Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(6):276-283**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Run-Up Characteristics of Inverter Fed Induction Motor Drive Electric Vehicle

Shereen A. Elsayed[1], Basem E. Elhaghi[2], Hamed A. Ibrahim[1], Fathy Abd-Elkader[3]

[1]Faculty of Industrial Education, Suez University, Egypt
[2]Faculty of Engineering, Suez Canal University, Egypt
[3]Faculty of Engineering, Monofia University, Egypt

Abstract To simulate an electric vehicle drive with an induction motor, a frequency converter is needed. This combination of motor and converter led to many possible characteristics. In this paper, the run-up characteristics of induction motor loaded by the electric vehicle are obtained through the wide variation of speed.

Keywords three phase induction motor, control indication motor, traction application

Introduction

The three-phase induction motor is used widely in the modern ac drive system, that has simple structure, low price, good durability and smooth capacity, as well as being maintained easily [1].

Recently, attention has been given back to electric vehicles has been given more attention after 100 years. Combustion engines in addition to electric motors powered the first modern vehicles in the last century unexpectedly. Electric vehicles quickly disappeared mainly as a result of the poor performance of the battery and the low cost of gasoline at that time. The increasing concern of the reduction of fossil fuel, and the significantly improved battery performance, has brought electric vehicles back [1-4].

An electric motor can propel a vehicle by changing electrical energy into mechanical energy. Electric motors have various advantages over combustion engines according to conversion efficiency, power density, and low-speed torque characteristics. Furthermore, electric motors can change mechanical energy back to electrical energy when it operates in braking mode. Such characteristics of electric motors make electric drive more powerful, more energy efficient, and more compact.

The need for comparing polyphases induction motor (IM) control methods has appeared for quite some time. Some methods, such as field-oriented control (FOC), were introduced in the late 1970s, while others, such as direct torque control (DTC), were developed in the mid-1980s. A bustle of different controllers was introduced in the late 1980s till today.

This was because variable frequency drives have become popular since the advent of power electronics in the 1960s. The use of the bipolar junction transistor (BJT) and then the field effect transistor (FET) have played a role in the conversion between different types of power sources. The use of power electronics has enabled the control of a motor’s frequency that has got rid of the need to start and run motors from line frequency [2].

The fact that there are so many different types and variations of controllers, resulted in the need to divide the groups of controllers into application specific groups; a few of these groups include: hybrid electric vehicles (HEVs) or electric vehicles (EVs); motor drives for industrial processes; general industrial uses as pumps, compressors, and air conditioning units; and finally household appliances as washing machines the bulk of this work will attempt to survey the existing literature in addition to compiling relevant results and then compare and contrast four different motor controllers.

This paper attempts to group control algorithms with their corresponding applications and to give them a specific performance status, such as "high-performance" or "low-performance" by use of different operational metrics: one example is a parameter sensitivity analysis of each algorithm. DTC and IFOC will be studied in depth [5-12].

Mathematical Model of Three-Phase Induction Motor

Some of the important steady-state performance features of a polyphase induction motor are the variation of current, speed, and losses as the load-torque requirements change, and the starting and maximum torque. Performance calculations can be made from the corresponding circuit [12-14].

Calculations can be made on a per-phase basis, with the assumption that balanced operation of the machine. Total quantities can be obtained through using a proper multiplying factor. The equivalent circuit of (Fig. 1) is usually employed for the analysis. The core losses, most of which occur in the stator, in addition to friction, wind age and stray-load losses are included in efficiency calculations

