Field Oriented Control of Single Phase Induction Motor

Rajesh Thinga¹, Sanjeev Gupta², S. P. Phulambikar³
¹PG Scholar, ²Associate Prof., ³Head of Dept, Dept. of EE, Samrat Ashok Technological Institute, Vidisha, M.P., India

Abstract—In this paper field oriented control scheme for single-phase induction motor is investigated and model was simulated in the MATLAB simulation. By applying this methods, an induction machine can be analyze and operate similar to the dc machine as this method provides the decoupling effect to the motor. By controlling the d-axis and q-axis current the speed and torque of the single-phase induction motor can be controlled independently and this will reduce the analytical complexities of the motor as it will reduce the parameter variation and some quantities in the analysis can be neglected.

Keywords—Single-Phase Induction Motor Drives, Field Oriented control.

Abbreviations and Acronyms:- IM-Induction motor, FOC-field oriented control, mmf-magneto motive force.

I. INTRODUCTION

Home appliances (washing machine, refrigerator blender, mixer, hair dryer, dishwasher, microwave oven ) and comfort conditioning (air conditioner, boilers, fans, furnace, water, pump heat pump) requires relatively less electric power from ten of watt’s to about 2kW to drives actuating electric motor which are generally supplied from single phase utility supplies. The use of single-phase power supply ensure that the appliance can be used in the areas where single or/and three phase power supplies are available. Hence, most of the existing electric motor used for these application are varies types of single-phase machines such Induction, synchronous, interior permanent magnet and universal ac machine. These loads operate over a range of speed. Such loads are generally termed as variable speed drives. Sometimes these drives demands a precise adjustment of speed (for quality purposes) in a step less continuous manner over the complete speed range required. These electric motor are used to control the speed/torque/position of the connected loads the torque may also be the function of speed e.g. in a fan type or pump type the load torque is proportional to the square of speed. These load may driven by hydraulic, pneumatic or electrical motor system. When the system drives with the electrical motor gives an advantageous feature of modification of speed torque characteristic of motor with respect to load torque characteristic. It has a sufficient overload capacity and can be overload for short periods without affecting the life of the motor.

Sn = \frac{\text{Backward field speed} + \text{Rotor speed}}{\text{Backward field speed}}

Sn = \frac{Wms + (1-s)Wms}{Wms} = 2 - s

Torque due to forward field

Tf = \frac{1}{Wms} l^2 s Rf

Torque due to backward field

Tb = \frac{1}{Wms} l^2 s Rb

Torque of the backward field is in opposite direction to that of forward field. Therefore, net developed torque

T = Tf - Tb = \frac{l^3}{Wms} (Rf - Rb)

II. SINGLE PHASE INDUCTION MOTORS

Single-phase induction motors are inferior in performance and larger in weight and volume compared to three-phase motors of the same rating. However, they are simple, robust, reliable and less expensive for small ratings. They are employed in low power drives in small industries and domestic and commercial applications, where only single-phase supply is available. They are generally available up to 2kW rating. Applications are many such as compressors in refrigerator and air-conditioners, washing machines, dryers, fans, pumps, domestic appliances.

A single phase induction motor has a cage rotor and a single phase winding in the stator. The pulsating mmf produced by ac current in stator winding can be considered to be equivalent to two constant amplitude mmf wave induces its own rotor current and produces induction motor action just as in a 3-phase motor. When the rotor is stationary, it reacts equally to both waves, and no torque is developed. Therefore a single phase induction motor with single stator winding inherently has no starting torque. But if started by auxiliary means, it will develop torque and continue to run. When the rotor is running, induced rotor currents are such that their mmf opposes the reverse stator mmf to a greater extent than they oppose the forward stator mmf.

III. FIELD ORIENTED CONTROL

Vector control, also called field-oriented control (FOC), is a variable frequency drive (VFD) control method which controls three-phase AC electric motor output by means of two controllable VFD inverter output variables:
In vector control, an IM or synchronous motor is controlled under all operating conditions like a separately excited DC motor. That is the AC motor behaves like a DC motor in which the field flux linkage created by the respective field and armature(or torque component) currents are orthogonally aligned such that, when torque is controlled, the field flux linkage is not affected, hence enabling dynamic torque response.

