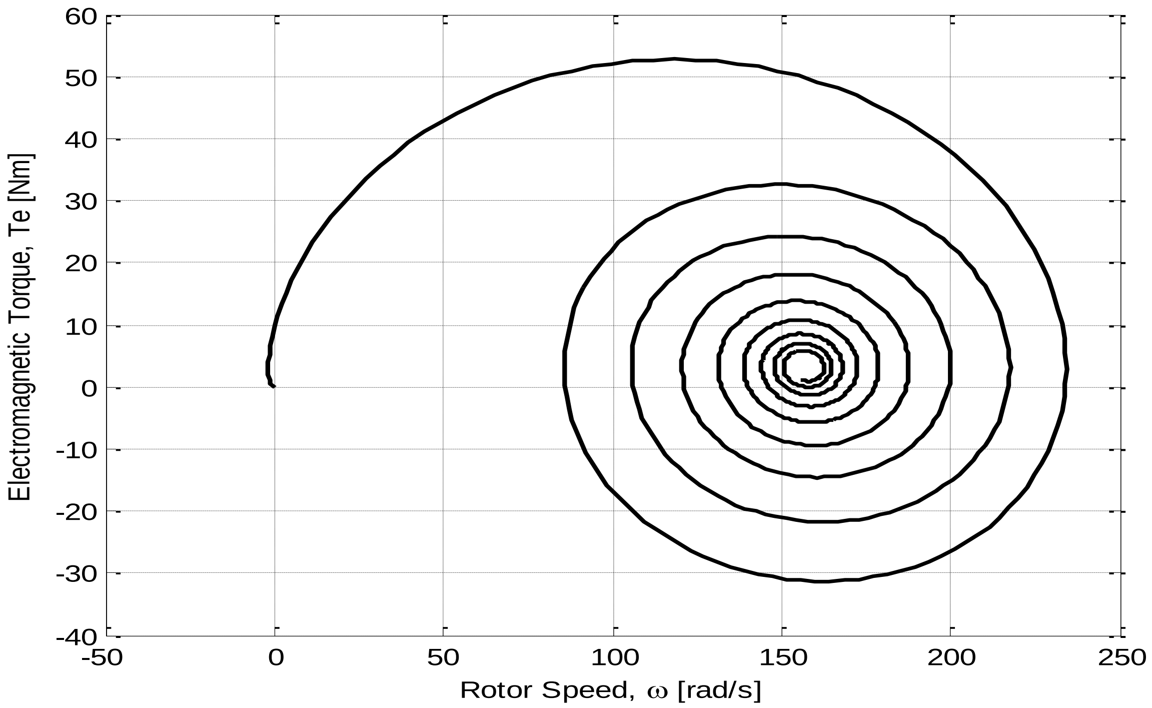

Figure9: Graph of Industrial Noddle PM Motor Electromagnetic Torque against Rotor speed at run-up Condition.

4.0 Results Analysis

The industrial noddle PM Motor shows the effect of varying the stator resistance on the transient performance of the PM motor. At lower values of the stator resistance, PM motor possesses initial peak magnitude of the rotor speed and motor torque. The maximum load angle was attained at high value of the stator resistance. The effect of varying the equivalent field current was investigated, as the equivalent field current increases, the rotor speed, rotor torque become more pulsation.

The results of industrial noddle PM motor are: I_1 = 1.43Aac, I_2 = 2.23Aac, E_1 = 400-V, the PM motor toque was 15.8 1bf.in and apparent power =522 VA. The results of no-load characteristic of industrial noddle PM motor are, Average current = 0.62, Apparent power = 223VA, Real power72w, Reactive power = 211var, Power factor = 0.323. The results of characteristic of industrial noddle PM motor when the resistance was set at zero ohms and at the torque of 91bf.in are: Average current = 1.08Aac, Apparent power = 378 VA, real power = 290w, reactive power = 242var, power factor = 0.772, horse power = 0.220, efficiency = 56.6%. The results of characteristic of industrial noddle PM motor when the resistance was set at 16Ω and at the torque of 91bf.in are: Average current = 1.03Aac, apparent power = 377 VA, real power = 283w, reactive power = 240var, power factor = 0.768, horse power = 0.117, efficiency = 30.8%. The results of no-load and full load characteristic ratio of industrial noddle PM motor when the torque is at 91bf.in are: Average starting current to full load current = 1.42Aac, starting torque to full load torque = 1.76, full load current to no load current = 1.70.

5.0 Conclusion

When the Industrial Noddle PM Motor approaches normal operating speed, the resistance reduced gradually, the starting torque of the Industrial Noddle PM Motor was very high because of the rotor winding resistance. Industrial Noddle PM Motor has a variable speed capability as a special future for varying resistance, that's make it possible to vary the percentage slip and the Industrial Noddle PM Motor speed. The power factor improves with loading as loading increases, the machine delivered power, the real input power increases proportionately and the reactive power required for the machine magnetic field remain relatively constant.

PM drives performances experimental were carried out and simulation results of the characteristics run-up of a PM has been presented graphically. The result show that as PM transient and speed varies is highly sensitive to rated voltage, stator resistance and equivalent field current value. This must be regulated during PM motor design and is recommended for Noddle Industries, food processing plants and plants Machines designers.

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