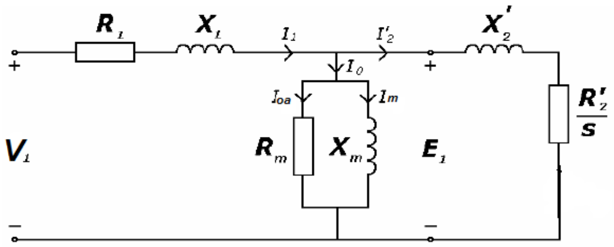

Figure 1: Phase equivalent circuit of Induction Machine

In Fig.1, the stator phase current I_1 is calculated by

$$I_1 = \frac{V_1}{Z_T} \quad (1)$$

Where:

$$Z_T = \sqrt[2]{\left(R_T{}^2 + X_T{}^2\right)} \quad (2)$$

$$R_T = R_{21} + R_1 \quad (3)$$

$$X_T = X_{21} + X_1$$

$$R_{21} = \frac{\left((R_{mm} * R_{2m}) + (X_{mm} * X_{2m})\right)}{A_{z2}} \quad (4)$$

$$X_{21} = \frac{\left((X_{mm} * R_{2m}) - (R_{mm} * X_{2m})\right)}{A_{z2}} \quad (5)$$

$$A_{Z2} = \left(R_{2m}{}^2 + X_{2m}{}^2\right) \quad (6)$$

$$X_{mm} = (R_{Zm} * X_2) + (R_{2S} * X_{Zm}) \quad (7)$$

$$R_{mm} = (R_{2S} * R_{Zm}) - (X_2 * X_{Zm}) \quad (8)$$

$$R_{2m} = R_{2S} + R_{Zm} \quad (9)$$

$$X_{2m} = X_2 + X_{Zm} \quad (10)$$

$$R_{2S} = \frac{R_2}{S} \quad (11)$$

$$Z_{Zm} = \sqrt[2]{\left(R_{Zm}{}^2 + X_{Zm}{}^2\right)} \quad (12)$$

$$X_{Zm} = \frac{X_m * R_m{}^2}{A_{Zm}} \quad (13)$$

$$R_{Zm} = \frac{R_m * X_m{}^2}{A_{Zm}} \quad (14)$$

$$A_{Zm} = \left(R_m{}^2 + X_m{}^2\right) \quad (15)$$

The motor input power factor (PF) is

$$PF = \frac{R_T}{Z_T} \quad (16)$$

The motor input power (P_1) is

$$P_1 = 3 * V * I_1 * PF \quad (17)$$

The rotor phase e.m.f. referred to stator (E_2) is

$$E_2 = I_1 * Z_{2S} \tag{18}$$

Where:

$$Z_{2S} = \sqrt[2]{(R_{2S}{}^2 + X_{2S}{}^2)} \tag{19}$$

The stator magnetising current (I_m) is

$$I_m = \frac{E_2}{X_m} \tag{20}$$

The rotor phase current referred to stator (I_2) is

$$I_2 = \frac{E_2}{Z_{2S}} \tag{21}$$

The motor torque (T) is

$$T = \frac{9.554 * P_2}{N} \tag{22}$$

The motor output power (P_2) is

$$P_2 = 3 * I_2{}^2 * R_2 * \frac{(1-S)}{S} \tag{23}$$

The motor efficiency (**η**) is

$$\eta = P2_{/}P1 \tag{24}$$

where:

R_1 = stator phase resistance

R^{-}_2 = rotor phase resistance referred to stator.

R_m = iron loss phase resistance.

X_1 = stator phase leakage reactance.

X^{-}_2 = rotor phase leakage reactance at standstill referred to stator.

X_m = phase magnetizing reactance.

I_1 = stator phase current.

I_2 = rotor phase current referred to stator.

I_0 = no load phase current

I_m = phase magnetizing current.

E_1 = Stator phase e.m.f.

V_1 = Input phase voltage.

S = slip

Simulation Results

During the variation of inverter frequency, the voltage will be varied by the classical relation (V/f = constant and V = constant) as shown Fig. (2).

When the motor load is high at low speeds, the motor voltage will be boosted to higher values up to the base frequency Fig. (2). Also, the motor voltage will be increased after the base frequency (50 Hz) tell a value of 30 % of rated voltage at100 Hz as shown in Fig. (2). this operation is to make the motor able to drive the vehicle up to the double frequency.

