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Simulation and Speed Control of Motor Drives Using Space Vector Modulation for Three Phase Induction Motor.

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Abstract – Induction motor speed control is relatively difficult, because the generated torque and flux are related or not free.In addition to adjusting the speed, it requires inverter control. The inverter output is not a pure sinusoidal signal but it is the result of the switching. Therefore, it is necessary to be able to fix the method of switching the inverter output signal that canadjust induction motor speed with load changes. Its durability, low cost and robustness, induction motors are the most popular electric motors. The induction motors, however, are not capable of variable speed operation automatically. This is why older dc motors were found in most electric drives. But modern advances in induction motor speed regulation methods have culminated in their wide-ranging usage in nearly all electric drives. The most frequently used closed loop constant V / f speed control system is a multi-methods for induction power, such as polar shift, frequency variance, variable rotor resistance, variable stator voltage, constant V/f regulation, slip recovery method, etc. The V / f ratio is kept constant in this system, which in turn holds the magnetizing stream constant to hold its maximal torque unchanged. The stator resistance and engine induction (both rotor and stator) should be held low while an induction motor is started to minimize the stable state period and also to avoid jerks during initialization. On the other side, a higher rotor resistance value contributes to fewer jerks and has little effects on the continuous condition duration. The induction vector control research allows for a decoupling research in which the torque and the flow components can be regulated separately (just as in the dc motor). This simplifies the study than the identical circuit per step.
Index Terms - Three Phase Induction Motor, Space Vector Modulation, V/F Control, Transient Analysis, Slip, Steady State Analysis, Induction Motor Electric Motor Drive, Matlab , Simulink.

I. INTRODUCTION

Three phase Induction motors have been the workforce for several industrial, manufacturing, propulsion and transportation applications for the past several years. A rough estimate shows that about 64 percent of the industrial motors belong to induction motors. The operational modes of an induction motor in an industrial environment can be divided into three:

1) starting,
2) speed control and
3) energy efficient operation.

In starting and speed control modes, the dynamic response of the drive is uppermost in the mind, whereas energy efficient operation is performed during steady state operation. Several papers have already been published in the above-mentioned areas. This thesis work employs a few biologically inspired optimization algorithms towards the performance enhancement of the three-phase induction motor during starting, speed control and energy efficient operations. The following sections carry out the literature survey on the above-mentioned modes of operation of induction motor.Be it domestic application or industry, motion control is required everywhere. The systems that are employed for this purpose are called drives. Such a system, if makes use of electric motors is known as an electrical drive. In electrical drives, use of various sensors and control algorithms is done to control the speed of the motor using suitable speed control methods. The basic block diagram of an electrical drive is shown below:

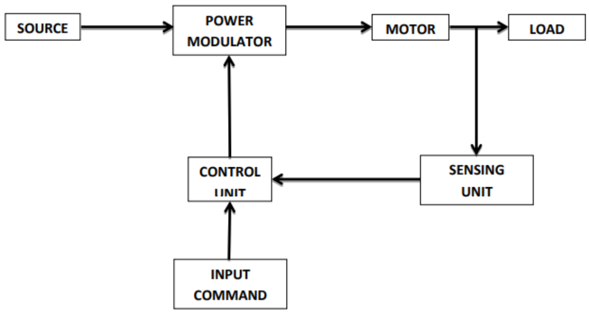


Figure 1: Block diagram of an electrical drive

Earlier only dc motors were employed for drives requiring variable speeds due to ease of their speed control methods. The conventional methods of speed control of an induction motor were either too expensive or too inefficient thus restricting their application to only constant speed drives. However, modern trends and development of speed control methods of an induction motor have increased the use of induction motors in electrical drives extensively. Induction motor.In this paper, we have studied the various methods of speed control of a 3- and compared them using their Torque-Speed characteristics. Also, the transients during the induction motor were studied using MATLAB Simulink and the effects of starting of a 3- various parameters such as rotor and stator resistances and inductances were analysed. Also different control algorithms such as P, PI and PID control were studied by simulating them in MATLAB Simulink and were compared.

