IMPROVINGSTARTINGCHAR**ACTERISTICS OF SQUIRREL-CAGE MOTOR BY USING V/F CONTROL METHOD**

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ABSTRACT:-

This paper presents one of the most successful method controllers of 3-phase squirrel-cage IM motor which is employing V/F method with application of pulse width modulation (PWM), this dynamic model is implemented using Mat Lab simulation program. The improved techniques of suggested model presents high performance of improving the starting characteristics (starting current , starting torque) of the double comparison with single-cage IM using PWM techniques at constant V/F control. Simulation results refers to the characteristics of double-cage better than single cage and shows that the satisfy performance and good response of this model.

Keywords:- Induction motor IM, single, double cage, V/F control and PWM technique.

الخلاصة:-

يقدم هذا المقال واحدة من اهم طرق السيطرة الناجحة للمحرك ثلاثي الاطوار ذات القفص السنجابي والذي يعمل بطريقة V/F مع تطبيقات لمضمن عرض الحزمة (PWM) هذا النموذج الديناميكي يعمل باستخدام برنامج المحاكاة Mat Lab . التقنيات المحسنة للنموذج المقترح تقدم الاداء العالي لتحسين خصائص البدء (تيار البدء، عزم البدء) للمحرك ثنائي القفص مقارنة مع المحرك احادي القفص ثلاثي الاطوار باستخدام تقنية مضمن عرض الحزمة عند مسيطر V/F ثابتة.نتائج المحاكاة تشير الى ان الخصائص لثنائي القفص هي افضل بكثير من احادي القفص وتبين الاداء المحسن والاستجابة الجيدة لهذا النموذج.

1-IN TRODUCTION:-

The construction of three- phase induction motors haven't any mechanical commutations therefore these types of the motors are use in most of industrial application. [5], [6], [2], [9]. The induction motor has large speed range, high robustness and efficiency, low manufacturing cost. [6],[10].The cage-type machine of induction drives have applications in the industry that include:- textile mills , papers, fans, pumps , air-conditioners, heat pumps , rolling mills and wind generation systems, vehicles, home applications , machines tools robotics .The range power of these machines cover fractional and horse-power to megawatts. In this time there is most application in the process control because the energy saving aspect to variable- frequency drives. [2].All these applications have drastic move away from analogue motor control to precision digital control that use variation processors digital control of induction motor results led to more efficient operation of the motor gives lower power dissipation and longer life wide. Today the various control techniques of induction motor are generating variable frequency supply that V/F is the constant ratio of voltage to frequency. [6].This technique is known as V/F control principles is good understood with the introduction of solid-state inverters, the constant V/F control become widely.[1]. Nowadays the advances development of power electronics technology and high speed computers with associated high speed microcontrollers A.C. drive system have been available alternative to D.C. machines for variable speed applications. The induction motors have merits over the other types of industrial motors. [2]. the important of machines control algorithm fast-switching power semiconductors devices, most precise (pulse width modulation) increases particularly interest. Recently the pulse width modulations have large variety in methods that which a survey was given. The large utilization the ac machine drives application, of the dc bus voltage is extremely important leds to obtain the maximum output torque at all operating conditions. [8]. There are many limitations of variable speed drives represents longer space, low speed ,poor efficiencies so, by using the power electronics to achieve the variable speed drive into a high efficiency, smaller size and high reliability. The advance in improving of control system using frequency has been designed by combinations of PWM controller. [10].This study presents the implemented system to develope the starting characteristics of induction motor for constant V/F of the motor, the comparison is done between single and double-cage induction motor drives by using PWM techniques which improve the performance of induction motor by eliminating the current harmonics of the motor.

2-DOUBLE-CAGE IM:-

The field control techniques can be used to control the torque developed of induction machine from flux regulation. In induction motor for variable speed drives to obtain minimize losses; the rotor resistance should be designed as low values. In construction with a general purpose induction motor, there is honked to compromise the design of the rotor cage in order to achieve adequate starting torque. In large machines (mill drive systems), high rotor current flows in rotor, therefore the rotor cage is also design large. [4].