Vector control accordingly generates a three-phase PWM motor voltage output derived from a complex voltage vector to control a complex current vector derived from motor’s three-phase stator current I/P through projections or rotations back and forth between the three-phase speed and time dependent system and these vector’s rotating reference frame two coordinate time invariant system. Such complex stator motor current space vector can be defined in a(d,q) coordinate system with orthogonal components along d-axis and torque component of current is aligned along the q-axis.

The Induction motor (d, q) coordinate system can be superimposed to the motor’s instantaneous (a, b, c) three-phase sinusoidal system accompanying image. Components of the (d, q) system current vector, allow conventional control such as proportional and integral or PI, control as with DC motor.

FOC is a control technique that is used in AC synchronous and induction motor applications. It was originally developed for high-performance motor applications which can operate smoothly over the full speed range, can generate full torque at zero speed, and is capable of fast acceleration and deceleration but that is becoming increasingly attractive for lower performance applications as well due to FOC’s motor size, cost and power consumption reduction superiority.

Not only is FOC very common in induction motor control applications due to its traditional superiority in high-performance applications, but the expectation is that it will eventually nearly universally displace single-variable scalar volts-per-Hertz(V/f) control.

There are two vector control methods, direct or feedback vector control (DFOC) and indirect or feed forward vector control (IFOC), IFOC being more commonly used because in closed-loop mode such drives more easily operate throughout the speed range from zero speed to high-speed field-weakening. In DFOC, flux amount and angle feedback signals are directly calculated using so-called voltage or current models. In IFOC, flux space angle feed-forward and flux magnitude signals first measure stator currents and rotor speed for then deriving flux space angle properly by summing the rotor angle corresponding to the rotor speed and the calculated reference value of slip angle corresponding to the slip frequency. Sensorless control of AC drives is efficient for cost and reliability considerations.
Three phase supply is converted into DC by rectifier. Then, the DC is converted into AC by inverter. The inverter IGBT switching pulses are controlled by the current regulator. Gate pulses to the IGBT are provided by the current regulator which uses the speed comparison of the reference speed and motor speed. Based on these pulses inverter output varies to maintain the variable current and voltage constant. By this method speed control of single phase induction motor is controlled by the FOC technique effectively.

V. SIMULATION RESULT

The proposed FOC for variable speed drive for SPIM is shown in fig.1, and its performance in speed and flux control is proved by simulation. The 0.25 HP, 2pole SPIM is started at no load and accelerated to 1500 rpm. The proposed simulation result estimates accurately the rotor speed and torque.

The torque is initially zero, after it develops required torque about 4 Nm and finally settles to a low value. The speed and torque characteristics are shown below in fig.6 and fig.7 resp.

VI. CONCLUSION

The field oriented control for single phase induction motor was successfully implemented and the result was observed on the MATLAB Simulink environment, speed control is achieved without the use of any sensor.
For any single phase induction machine field oriented control technique is one of the best techniques for the speed control. It allows the decoupled control of the motor flux and electromagnetic torque. After decoupling, the induction motor can be controlled as a DC motor and the electromagnetic torque and current can be control independently. As the overall performance of the induction machine is directly related to the performance of current control. Therefore, decoupling of the control scheme is acquired by the compensation of the coupling effect between q-axis and d-axis current dynamics. This current control makes the system more efficient and energy saving. It is found that the single phase induction motor equation are more complex than of the three phase-phase induction machine due to the fact that the main and auxiliary stator windings have different resistance and inductance. However, the use of field orientation control an unbalanced single-phase machine requires special attention because the mathematical model for this type of machine is similar to that of an asymmetrical two phase machine. From the simulation result for the various parameters it was observed that there is very less current spikes for the different set of speed and applied voltage and the spikes are almost at the same level for the sets of speed and supplied voltage although the settling time is varying for all speed and it was conclude that the system is robust to parameter variation and gives the alternates for the conventional way of speed control of induction motor.

REFERENCES


[5] Rotor-Flux-Oriented Control of a Single-Phase Induction Motor Drive BY Maurício Beltrão de Rossiter Corêa, Cursino Brandão Jacobina, Senior Member, IEEE, Antonio Marcus Nogueira Lima, Member, IEEE, and Edison Roberto Cabral da Silva, Senior Member, iee, iee transactions on industrial electronics, vol. 47, no. 4, august 2000


[7] Sensorless indirect stator field orientation speed control for single-phase induction motor drive by Mohamed Jemli, Hechmi Ben Azza, Mohamed Boussak, senior member, ieee, and Moncef Gossa. ieee transactions on power electronics, vol. 24, no. 6, june 2009