II. CONSTRUCTION OF INDUCTION MOTOR

The Induction Motor has a stator and a rotor. The stator is wound for three phases and a fixed number of poles. It has stampings with evenly spaced slots to carry the three-phase windings. The number of poles is inversely proportional to the speed of the rotor. When the stator is energized, a moving magnetic field is produced and currents are formed in the rotor winding via electromagnetic induction. Based on rotor construction, Induction Motors are divided into two categories.

In Wound-Rotor Induction Motors, the ends of the rotor are connected to rings on which the three brushes make sliding contact. As the rotor rotates, the brushes slip over the rings and provide a connection with the external circuit.

In Squirrel-Cage Induction Motors, a ―cage‖ of copper or aluminum bars encase the stator. These bars are then shorted by brazing a ring at the end connecting all the bars. This model is the more rugged and robust variant of the Induction Motor.

2.1 Induction Motor Principle:

Principle: It is an asynchronous motor when 3ph supply is given to the stator, flux is induced in the stator and due to the mutual induction flux is transform from stator to rotor. The current is generated in the rotor due to short circuit copper bars in the rotor cuts the rotating flux .Hence torque is experienced and rotor rotates. When the stator winding is energized by a three- phase supply, a rotating magnetic field is set-up which rotates around the stator at synchronous speed Ns. This flux cuts the stationary rotor and induces an electromotive force in the rotor winding.

As the rotor windings are short-circuited a 8 current flows in them. Again as these conductors are placed in the stator‟s magnetic field, this exerts amechanical force on them by Lenz"s law. Lenz"s law tells us that the direction of rotor currents will be such that they will try to oppose the cause producing them. Thus a torque is produced which tries to reduce the relative speed between the rotor and the magnetic field. Hence the rotor will rotate in the same direction as the flux. Thus the relative speed between the rotor and the speed of the magnetic field is what drives the rotor. Hence the rotor speed Nr always remains less than the synchronous speed Ns. Thus Induction Motors are also called Asynchronous Motors.

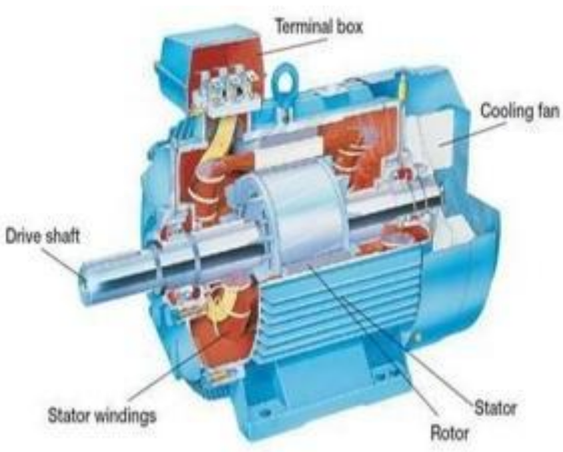


Figure 2: Internal parts of induction motor

2.2 Factors Affecting Efficiency of Induction Motor Drives

There are several factors which affect the efficiency of induction motors drives such as partial loading, harmonics, rewinding, power quality, parameter variation etc. These factors are discussed in brief in the following sections.

Partial Loading

Among all electrical AC drives, 3-Φ induction motors are mainly used due to its inherent advantages i.e. ruggedness, reliability, relatively low cost and easy operation. These machines offer years (around 20 yrs) of service when precisely selected, operated and maintained. In general, induction motor handles around 70% industrial load on a utility, therefore it becomes imperative to pay major attention to the maximum efficiency operation of such AC derives. Fundamentally, high efficiency operation of induction machine can be obtained when it is operated near to rated speed and torque. The significant improvement in machine materials, design and construction techniques may further improve the induction motor efficiency.