The construction of squirrel-cage winding includes of layers short circuited bars by end rings .The upper bars have higher resistance and smaller cross-sectional area than the lower bars [7].

The effective resistance (R_{eff}) and leakage inductance of double-cage rotor vary with frequency because at the low rotor-frequencies corresponding to small slips, reactance can be neglected and the rotor resistance reaches that of the two layers in parallel.[3].

3-INDUCTION MOTOR MATHEMATICAL MODEL :-

At start condition the rotor resistance of squirrel- cage induction motor is very large compared to rotor resistance at running (fixed and small). The rotor current has frequency equal the supply frequency, hence, the starting torque per ampers is very poor ,because at standstill the starting current flows in the rotor is very large in magnitude and very large angle behind the rotor induced e.m.f in the rotor .The starting torque represents in equation:- [11]

$$T_S=K_1E_2I_2COS\varphi_2 \tag{1}$$

Where:-
T_S = starting torque, E_2 = e.m.f induced in rotor per phase at standstill, I_2 =rotor current at starting, Φ_2 = angle between rotor e.m.f and the rotor current, K_1= constant

Figure (**1**) shows equivalent circuit of double-cage induction motor.

The starting current of the squirrel cage IM is (5 to 7) times of the the full load current and the starting torque is 1.5 times the full load torque, therefore these types of motors are not used in where applications of heavy loads [11].

4-V/F CONTROL AND IMPROVE STARTING CHARACTERISICS OF IM:-

In a squirrel cage rotors in a squirrel cage rotors no resistance can be inserted at the starting as this done wound-rotor can be developed in many a way.[11].The various schemes all make use of the inductive effect of the slot-leakage flux on the current distribution in the rotor bars. [7].

The voltage applied to the stator is proportional the torque developed on the shaft of the motor and directly proportional to the angular velocity and the product of stator flux. This led the stator the flux produced by proportional to the ratio of V/F(applied voltage and frequency of supply).

The torque can be remain constant at all speed range at ratio of voltage to frequency constant .the ratio V/F makes the most common speed control of an induction motor. The torque developed is proportional to the (Voltage/Frequency).The ratio must be constant although we vary the voltage and frequency ,with various speed rang the torque produce in induction motor will remain constant, figure (**2**) shows the torque-speed characteristics of IM with V/F control .The (voltage and frequency) ratio reaches the maximum value at the base speed. [6].

The torque- speed characteristics of the V/f control reveal the following:-

1-the current at starting is low.

2-the stable operating region of the motor is increased instead of simply ruing at its rated speed, the motor can be run typically from 5% of the synchronous speed up to the base speed. The torque generated by the motor can be kept constant throughout this region.

3-since almost constant rated torque is variable over the entire operating ranges the speed range of the motor becomes widely user can be set the speed as per the load requirement, thereby achieving the higher efficiency. [6].

5-IMPROVING MODEL OF IM BY USING INVERTER:-

The desired sinusoidal voltage can be produced by pulse width modulation at a particular frequency to the squirrel cage of IM inverter is controlled, A PWM provides higher performance because more efficient and typically.[10]. Figure (**3**) shows the block diagram of induction motor using bridge and inverter rectifier to improve the starting of IM, figure (**4**) shows the block diagram of induction motor by using (PWM) that proposes in this study, and figure (**5**) shows the construction of the modeling use in this study.[12].

This study presents the model that is designed in order to compare between double-cage and single-cage IM by using the power electronics elements. So this model consists of 3- phase full bridge rectifier which is designed using (6A10BL) power diodes, the second part of model is three full bridge inverter which is PWM, the output of PWM is filtered by (300µf, 900V) capacitor which is used to filter the harmonics of IM and three- phase induction motor is the last part of the model.

