SSRG International Journal of Electrical and Electronics Engineering
ISSN: 2348 – 8379 / https://doi.org/10.14445/23488379/IJEEE-V8I12P101

Volume 8 Issue 12, 1-4, Dec 2021

Original Article

Double Stator Induction Machine for Variable Speed And Variable Torque Applications

Anagha R. Soman[1], R. M. Holmukhe[2]

[1]*Associate Professor, Electrical Department, MMCOE, Pune*
[2]*Associate Professor, Electrical Department, BVDUCOE, Pune*

Received Date: 07 September 2021
Revised Date: 11 December 2021
Accepted Date: 25 December 2021

Abstract *- Conventional Induction machine has only one drawback of not having a smooth speed control if compared with DC Machines. But because of recent developments in technology such as semiconductors, drives, this drawback can be ruled out. A conventional Induction machine has a single speed-torque characteristic. The application of a respective machine depends on the load characteristics. Many applications in the industry need variable torque and variable speed. A double stator induction machine is so designed that there are two different stator windings housed in the same stator core, which then gives the best of both machines in a single machine. Using a simple controller, a wide range of speed and torque is available using a single machine. Such machines will find applications in the Textile, EV, Food industries where variable torques and speeds are required.*

The windings housed in the stator core can be for the same/ different.number of poles [1]. As per the rotor construction, the conventional induction machines are classified as squirrel cage and Split wound. Both these constructions have their own merits and demerits. Typically, Squirrel cage induction motors find applications in vivid areas due to simple and rugged construction and negligible maintenance. This type of Induction machine has versatile applications in various fields, covering almost 90% share in the electrical machines market. Speed -torque characteristics of such machines are almost constant. The variation in torque can be achieved by changing resistance in the rotor circuit. However, in squirrel cage induction machines, this method is not feasible. The only way to vary torque or speed is the stator side control. Stator side control methods are change of poles, change of supply frequency, change of supply voltage, change of the ratio of voltage/frequency, and adding an additional resistance/impedance in stator circuit. The common methods to vary the speed as discussed above are not flexible enough to achieve the required Torque-Speed characteristics of the motor suitable to the load requirement pertaining to a particular application. In addition to this, these methods also have a problem that the electrical frequency changes with the mechanical speed ($n = (2f/p)(1-s)$). *Hence, smooth control* over Torque-speed is not *feasible. Voltage Source Inverter (VSI) fed Induction machine does not face this issue. But this induces harmonics in the system and makes the machine less reliable and also costlier. Variable Frequency Drives (VFD) require filters to limit the rate of change of voltage (dV/dt) up to 6 kV/ µS, which otherwise may cause insulation failure. As per the above discussion, it is concluded that a Double Stator Induction Machine (DSIM) can provide a better option for variable speed applications.*

Keywords - *Torque-Speed characteristics, DSIM, VSI*

I. INTRODUCTION

For applications such as EV, textile industry, and food industry, a smooth and reliable speed control, high torque, and fast dynamic response even at lower speeds and constant power in high speeds is crucial. DC machines are a favorite option if compared to Induction machines in this regard. Induction machines are also known as the workhorse of the industry due to their robust design and construction, good overload capacity, less cost and zero maintenance, small slip, and satisfactory performance under all working conditions. With the latest advances in Power Electronics and Digital Control Theory (computer-aided design) and the availability of better materials, the induction motor has proved its mettle as the most favorite machine in the industry for constant/variable speed applications. This paper discusses the design and development of DSIM for operations with a wide range of speed and torque, unlike conventional Induction machines. This is achieved by providing an extra stator winding, as shown in fig. 1.1

[1]This work was supported fully by TEQUIP Grant received through BVDUCOE, Pune and Minor research grant from Bharati Vidyapeeth Deemed University.

