Performance Analysis of Dual Stator Induction Motor

Prof. Anagha R. Soman[1], Sachin Madaan[2], Shubh Gupta[3], Abhishek Singh[4], Virendra Yadav[5], Ankit Tiwari[6]

[1]Professor,Dept. of Electrical Engineering, Bharati Vidyapeeth Deemed University College of Engineering, Pune
[2,3,4,5,6] Student, Dept. of Electrical Engineering, Bharati Vidyapeeth Deemed University College of Engineering, Pune

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Abstract: *This paper presents detailed study of the performance of a dual stator winding induction motor. Each stator is fed with a variable frequency variable voltage inverter, with a common dc-bus. First we supply power to individual stator winding and perform no-load and blocked rotor tests whose results are used to plot circle diagram for each stator in order to find the different parameters of the motor. Then load tests are done on the two stators separately as well as simultaneously and torque speed curves are plotted for both configurations.*

Keywords: *dual stator, induction motor, performance analysis, torque-speed curve*

1. INTRODUCTION

The fabricated induction motor comprises of two separate stator windings wound for different number of poles (4/12) and a standard squirrel cage rotor. The number of poles can be whatever number we wish them to be, but it is preferred to have a configuration with pole ration 1:3, in order to ensure better utilization of the magnetic material, avoid saturation at local points and losses that may occur in stator. Both the stator winding is fed from two independent variable frequencies, variable voltage inverter which share a common DC-bus.

The peak magnetic loading is obtained by the combination of the MMFs produced by the two stator windings and must be same to that of a motor which has an equivalent stator design. Even though the peak magnetic field is similar in both the cases, with the exception of points of peak flux, the DSIM is much less saturated. Therefore, the iron losses yoke of the motor should be reduced. The rotor of the motor, being standard squirrel cage, guarantees the simultaneous coupling of both the stator current distributions with the rotor flux and production of the desired torque.

Because of this decoupling which is produced due to winding being of different pole number, the dual stator induction motor behaves as two separate induction motors which are mechanically coupled through a shaft. Thus, under any operating condition, the determination of stator frequency is done by a combination of factors like the rotor speed, slip frequency and the added variable of second torque component. This feature provides a significant advantage while implementing simple speed sensor less scheme.

The frequency of the stator having lower number of poles can be boosted with application of a regulated amount of torque with winding having higher number of poles, thus leading to limitation of the minimum electrical frequency in the winding having lower number of poles to a specific value. This is particularly of importance during operation at zero speed, where the conventional induction motor becomes unobservable. While in a DSIM, operation at zero speed does not mean that the excitation frequency is zero as well. This make the system observable at all speeds.

The operation of the motor can be done in two different modes: the synchronous mode, where the frequency of the voltage supply fed to the two stators of the motor are in the same ration as the ratio of the number of poles in the two stators, and the asynchronous mode, where the frequency of the stator winding with lower number of poles is held constant at a particular value. These two modes of operation of the DSIM are shown in figure 1.

2. OBJECTIVES

The objectives of this paper is to analyze the performance of the motor while operating in different configurations. First, the motor will be operated and tested with powering of the two stator windings separately, in order to find out the different performance indices and draw the equivalent circuit diagrams of the motor. Second, the motor is operated and tested with power supply being fed to both the stator windings, in order to study how the performance of the motor was affected by the introduction of second stator winding. Also, torque speed curves of the motor in different configurations are plotted and analyzed.