III. SPEED CONTROL OF INDUCTION MOTOR DRIVES (METHODS)

1. V / f control or frequency control.
2. Changing the number of stator poles.
3. Controlling supply voltage.
4. Change in the resistance of stator and rotor circuit

V/f control or frequency control: We vary the stator voltage in such a way that the flux remains constant by simultaneously varying the supply frequency such that the ratio V/f remains constant. The AC supply is rectified and then applied to a PWM inverter to obtain a variable frequency, variable magnitude 3-ph AC supply.

The electromagnetic torque developed by the motor is directly proportional to the magnetic field produced by the stator and the flux produced by the stator is proportional to the ratio of applied voltage and frequency of supply. Therefore, by varying the voltage and frequency by the same ratio, flux and hence, the torque can be kept constant throughout the speed range. This makes constant V/f method the most common speed control method of an induction motor.

Changing the number of stator poles: In this case of speed controlling method , it is very complicated to change the stator poles where it is time taking and there is change in design of the induction motor .so in this method we cannot make any change in stator poles so, we rarely use this method.

Controlling supply voltage: A very simple and economical method of speed control is to vary the stator voltage at constant supply frequency. The three-phase stator voltage at line frequency can be controlled by controlling the switches in the inverter. As seen from the equation the developed torque is proportional to the square of the stator supply voltage and a reduction in stator voltage will produce a reduction in speed. Therefore, continuous speed control may be obtained by adjustment of the stator voltage without any alteration in the stator frequency

Change in the resistance of stator and rotor circuit: In this method of speed control of three phase induction motor rheostat is added in the stator and rotor circuit due to this voltage gets dropped .In case of three phase induction motor torque produced

is given by T ∝ sV2 2 . If we decrease supply voltage torque will also decrease. But for supplying the same load , the torque must remain the same and it is only possible if we increase the slip and if the slip increase motor will run reduced speed. In this way we can control the speed of induction motor

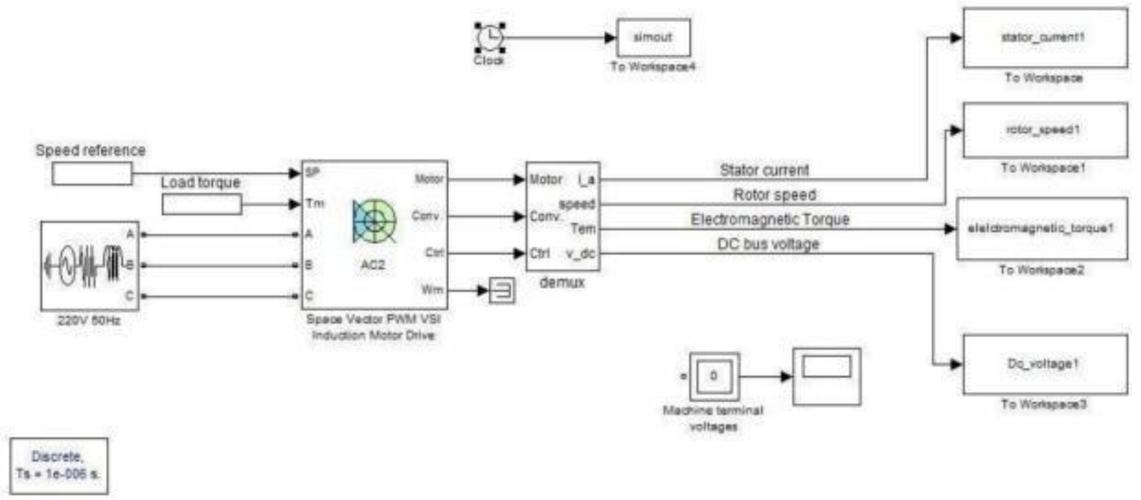
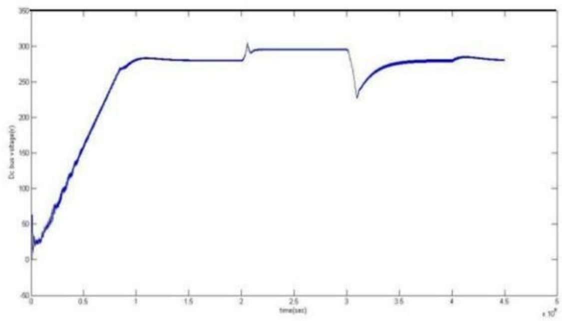