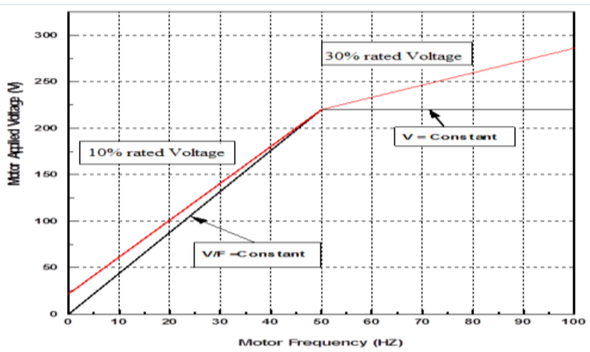

Figure 2: Variation of motor voltage with frequency.

Fig. (3) Shows the variation of motor torque during the run-up at different frequencies. Also, the vehicle load torque is varied with speed as shown. Due to the voltage boost at low frequencies, the motor maximum torque is nearly constant, so the vehicle acceleration will be high.

With voltage boost at high frequency, the motor can drive the high torque load. With voltage boost at high and low frequencies, the total iron and copper losses still near the same value at full load with base frequency (50 Hz).

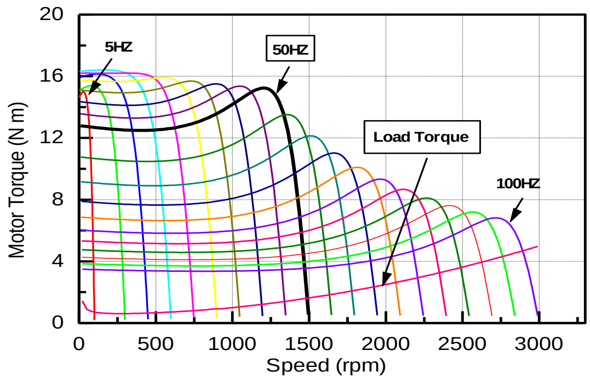

Figure 3: Variation of motor torque with speed, at voltage boost of 10% at low frequency and voltage boost of 30% at 100Hz

Fig. (4) Shows the torque-speed characteristic of motor during the run-up at different frequencies without voltage boosting low frequency and higher frequency. During the variation of inverter frequency, the voltage will be varied by the classical relation V/f = constant. From this figure, it is clear that the torque at low and high frequency is low and this could be a problem for loads which require a high starting torque as shown Fig. (4).

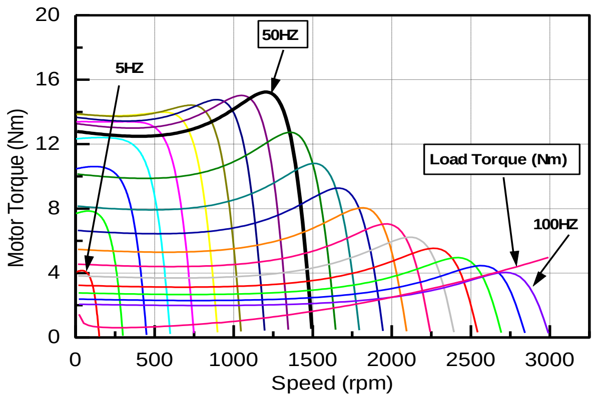

Figure (4): Variation motor torque without voltage boosting Low frequency and higher frequency.

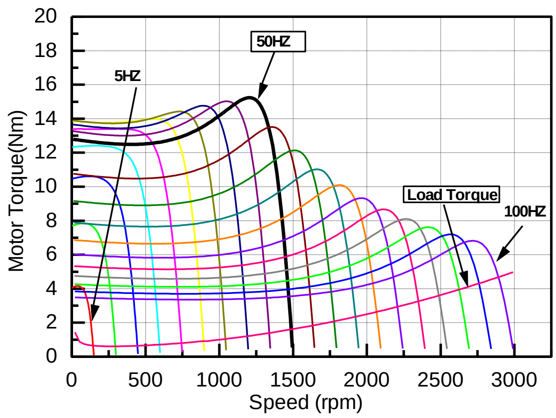

Figure 5: The variation motor torque with low frequency is V / F = constant and high frequency the voltage boosted by 30% at 100Hz.