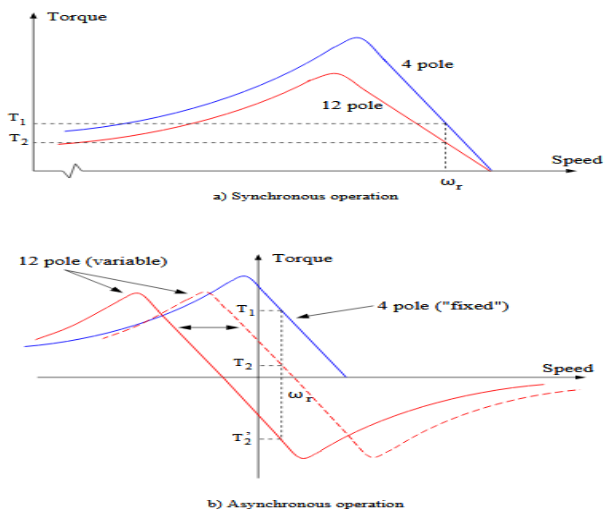

Fig 1. Two modes of operation of DSIM

3. TESTING AND ANALYSIS

The different test that were performed on the motor are:

(i) Stator resistance and inductance measurement
(ii) No-load test
(iii) Blocked-rotor test
(iv) Load test

3.1. Stator Resistance and Inductancee Measurement

The first step of stator resistance and inductance measurement, is to check the continuity of the different stator winding using a digital multimeter. In the next step, an LCR meter is used to measure the resistance and inductance of each winding. The LCR meter was configured for 100 Hz and series connection. The results of stator resistance and inductance measurement are as shown in table 1.

Table 1.a. Resistance and Inductances of 4pole stator windings

Stator Winding	Resistance (Ω)	Inductance (mH)
U_1,U_2	5.964	24.20
V_1,V_2	5.939	24.15
W_1,W_2	5.851	24.07

Table 1.b. Resistances and Inductances of 12pole stator winding

Stator Winding	Resistance (Ω)	Inductance (mH)
U_1,U_2	11.63	39.26
V_1,V_2	11.23	39.28
W_1,W_2	10.87	39.12

3.2. No-load and Blocked-rotor test

The conventional way of doing no-load and blocked rotor tests is the two-wattmeter method. But, instead of using the two-wattmeter method, we used a graphical Power Quality Analyzer, in order to increase the accuracy of the process. The connections are made as shown in figure 2. After making the connections, power supply is switched ON and power, voltage and current are measured for no-load (P0, V0, I0) and blocked-rotor (P1, V1, I1) configurations of both 4pole and 12 stators of DSIM.

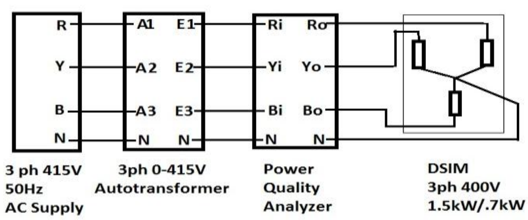

Fig 2. Circuit Diagram for no-load and blocked rotor tests

$$pf_0 = \frac{P0}{\sqrt{3} * V0 * I0}$$

$$I_e = I_0 * pf_0$$

$$I_m = \sqrt{I0^2 - Ie^2}$$

$$Z_m = \frac{V0}{\sqrt{3} * I0}$$

$$R_m = \frac{V0}{\sqrt{3} * Ie}$$

$$X_m = \sqrt{Zm^2 - Rm^2}$$

$$pf_1 = \frac{P1}{\sqrt{3} * V1 * I1}$$

$$\varphi_0 = \cos^{-1} pf0$$

$$\varphi_1 = \cos^{-1} pf1$$

$$I_s = \frac{I1}{V1} * V_{rated}$$

$$Z_{sc} = \frac{V1}{I1}$$

$$R_{sc} = \frac{P1}{I1^2}$$

$$X_{sc} = \sqrt{Zsc^2 - Rsc^2}$$

$$r2d = Rsc - R_1$$

$$x2d = \frac{Xsc}{2}$$

From the above equations, we find out the power factor at no-load and blocked rotor conditions, magnetizing current, magnetizing impedance, resistance and reactance, and rotor resistance and reactance referred to the primary side. The results obtained are used to draw circle diagrams for both the stator windings of DSIM. The circle diagrams are as shown in figure 3. From the circle diagram, we find out the various performance indices such as maximum input, maximum output, maximum torque, efficiency, maximum power factor, full load current etc. of the motor when the stators are powered separately. The results are shown in table 2.

