DIRECT TORQUE CONTROL OF INDUCTION MOTOR USING SPACE VECTOR MODULATION: A REVIEW

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ABSTRACT: The torque and current ripple are occurred in the conventional DTC. Reason of undesired torque and current ripple is low number of voltage vectors applied to the motor controlled by the conventional DTC technique. The speed of induction motor is controlled by varying the stator flux through a PI flux controller. The tuning of PI controller is carried out by varying proportional gain and integral gain in a predetermined manner. The selected values of proportional gain have been taken to improve the speed response of the induction motor drive for given values of integral gain and integral time constant. After reaching satisfactory value of proportional gain, the integral gain is varied to obtain an improved response keeping proportional gain and integral time constant unchanged. On observing the speed response of the drive suitable adjustments is again attempted in proportional gain to further improve the dynamic behavior of the drive. Very encouraging results will obtain to simulate it in MATLAB.
Keyword: DTC, PI Flux Induction Motor, Space Vector Modulation, MATLAB.

I. OVERVIEW OF INDUCTION MOTOR

An induction motor or asynchronous motor is a type of alternating current motor where power is supplied to the rotor by means of electromagnetic induction. There are several ways to supply power to the rotor. In a DC motor, this power is supplied to the armature directly from a DC source while, in an induction motor, this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator is essentially the primary side of the transformer and the rotor is the secondary side. Unlike the normal transformer which changes the current by using time varying flux, induction motors use rotating magnetic fields to transform the voltage. The current in the primary side creates an electromagnetic field which interacts with the electromagnetic field of the secondary side to produce a resultant torque, thereby transforming the electrical energy into mechanical energy. The induction motors have many advantages over the rest of the types of motors. The main advantage is that induction motors does not require an electrical connection between the stationary and the rotating parts of the motor. Therefore, they do not need any mechanical commutator (brushes), making these motors as maintenance free motors. Besides, induction motors also have low weight and inertia, high efficiency and a high overload capability. Therefore, they are cheaper and more robust, and less prone to any failure at high speeds. Furthermore, the motor can work in explosion prone environments because no sparking is feasible as per design.

1.1 OBJECTIVE

1. To develop a MATLAB code for direct torque control of induction motor using space vector modulation.
2. To study the dynamic response of the model.
3. To tune PI flux controller for speed regulation using the DTC scheme.

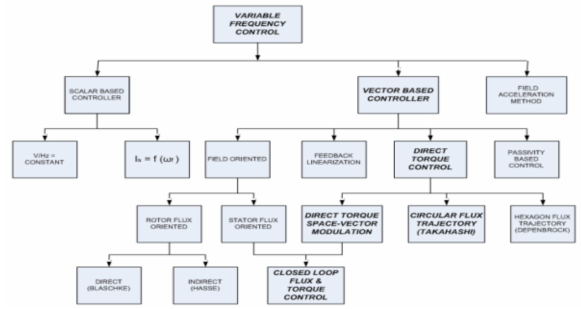

Fig. 1.1 Overview of induction motor control methods

The main features of DTC are:

1. Direct control of flux and torque (by the selection of optimum inverter switching vectors).
2. Indirect control of stator current and voltage.
3. Approximately sinusoidal stator flux and stator currents.
4. Possibility of reduced torque oscillations: torque oscillations depend on duration of zero-switching vectors.
5. High dynamic performance.
6. Inverter switching depends on widths of flux and torque hysteresis bands.

The main advantages of DTC are:

1. Absence of coordinate transformations.
2. Absence of separate voltage modulation block.
3. Absence of voltage decupling circuits.
4. Reduce parameter sensitivity.
5. Very good dynamic properties.
6. Minimal torque response time.

The main disadvantages of DTC are:

1. High ripple torque.
2. Changing switching frequency.
3. Requirements of flux and torque estimators.
4. Possible problem during starting and low speed operation and during changes in torque command.

Application of DTC in various fields:
1. Battery driven electric vehicle.
2. In traction application (diesel-electric application, electric cars).
3. In HVDC application for improving the power quality.
4. Where high dynamic performance, precision and reliability is required like
- ✓ Robotics
- ✓ Serve drive
- ✓ Machine tools
- ✓ Air conditioning system

This piece of work is an attempt to develop a MATLAB code for direct torque control of induction motor using space vector modulation. In order to achieve that, at first, the general dynamic model of the induction, which is represented by a sixth order state space equation, is created on the application software platform. Then, the behavior of the model is studied by traces of various performance parameters under numerous working conditions and later validating those plots by available references.