Fig. (5) Shows the variation of motor torque during the run-up at different frequencies. During the variation of inverter frequency, the voltage will be varied by the classical relation V/f = constant at low frequencies, Also, the motor voltage will be increased after the base frequency (50 Hz) tell a value of 30 % of rated voltage at 100 Hz as shown in Fig. (5).

Fig. (6) Shows the motor current versus speed (N) at different frequencies. During the variation of inverter frequency, the voltage will be varied by the classical relation V/f = constant at low frequencies, Also, the motor voltage will be increased after the base frequency (50 Hz) tell a value of 30 % of rated voltage at 100 Hz, the motor start current is higher values at the base frequency (50 HZ) .

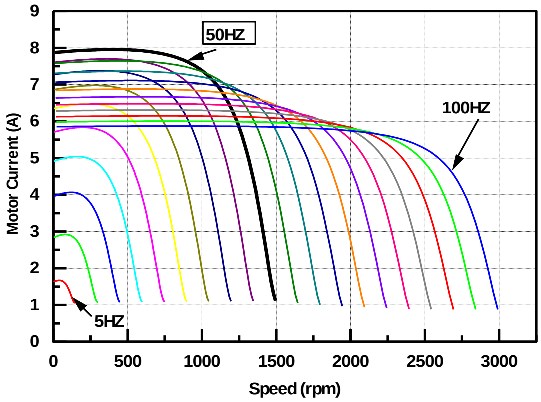

Figure 6: The variation motor current with low frequency is V / F = constant and high frequency the voltage boosted by 30% at 100 Hz.

Fig. (7) Shows the variation motor input power during the run-up at different frequencies. During the variation of inverter frequency, the voltage will be varied by the classical relation V/f = constant at low frequency, Also, the motor voltage will be increased after the base frequency (50 Hz) tell a value of 30 % of rated voltage at 100 Hz. From the figure, it can be noted that the motor maximum input power is nearly constant.

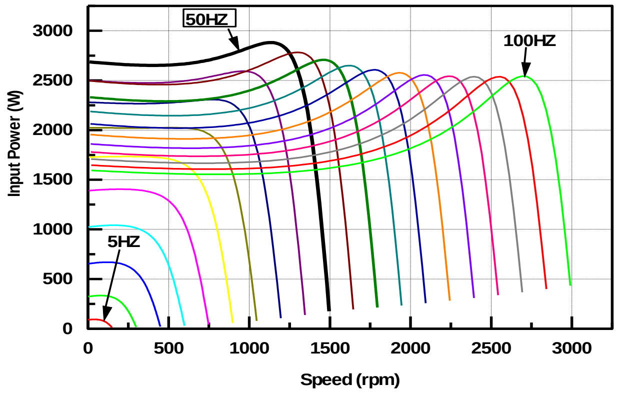

Figure 7: Motor input power (Pin) versus speed (N) for various frequencies

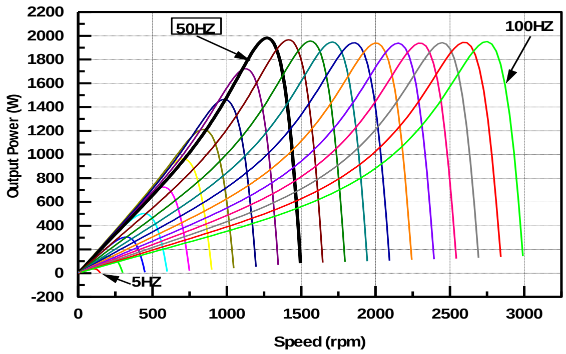

Figure 8: Output power (Po) versus speed (N) for various frequencies

Fig. (8) shows the output power-speed curve of motor for different values of frequencies. The plot depicts that as the speed is increased, the output power increases. Due to the voltage boost at high frequencies, the motor maximum output power is nearly constant, so the vehicle acceleration will be high.