6-RESULTS SIMULATION:-

Simulation results were obtained at constant V/F control of induction motor drives that is fed by inverter with single and double squirrel cage by using pulse width modulation refers to:-

1- The mechanical characteristic (torque-speed) of the single and double-cage rotors of induction motor shows in figure (**6**) at constant V/F. these results indicate to a higher starting torque of double –cage than single-cage rotor, but the double-cage has a smaller maximum torque , these results can be shown in table (**1**) .

2-Tthe double- cage rotor consists of two layers (upper and lower),the simulation results refers to higher starting torque characteristic in upper-layer comparison than lower-layer which can be shown in figure (**7**) and table (**2**).

The summation of two components curves led to torque- speed characteristics.

3-The current-speed characteristics that obtained of simulation program indicates to starting and rated currents for single-cage are higher than double-cage, those results can be shown in figure (**8**) and table (**3**).

4- In figure (9) and (10) shows the torque- speed curves of single and double-cage rotor respectively for several excitation frequencies of three phase induction motor operating with its air gap flux remain constant at all rated condition value for all values of slips, These curves shows that the value of the torque remains the same at given value of the slips speed for any value of speed, these results can be seen in table (**4**) and (**5**) respectively.

5-The simulation results of the torque-speed curves for single and double-cages motor respectively shown in figure (**11**) and (**12**)that use excitation voltage based on stator V/F of air gap magnetic flux constant at rated value and rotor currents gives the same pull out torque. The curve of speed of magnetic field is low has much higher value of pull out torque and this speed is properly with magnetizing voltage (E_m) so that stator curve will be determined by stator terminal voltage and the stator winding resistance so the stator current remains constant when terminal voltage is fixed at all slips speed, these results can be shown in table (**6**) and (**7**).

6-Figure (**13**) and (**14**) shows the starting torque and current for different starting frequencies for single and double-cage motor respectively, the simulation results can be shown in table (**8**), (**9**).

With a low frequency start, the rotor reactance is low , hence the induced rotor current are much closer in phase to the voltage so giving high torque with high power factor and consequently minimum starting current magnitude.

7-CONCLUSION:-

By use of double-cage rotors, squirrel-cage motors can be designed to have the good starting characteristics resulting from high rotor resistance at start and at the same time good running characteristics resulting from low rotor resistance at running.

The design of double-cage rotor is necessarily somewhat of a compromise and the motor lacks the flexibility of the wound-rotor machine with external rotor resistance.

The current demanded by the induction motor for a direct-on line stator fixed frequency has a magnitude of approximately six times the normal full load current. With a fixed- frequency source, this starting current can only be reduced by voltage reduction. However, using the inverter drives it is possible to start at low frequency, and then raise the frequency to accelerate the motor.

8-REFERENCES:-

[1] Alfredo Munoz-Garcia Thomas A. Lipo and Donald W.Novotny, "A New induction motor V/F control method capable of high- performance regulation at low speeds", IEEE Transactions on industry applications, vol. 34, no.4, July/August 1998,pp 813-820.
[2] C. Saravanan, A.Mohamed Azarudeen and S.Selvakumar, "Performance of three phase induction motor using modified stator winding ", Global Journal of researches in Engineering Electrical and Electronics Engineering, vol.12, Issue 5 version 1, April 2012.

[3] C.U. Ogbuka, and M.U.Agu, "A Modified Closed Loop V/F Controlled Induction Motor Drive",the Pacific Journal of Science and Technology, May 2009, Vol.10, NO.1, pp 52.

[4] J. K. Seok and S.K.S ul, "Pseudorotor- flux- oriented control of an induction machine for Deep-Bar-Effects compensation ", IEEE Transactionon industry applications, vol. 34, no. 3 may/June, 1998.

[5] Mohamed Y. Kaikaa , Fatima Badaa, Abdelmalek Khezzar, Mohamed Boucherma, "Analytical analysis of rotor slot harmonics in the line current of squirrel cage IM", Journal of Electrical Engineering, vol. 57, no. 1,2006, 12-19.