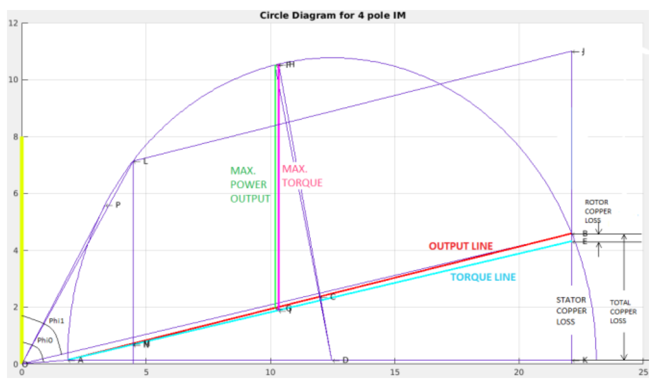

Fig 3.a Circle Diagram for 4pole stator winding

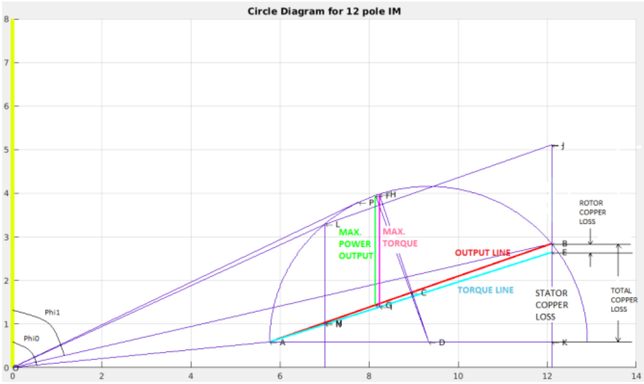

Fig 3.b Circle Diagram for 12pole stator winding

Table 2. Results of Circle Diagram

Property	Values for 4pole stator winding	Values for 12 pole Stator winding
Max. Power Input	2014.5 W	1274.7 W
Max. Power Output	1598.8 W	771.22 W
Max. torque	1614 W	794.59 W
Efficiency	89.93%	65.25%
Slip	0.36%	.46%
Full load Current	8.4 A	6.38 A
Full load pf	0.8475	0.3134
Max. pf	0.858	0.4389
Current at Max. pf	6.53 A	8.64 A

As was expected, the 4pole induction motor has much better maximum output, efficiency, power factor when compared to the 12 pole induction motor. Finally, using the information collected so far, we drew equivalent circuit diagram for the 4pole and 12pole stator windings of motor. These equivalent circuit diagrams are as shown in figure 4.