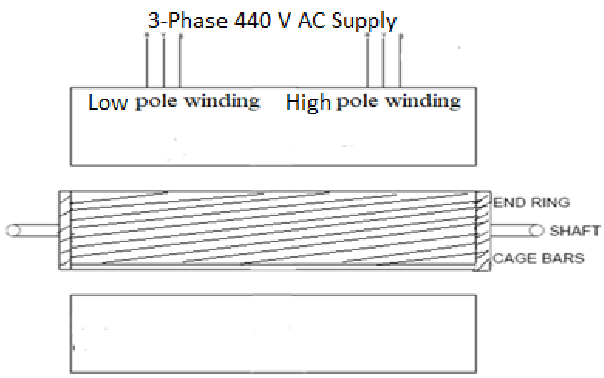

Fig. 1.1 Cut section of DSIM

II. DEVELOPMENT OF DUAL STATOR-WINDING INDUCTION MACHINE (DSIM)

Multi-speed electrical machines and drives (being brushless machines) find versatile applications if compared to the conventional 3-phase Induction machines. This is due to higher power density and fault-tolerant capability. This is the reason why more and more researchers are attracted to this brushless option for applications such as electric vehicles and the renewable energy sector. These machines are rugged mechanically and require low maintenance. DSIM is an innovative type of multi-speed machine having all the goodness of squirrel cage rotor and carries two different stator windings in the same stator core. DSIM is categorized as split wound and self-cascaded. The split wound machines can again be classified on the basis of whether winding is divided into two equal sections or in two unequal sections. The initial conventional construction of DSIM was such that the stator winding consisted of two same windings, which resulted in the mutual coupling, which in turn resulted in very high circulating currents generated even for a small change in supply voltage. Since the harmonic currents have low impedance, the circulating currents are high for non-sinusoidal supply. This results in higher stator losses and overheating of the machine, which will need higher semiconductor device ratings of control circuits. If the windings are not the same, i.e., different numbers of poles, resulting torques oppose each other.

Testing of the DSIM is carried out such that one of the stator windings is fed with rated voltage, frequency, and the other at variable voltage. The setup results in a wide range of speed and torque.

The brushless feature of DSIM thus finds wide scope in applications such as extracting renewable energy, traction drives, Microgrids, etc.

Because of the difference in the number of poles, there is a decoupling effect resulting in the behavior of the DSIM such that the two different induction machines are mechanically coupled to one shaft. So, all the control methods used for conventional induction machines apply to DSIM. The two stator windings are not connected to each other electrically, so a faster dynamic response can be achieved. As the stator windings are symmetrical, no issues regarding mutual coupling and circulating currents. In any working condition, the stator frequency of DSIM depends on the slip frequency, rotor speed, and another torque component. Hence there is no impact of supply frequency on speed, unlike conventional Induction motor. i.e., zero supply frequency does not cause zero speed.

To decrease the magnetic coupling between two stator windings, the two stator windings are wound such that they have a different number of poles, e.g., 4 and 12. Both the stator windings are separately supplied either by (i) two voltage source inverters to get variable frequency at variable voltage inputs or by (ii) two 3-phase dimmer stats to provide variable sinusoidal voltage inputs.

Two different operation modes are considered in the project, i.e., synchronous and asynchronous.

III. TESTING AND ANALYSIS OF DSIM

This section deals with the design, development, testing, and analysis of DSIM. Many different designs of 3-phase induction motors were tried by researchers for the betterment of performance [2]. DSIM is one of such different designs in which an extra winding is provided in the same stator core. The second torque component in DSIMhas a deep impact on the speed-torque characteristics of this machine.

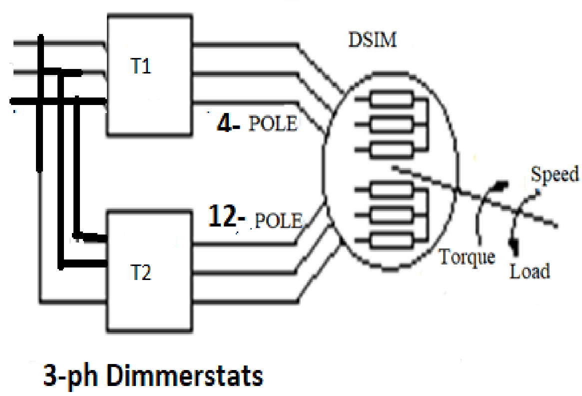

Fig 1.2 Testing of DSIM

A wide range of torque-speed characteristics is the ultimate goal for using DSIM to be used in various applications needing variable torque and variable speed. This experimental setup for the load test is executed by coupling IM with a DC generator, thus loading it electrically.