[6] M.S.Aspalil, Asha R[2], P.V.Hunagund[3], "Three phase induction motor drive using IGBTS and constant V/F method", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering vol. 1, Issue 5, November 2012.

[7] M. Y. Kaikaa, F. Babaa, A. Khzzar and M. Boucherma, "Analytical Analysis of Rotor Harmonic in the Line Current of Squirrel Cage Induction Motors", Journal of Electrical Engineering, Vol.57, N0.1, 2006,PP 12-19.

[8] R. Linga Swamy and P. Satish Kumar, "Speed control of space vector modulated inverter driven induction motor", Proceedings of the International mult conference vol.II, March, Hong Kong, 2008

[9] SafdarFasal TK and Unnikrishnanl, "A Performance study of PI controller and Fuzzy logic controller in V/F control of three phase IM using space vector modulation ", transactions on Electrical and Electronics Engineering (ITSI-TEEE), vol.1, Issue 2, 2013.

[10] Shilpa V. Kailaswar, prof. R .A. Keswani, "Speed control of three phase induction motor by V/F method for Batching Motion System ", International Journal of Engineering Research and applications (IJERA), vol.3, Issue 2, March-April 2013 ,pp1732-1736.

[11]Thanga Raj, S.P.Srivastava and Pramod Agarwal, " Induction motor design with limited harmonic current using practical swarm optimization", International Journal of Electrical and Computer Engineering, 3:15 2008, pp 1000.

[12] Thida Win, Nang Sabai and Hnin Nandar Maung, "Analysis of Variable frequency three phase induction motor drive", World Academy of Science, Engineering and Technology, 18, 2008, pp 647-650.

Table (1): Torque-Speed characteristic in single and double-cage IM.

Single-cage		Double-cage		
Speed	torque	Speed	torque	V/F
0	135	0	160	0.13
200	150	200	170	0.13
400	170	400	175	0.13
600	175	600	180	0.13
800	197	800	193	0.13
1000	225	1000	212	0.13
1200	240	1200	220	0.13
1400	265	1400	235	0.13
1600	240	1600	212	0.13

Table (2): Torque-Speed characteristic in double-cage I**M**

Lower-cage		Upper-cage	
speed	torque	speed	Torque
0	16	0	132
200	18	200	120
400	23	400	110
600	25	600	96
800	34	800	80
1000	42	1000	65
1200	53	1200	53
1400	65	1400	42
1600	92	1600	20

Table (3): Current-Speed characteristic In single and double-cage.

Single cage		double-cage	
Speed	current	speed	Current
200	78	200	165
400	74	400	163
600	70	600	160
800	67	800	157
1000	65	1000	140
1200	57	1200	130
1400	54	1400	108
1600	45	1600	70

Table (4): Torque-Speed with constant Air gap.

F(HZ)	Speed (rev/min)	Torque (N-m)
15	450	30
30	90	65
45	1100	258
60	1700	132

Table (5): Torque-Speed of double-cage with constant air gap.

F(HZ)	Torque (N-m)	Speed (rev/min)
15	68	390
30	132	740
45	200	1160
60	264	1500

Table (6): Torque-Speed of single with constant V/F

F(HZ)	Torque (N-m)	Speed (rev/min)
15	545	450
30	500	700
45	265	1076
60	124	1700

Table (7): Torque-Speed of double-cage with constant V/F .