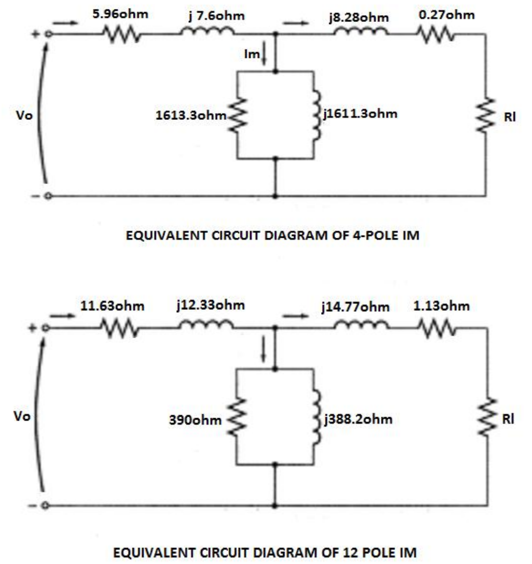

Fig 4. Equivalent circuit diagrams obtained from no-load and blocked-rotor test

3.3. Load test and Torque-speed curves

In the load test, the induction motor is mechanically coupled with a DC generator (1500rpm, 220V, 11A) which is separately excited by a DC power supply of 215V. The connections are made as shown in figure 5. The ammeter is used to measure the DC current and the voltmeter is used measure the DC voltage generated by the generator. As the number of lamps in the lamp bank that are switched ON increases, the loading on the DC generator and hence, the loading on the induction motor increases as well. An optical tachometer is used to measure the speed. The loading is increased till the point where the induction motor carries its rated current. The torque-speed curves for 4pole and 12pole stators powered separately are shown in figure 6. While the torque-speed curves for both the stator windings powered simultaneously is shown in figure 7.

The output of induction motor is input to a d.c. generator.

Output of d.c. generator = $V_T \times I_L$ W

Given $\eta_{gen} = 85\ \%$

P_{out} of induction motor = P_{in} of d.c. generator

= P_{out} of d.c. generator / η_{gen} = $(V_t\, I_L)/\eta_{gen}$ W

Torque produced by the induction motor

$$= \frac{Pout\ of\ induction\ motor}{speed\ of\ rotor}$$

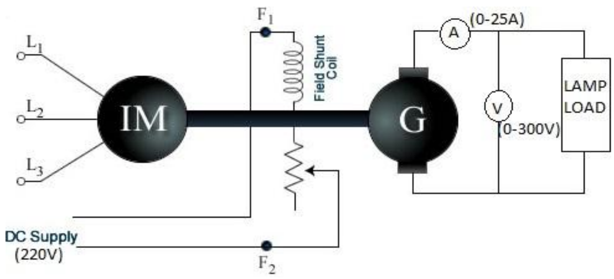

Fig 5. Circuit Diagram for Load test

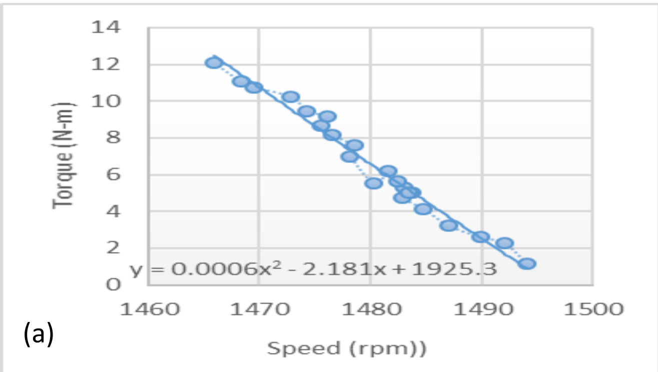

Fig 6.a Torque-speed curve for 4pole stator winding given 400V power supply while no supply is given to 12 pole stator winding

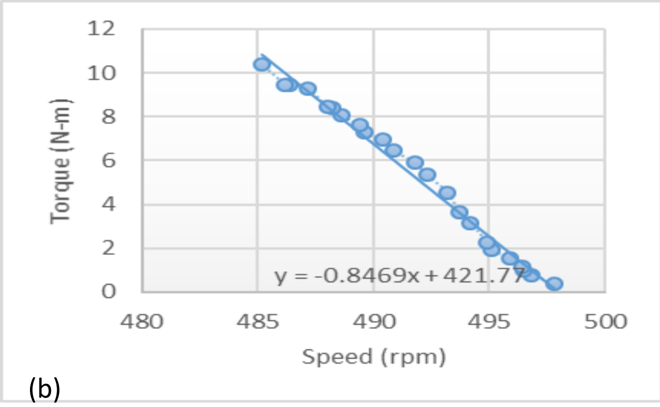

Fig6.b Torque-speed curve for 12pole stator winding given 400V power supply while no supply is given to 4pole stator winding