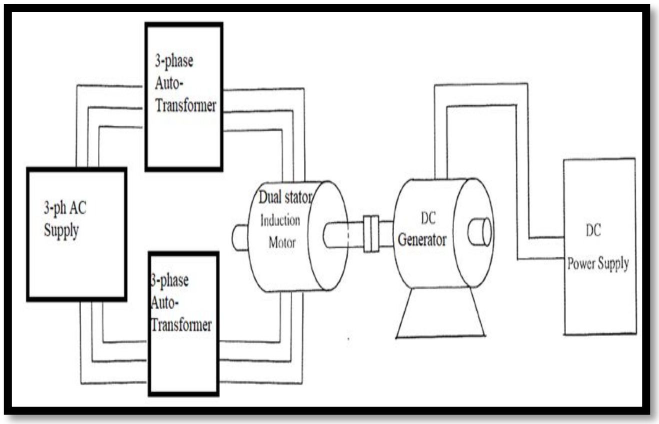

Fig. 1.3 Experimental set up for cases 1 and 2

The details are as under.

DSIM is tested for different input conditions to have a broader range of torque-speed characteristics. The four cases are as follows [3]:

- Variable voltage, constant frequency (VVCF) when both the torques produced are in the same direction.
- Variable voltage, constant frequency (VVCF) when both the torques produced are in the opposite direction.
- Variable voltage, variable frequency (VVVF) when both stator windings are in motoring mode.
- Variable voltage, variable frequency (VVVF) when one of the stator windings is in motoring mode and the other in generating mode.

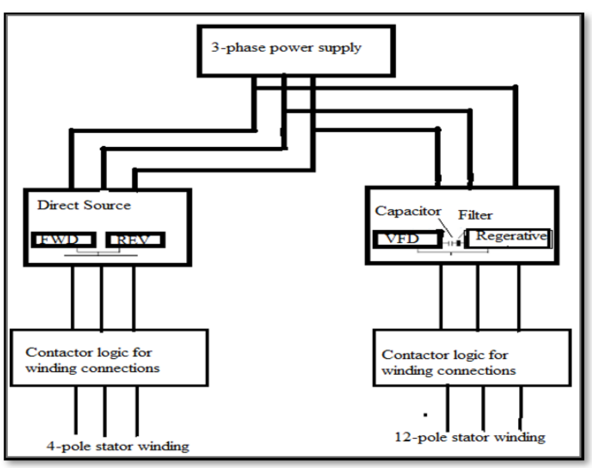

Fig.1.4 Schematic block diagram of panel

IV. RESULTS AND CONCLUSION OF TESTING

The experimental investigations of prototype DSIM are carried out for various input conditions such as the variable voltage at power frequency and variable voltages at variable frequencies. Also, these two conditions are again tested for the two subcases, i.e., (a) additive torques and (b) subtractive torques. Apart from the technical investigations about performance parameters, other factors like (a) vibrations, (b) noise, (c) temperature rise, etc., were also carefully observed during investigations, and care was taken to see that they do not cross the permissible limits. It is found that experimental results are in line with the simulation results.

Experimental results on prototype DSIM have been presented in detail as follows, showing a good correlation with the theoretical curves. From the testing results and analysis [4], it is concluded that variation in voltage supplied to the two stator windings results in a change in the resultant torque developed by DSIM. Four cases, as stated in section 1.3, are considered in this.

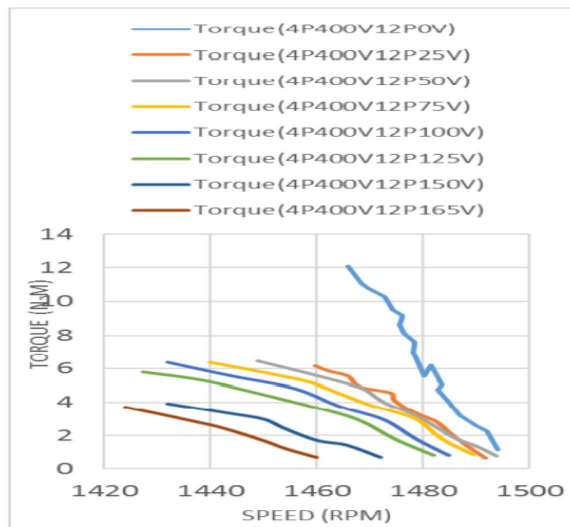

Fig. 1.5 Case 1(VVCF)

To summarize the results, when both the stator windings are excited simultaneously with power frequency and variable voltage to one of the windings and rated voltage to another, it is observed that

1. As we go on increasing the voltage applied to 12-pole winding, the net torque of DSIM decreases.
2. This is an asynchronous mode of operation
3. Torque produced by 12-pole winding is negative
4. As torque produced by 12-pole winding increases, the net torque decreases