F(HZ)	Torque (N-m)	Speed (rev/min)
60	265	1565
45	278	1100
30	285	785
15	1060	380

Table (8): Starting torque and current in single-cage

K values	Starting current	Starting torque
0.1	72	232
0.2	114	270
0.3	125	258
0.4	145	232
0.5	158	210
0.6	165	193
0.7	174	170
0.8	180	167

Table (9): Starting torque and current in double-cage

K values	Starting current	Starting torque
0.1	40	178
0.2	55	230
0.3	61	225
0.4	63	210
0.5	65	190
0.6	68	187
0.7	72	182
0.8	75	175
0.9	78	170
1	83	165

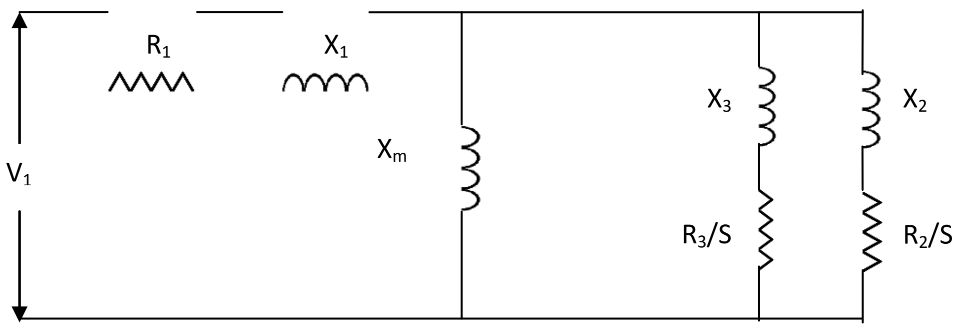


Figure (1): Equivalent circuit of double-cage IM

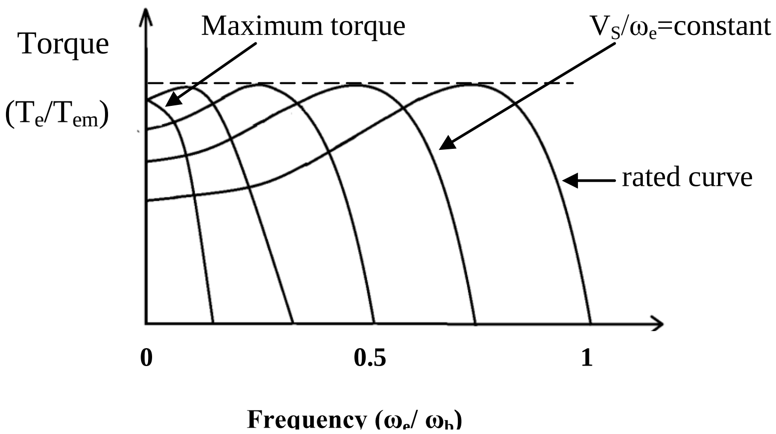


Figure (2): Torque- Speed characteristic of induction motor

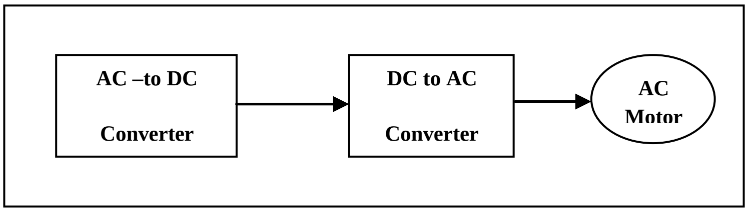


Figure (3): Block diagram of system

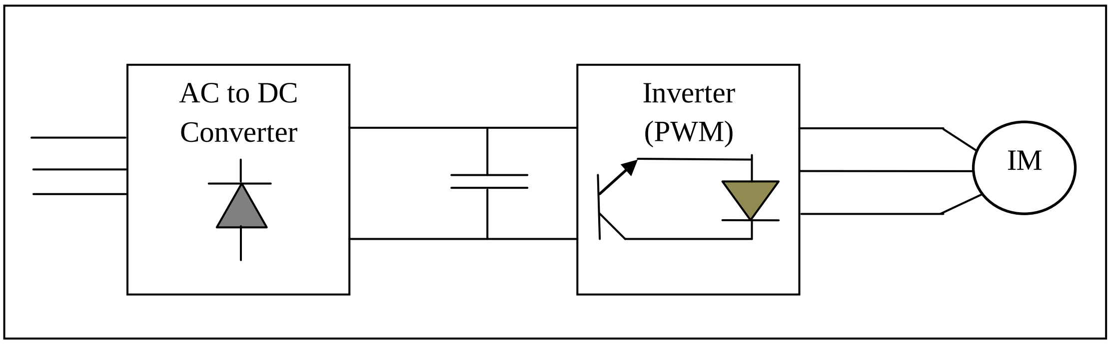


Figure (4): Block diagram of IM by using PWM .