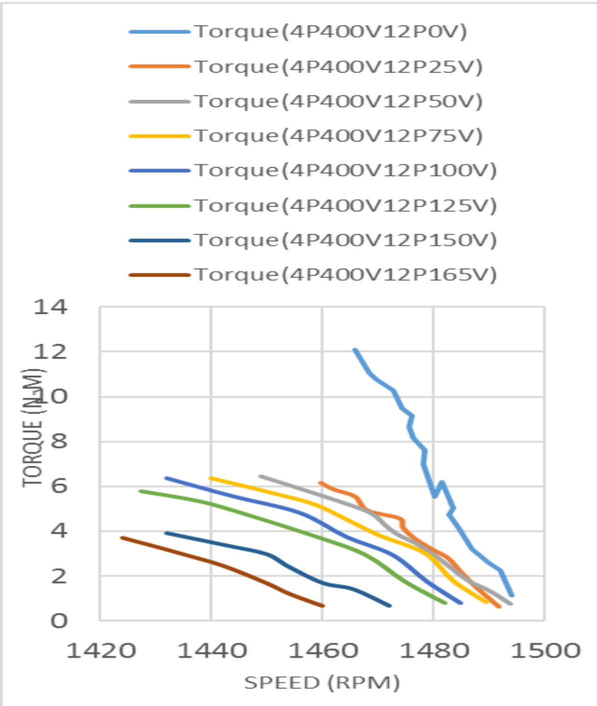

Fig 7. Torque-speed curve for both the stator winding being powered simultaneously. The 4pole stator winding is given 400V while the supply to 12 pole stator winding is varied from 0V to 165V.

4. CONCLUSION

Using the no-load test and blocked-rotor test along with the circle diagrams, various performance indices for induction motor were found. These performance indices show that the winding with lower number of poles has greater power output and efficiency than the winding with higher number of poles. Also, equivalent circuit diagram for the motor when power supply is connected to the stator windings separately are drawn.

From the load tests, it is shown that when powered separately the torque speed curve is the same as a conventional induction motor. When both the stator windings are powered simultaneously, as the voltage to 12pole stator winding is increased, the net torque output decreases. This is because the motor is being operated in asynchronous mode. Hence the torque produced by 12 pole stator winding is negative. Therefore, as the torque produced by 12 pole winding increases, the net torque decreases.

Even though, the efficiency seems to be decreasing in this case (which will improve when the motor is rum in synchronous mode), we are still gaining the ability to have greater control over the output of the induction motor. It was observed that by varying the voltage at the two stator winding terminals, we are able to change the torque provided by the motor while keeping the speed constant (by moving along the vertical direction).

We are also able to change at which the motor is running while keeping the torque constant (by moving along the horizontal direction). Thus, with the use of a dual stator induction winding, we are not confined to following a single torque speed curve but can reach any point on the graph as shown in figure 8.

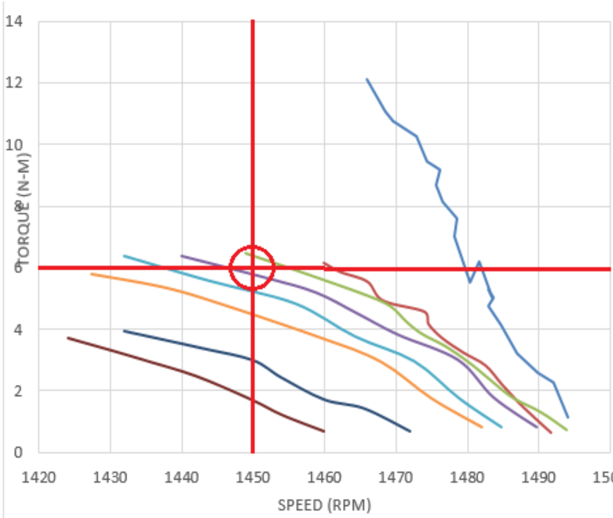

Fig 8. Graphing showing the way to control the output of motor by changing the input voltage.

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