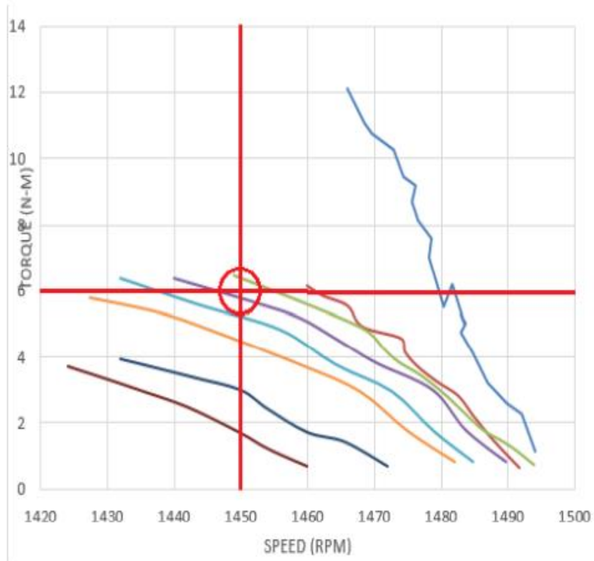

Fig. 1.6 Control the output of the motor by changing the input voltage

DSIM is a special case of multi-winding Induction machines having two electrically isolated dissimilar windings in stator and standard squirrel cage rotor. A comprehensive review is taken about the speed and torque variation of DSIM. The chapter discussed the machine as a strong contender in the future for application in electric vehicles

REFERENCES

[1] A. R. Munoz and T. A. Lipo, Dual Stator Winding Induction Machine Drive, IEEE Transactions on Industry Applications. 36(5) (2000) 1369-1379.

[2] S.Basak and C. Chakraborty, Dual Stator Winding Induction Machine, Problems, Progress, and Future Scope, IEEE Transactions on Industrial Electronics. 62(7) (2015) 4641-4652.

[3] A.R.Soman, Design And Development of Dual Stator Induction Machine, Ph.D. Dissertation, Dept. Elect. Eng., Bharati Vidyapeeth Deemed to be Univ. College of Engineering, Pune. (2020).

[4] A.R.Munoz-Garcia, Analysis and Control of a Dual Stator Winding Squirrel Cage Induction Machine, Ph.D. Dissertation, Dep. Elect. Comp. Eng., Univ. Wisconsin, Madison. (1999).

[5] Anagha Soman, Sachin Madaan, Shubh Gupta, Abhishek Singh, Ankit Tiwari , Performance Analysis of Dual Stator Induction Motor, International Research Journal of Engineering and Technology. 5(5) (2018) 1-6

[6] A.R.Soman, Dr.D.G.Bharadwaj, Dr.R.M.Holmukhe, Variation in Torque of DSWIM by Changing Voltage Keeping the Speed Constant, Asian Journal of Convergence in Technology. 5(1) 1-4

[7] A.R.Soman, Dr.D.G.Bharadwaj, Dr.R.M.Holmukhe, Multispeed Operation and Testing of the Dual Stator Winding Induction Machine, International Journal of Scientific & Technology Research. (2020).

[8] Paul C. Krause, Oleg Wasynczuk and Scott D. Sudhoff, Analysis of Electric Machinery and Drive Systems, International Research Journal of Engineering and Technology (IRJET), IEEE Press Series on Power Engineering, John Wiley and Sons Inc. Publication.

[9] Anagha Soman, Nupoor Lokhande, Performance Analysis of 3 Phase Dual Stator Induction Motor Using ANSYS Maxwell, International Journal of Pure and Applied Mathematics. 118(16) (2018) 269-281.

[10] Anagha Soman, Dr.D.G.Bharadwaj, Dr.R.M.Holmuk.,He Analyzing and Testing of the Performance of DSWIM by ANSYS Maxwell, International Journal of Scientific & Technology Research. (2020).

[11] A.R.Soman, Dr.D.G.Bharadwaj, Dr.R.M.Holmukhe, Analyzing Performance of 3-PH Dual Stator Induction Motor, Conference Proceedings of 2nd International Conference on Electrical Electronics and Computer Science, Siliguri. (2018).

[12] Luigi Alberti, and Nichola Bianchi, Impact of Winding Arrangement in Dual 3-Phase Induction Motor for Fault-Tolerant Applications, XIX International Conference on Electrical Machines-ICEM. (2010) 1-6.