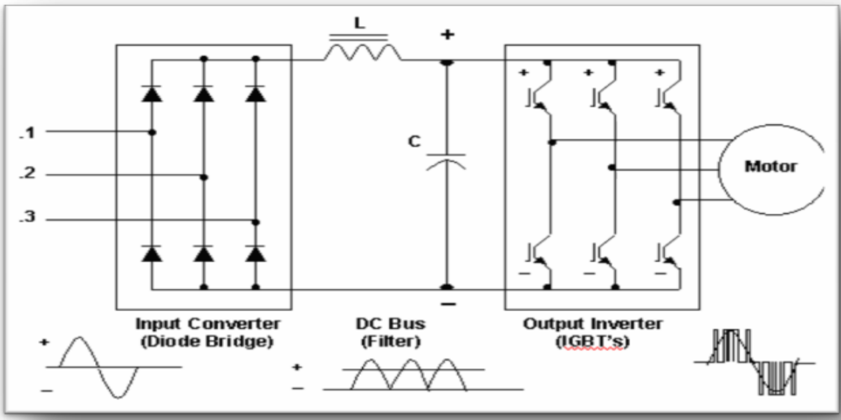


Figure (5): The construction of the model

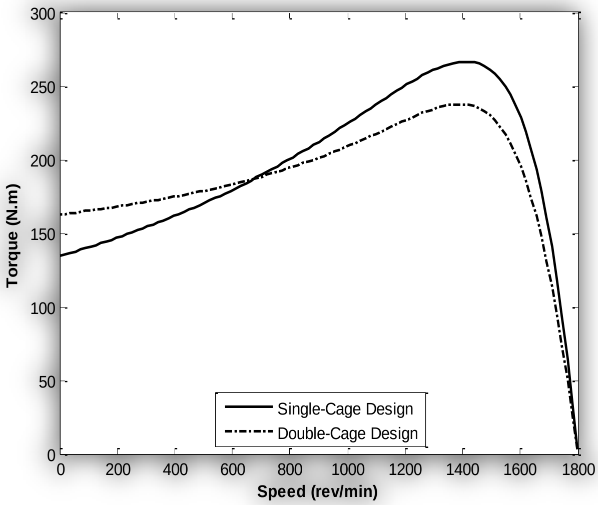


Fig. (6): Torque- Speed characteristic in single and double cage.