Fig. (9) Shows the variation of motor efficiency during the run-up at different frequencies. During the variation of inverter frequency, the voltage will be varied by the classical relation V/f = constant at low frequency, Also, the motor voltage will be increased after the base frequency (50 Hz) tell a value of 30 % of rated voltage at 100 Hz, This operation makes the motor efficiency Very good as shown in Fig. (9).

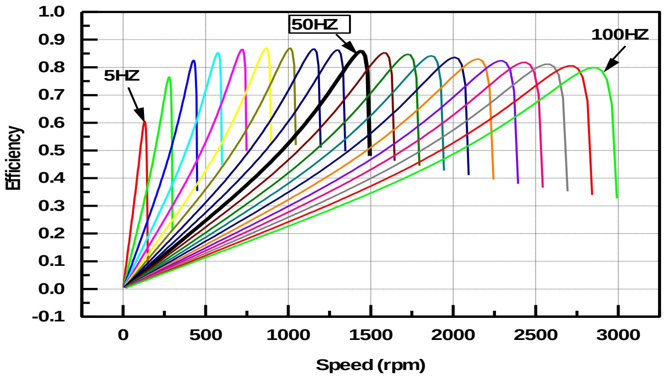

Figure 9: The efficiency (η) versus speed (N) for various frequencies.

Fig. (10) shows the Power factor (PF) versus speed (N) at different frequencies. From this figure, it can be note that the full load PF slight increases with increasing frequency over the rated value.

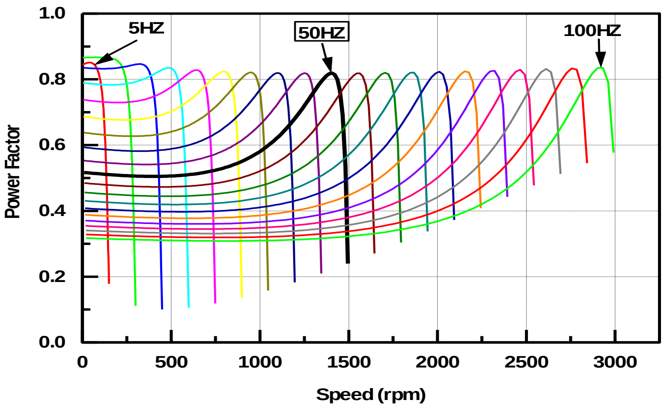

Figure 10: The Power factor (PF) versus speed (N) for various frequencies

Fig. (11) shows the power losses versus speed for different values of frequencies. From the graph, it is observed that as the speed is increased, the power losses decrease. Also when the voltage boost at high and low frequencies, the total iron and copper losses still near the same value at full load with base frequency (50 Hz).

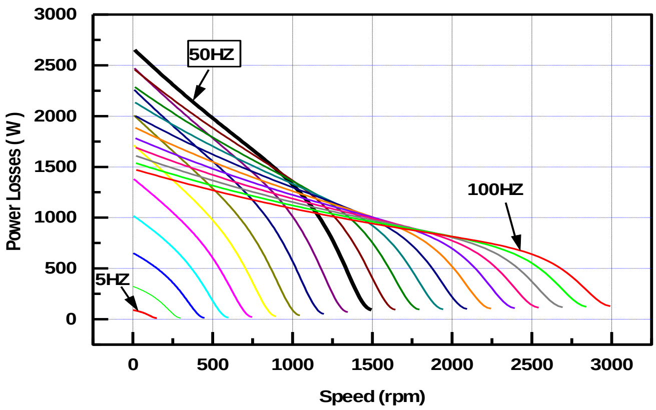

Figure 11: The Power losses (Plosses) versus speed (N) for various frequencies

Conclusion

This paper presents, the simulate an electric vehicle drive with an induction motor, this combination of motor and converter led to many very good characteristics at the run-up of induction motor loaded by the electric vehicle are obtained through the variation of speed. The simulation results versus speed for different values of frequencies. From the graph, it is observed that as the speed is increased, the power losses decrease. Also when the voltage boost at high and low frequencies, the total iron and copper losses still near the same value at full load with base frequency (50 Hz).