II. LITERATURE SURVEY

Takahasi and Noguchi (1985) introduced direct torque control as a new quick response and efficiency control strategy where in limit cycle control of both flux and torque, optimum inverter voltage selection with the help of a switching table and efficiency optimization in the steady state operation have been talked about [1].
T.G. Habetler, F. Profumo, M. Pastorelli, and L.M. Tolbert (1992) discussed the direct torque control of induction motor using space vector modulation. They describe a control scheme for direct torque and flux control of induction machines based on the stator flux field-orientation method. With the proposed predictive control scheme, an inverter duty cycle has directly calculated each fixed switching period based on the torque and flux errors, the transient reactance of the machine, and an estimated value of the voltage behind the transient reactance [2].
Kazmierkowski and Kasprowicz (1995) explain the advantages of direct torque control over field oriented control and give design of flux and torque controllers. The paper also deals with the problem of the direct torque control drive, at start and zero speed operation, by introducing an additional carrier signal to the torque controller input [3].
P. Vas (1998) discusses sensor less techniques associated with vector control and direct torque control concept in great detail using spacephasors to model and unify the treatment of the motors, proceeding with a control theory view of the overall drive systems and implementation of the physical realization of the drive system with the help of equations and block diagrams [4].
Lascuet Al (1998) deal with the torque, flux and current pulsations that occur during the steady state in direct torque control and their reflection on speed estimation, speed response and acoustical noise by introducing a direct torque and flux control method based on space vector modulation for induction motor sensor less drives [5].
Kang and Sul (1999) propose a direct torque control method to minimize torque ripple while maintaining constant switching frequency. In the proposed torque ripple control algorithm, the optimal switching instant is calculated at each switching cycle to satisfy ripple minimum condition based on instantaneous torque slope equations [6].
Boldea and Nasar (1999) present a comprehensive view of modern variable speed drives where in topology, performance, design element, simulation, test result and practical issues in industrial drives have been covered [7].

III. INDUCTION MOTOR CONTROL SCHEMES

The simple induction motor fulfills admirably the requirements of substantially constant speed drive. However, two factors have led to a re-examination of many of these applications: concern about process quality and productivity in manufacturing and about the cost of electric energy. An ability to adjust the speed of the industrial drive addresses both these concerns. The synchronous speed of an induction motor can be changed by changing the number of poles or by varying the line frequencies. The operating slip can change by varying the line voltage or by varying the rotor slip energy recovery.

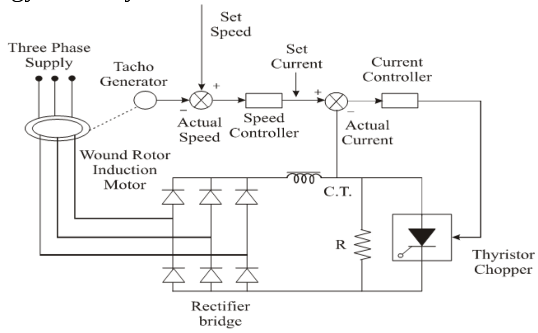

Fig. 3.1 Rotor resistance control.

3.1 ROTOR ENERGY RECOVERY

In rotor resistance control, if the slip power lost in the resistance could be returned to the AC source. The overall efficiency of the drive system would be very much increased. Here the diode bridge rectifies the rotor power. A smoothing coil is used to smooth the rectified current out. The output of rectifier is then connected to the DC terminals of inverter, which inverts this DC power to AC power and feeds it back of the AC source. The schemes pertaining to the rotor side control can be used only for wound rotor induction motors. Also, the rotor resistance control scheme suffers from the drawback of being less efficient and the slip energy recovery drive always has a lower power factor.

3.3 VARIABLE FREQUENCY CONTROL

With the advent of high-speed power electronics, inverters have become very successful in producing variable frequency voltage and currents and reduce total harmonics distortion. The variation of supply frequency can successfully control the speed of three-phase induction motor.

3.4 DIRECT TORQUE CONTROL

Direct torque control (DTC) is one of the most excellent control strategies of torque control in induction machine. It is considered as an alternative to the field oriented control (FOC) or vector control technique. These two control strategies are different on the operation principle but their objectives are the same. They aim to control effectively the torque and flux. Torque control of an induction machine based on DTC strategy has been developed and a comprehensive study is present in this research. Induction machine have provided the most common form of electromechanical drive for industrial, commercial and domestic applications that can operate at essentially constant speed. Induction machines have simpler and more rugged structure, higher maintainability and economy than DC motors. They are also robust and immune to heavy loading. Basically, there are two types of instantaneous electromagnetic torque-controlled AC drive used for high performance applications which are:

Vector Control (VC): Based on stator current control in the field rotating reference frame.

Direct Torque control (DTC): based on stator flux control in the stator fixed reference frame using direct control of the inverter switching.

IV. SIMULATIONS AND EXPECTED RESULTS

In MATLAB simulation has been initiated as per the above proposed theory of induction motor using space vector modulation. The response curves will find the gain on which specific parameters need for speed control of induction motor drive considered for investigation.

V. CONCLUSIONS AND FUTURE SCOPE

A suitable algorithm is needed to use to develop the MATLAB code to determine the dynamic response of induction motor drive using DTC scheme for speed control. The MATLAB code is adapted for carrying out research investigations to evolve a suitable PI flux controller for speed regulation of the induction motor drive considered for investigations. In other words, the speed of induction motor is controlled by varying the stator flux through a PI flux controller. A suitable mathematical model has to develop for direct torque control of induction motor drive from the reference so that the torque, speed and speed errors can calculate first which leads to the optimum pulse selection for VSI switching. Space vector modulation also need for determine the inverter switching state.

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