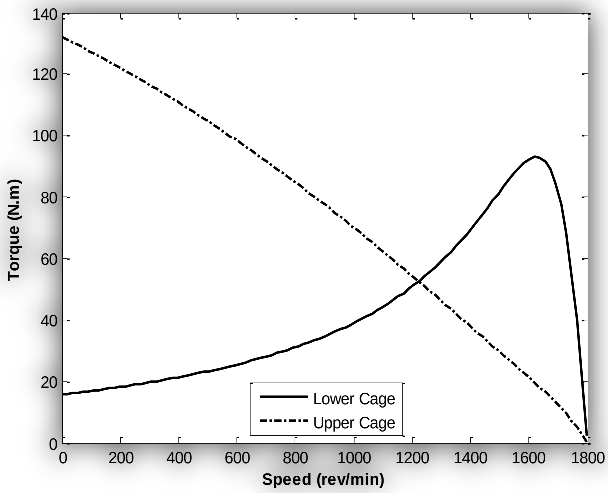


Fig. (7): Torque- Speed characteristic in lower and upper cage**.**

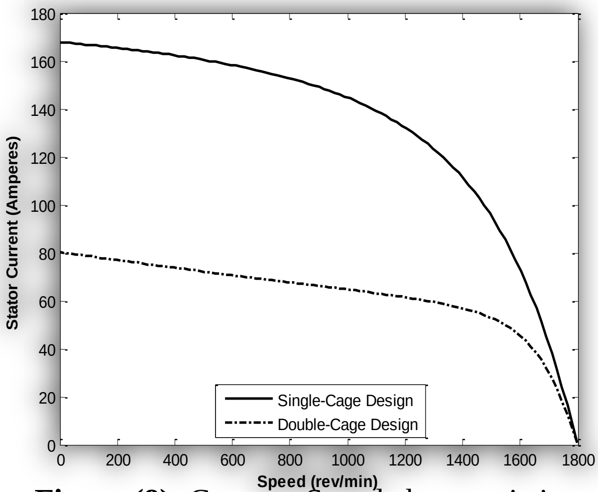


Figure (8): Current- Speed characteristic.

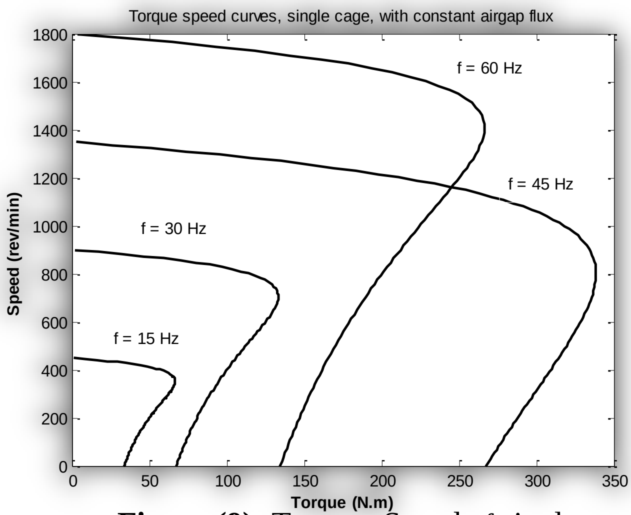
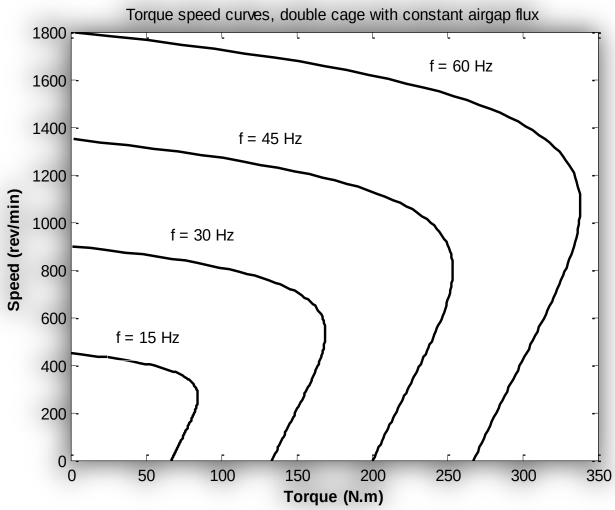