Acknowledgments

Thanks to Allah, the lord of the worlds, for his mercy, limitless help and guidance. Peace and blessings be upon Mohammed, the last of the messengers.

I would like to express sincere appreciation to my supervisors Prof. Dr. Fathy Abd-Elkader, Dr. Hamed Anwar Ibrahim and Dr. Basem E. Elhaghi for providing their advices and encouragements. Also, I am heavily indebted for their excellent guidance, warm discussions and regular meetings I had with them during the research. Special thanks to the faculty of industrial education specially the dean of the faculty and all staff members of the faculty for their advices, support and encouragement to complete the work. In addition, my thanks are given to my mother, my husband and my friends and colleagues for their advices and support. There are no words that describe how grateful I am to my family.

References

[1]. C.W. Ayers, J.S. Hsu, L.D. Marlino, C.W. Miller, G.W. Ott Jr., C.B. Oland. (2004). "Evaluation of 2004 Toyota Prius Hybrid Electric Drive System", Oak Ridge National Laboratory Report ORNL/TM/247.

[2]. J.S. Hsu, S.C. Nelson, P.A. Jallouk. (2005). C.W. Ayers, R.H. Wiles, S.L. Campbell, C.L. Coomer, K.T. Lowe, T.A. Burress,Report on Toyota Prius Motor Thermal Management, Oak Ridge National Laboratory Report ORNL/TM/33.

[3]. M. G. Kosowski and P. H. Desai. (2000). “A parallel hybrid traction system for GM’S precept PNGV vehicle,” presented at the Proc. SAE—Future Car Congr., Arlington, VA, Apr. 2–6, Paper SAE2000-01-1534.

[4]. M. SajediHir, Y. Hoseynpoor, P. Mosadegh Ardabili, T. Pirzadeh Ashraf. (2011). “Modeling and Simulation of Induction Motor Drive with Space Vector Control”, Australian Journal of Basic and Applied Sciences, 5(9): 2210-2216.

[5]. V. Garg. (2006). “Power Quality Improvements at ac Mains in Variable Frequency Induction Motor Drives,” Ph.D. dissertation, Indian Inst. Technol. Delhi, New Delshi.

[6]. J. A. Santisteban, and R. M. Stephan. (2001). "Vector control methods for induction machines: an overview," IEEE Trans. On Education, vol. 44, No.2, pp. 170-174.

[7]. Gordon, Slemon R. (1992). " Electric machines and drives", Addison Wesley Pub Co., Reading, Mass.

[8]. Patzak, Adrian, et al. (2015). "Driving range evaluation of a multi-phase drive for low voltage high power electric vehicles. In: Sustainable Mobility Applications, Renewables and Technology (SMART), 2015 International Conference on. IEEE,p. 1-7.

[9]. Krause, P. C. (1965). "Simulation of Symmetrical Induction Machinery", IEEE Trans. On Power Apparatus and Systems, 84, pp. 1038-1053, November.

[10]. Krause, P. C., Nozari, F., & Skvarina, T. L. (1978). "The Theory of Neglecting Stator Transients", IEEE Trans. On Power Apparatus and Systems, 98(1), pp. 141-148, January/February.

[11]. V. Garg. (2006). “Power Quality Improvements at ac Mains in Variable Frequency Induction Motor Drives,” Ph.D. dissertation, Indian Inst. Technol. Delhi, New Delshi.

[12]. J. A. Santisteban, and R. M. Stephan. (2001). "Vector control methods for induction machines: an overview," IEEE Trans. On Education, vol. 44, No.2, pp. 170-174.

[13]. MUETZE, Annette; STRANGAS, Elias G. (2016). "The useful life of inverter-based drive bearings: Methods and research directions from localized maintenace to prognosis". IEEE Industry Applications Magazine, 22.4: 63-73.

[14]. BOGLIETTI, Aldo, et al. (2008). "Efficiency analysis of PWM inverter fed three-phase and dual three-phase high frequency induction machines for low/medium power applications". IEEE Transactions on Industrial Electronics, 55.5: 2015-2023.