Figure (9): Torque- Speed of single cage with constant air gap



Figure(10): Torque- Speed of double-Cage motor with constant air gap

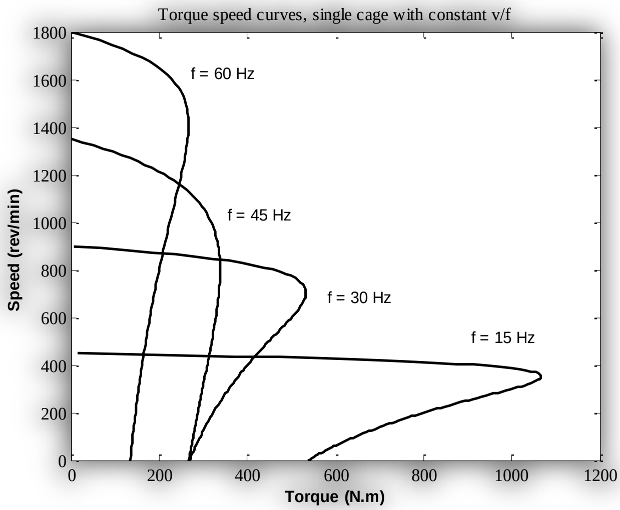


Figure (11): Torque-Speed of single-cage motor with constant V/F

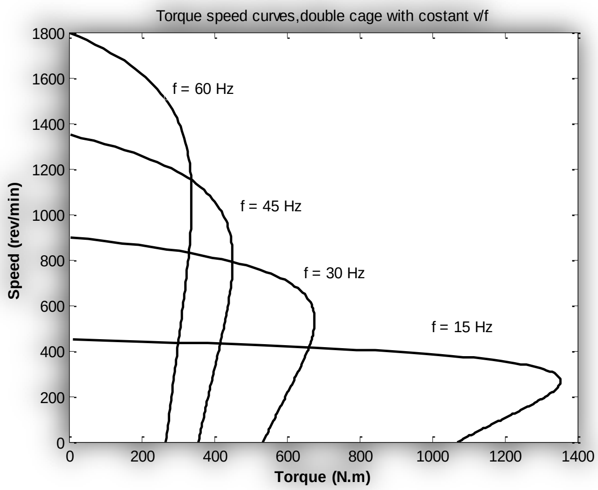
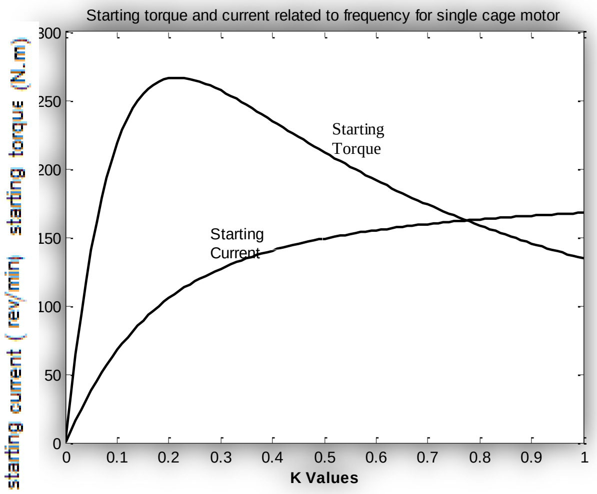


Figure (12): Torque - Speed of double-cage motor with constant V/F .



Figure(13): Starting torque and current related to frequency of single-Cage motor

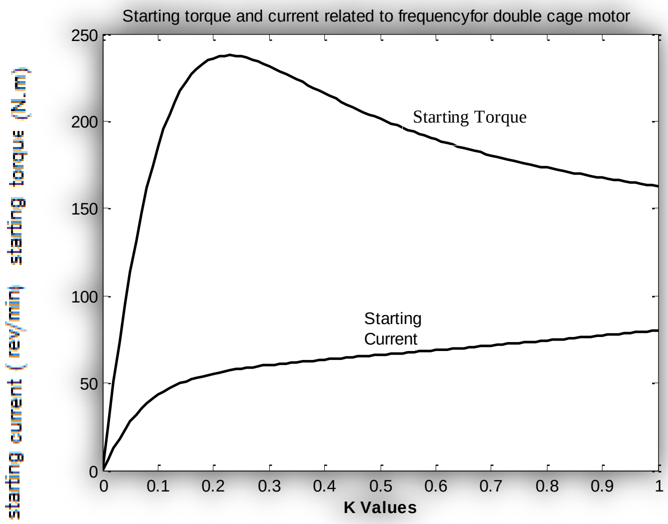


Figure (14): Starting torque and current related frequency of double-cage motor