Figure 3: open loop PI controller for v/f ratio control method

4. The waveforms of open loop PI controller of v/f ratio method:



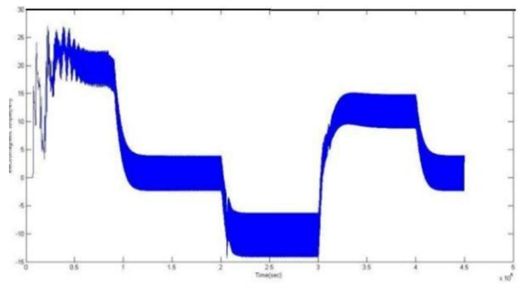


Figure 4: variation of dc bus voltage versus time **Figure 5: variation of torque versus time**

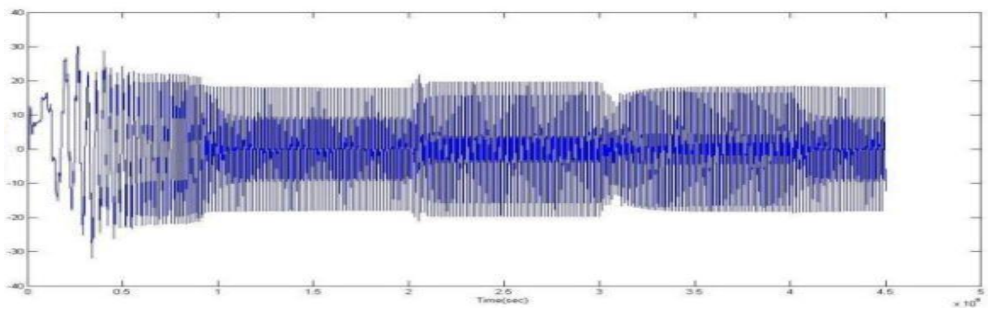


Figure 6: variation of stator current versus

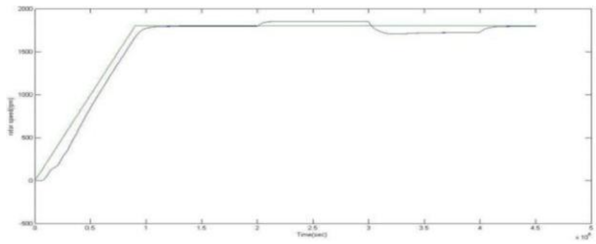


Figure 7: variation of rotor speed versus time

IV. FACTORS AFFECTING EFFICIENCY OF INDUCTION MOTOR DRIVES

The performance of the induction motor drives such as partial load, harmonics, rewinding, power consistency, parameter variance, etc. is influenced by many factors. The following articles address these considerations briefly.

Partial Loading

The 3-way induction engines are primarily used with all electrical AC drives due to their inherent advantages: robustness, durability, comparatively low costs and ease of service. These devices provide years of operation (around 20 years) when correctly picked, controlled and managed. In general, the induction engine manages an industrial load of around 70% on a utility, which implies it is crucial to pay greater attention to the full performance of such AC derives. Basically, when run close the rated speed and torque, high performance activity of induction machines can be accomplished. The substantial developmentin system parts, architecture and fabrication methods will further increase the motor performance in induction.

Harmonics

The function of the inverter driven induction motor at high frequencies contributes to losses due to two forms of harmonics: Space harmonics referred to as stray losses.The time harmonics in the excitation of a converter added to the unit, resulting in losses of time harmonic.

Stray Losses

The air flow difference of the space wave harmonics allows the system to experience street losses (high frequency errors). The key triggers of these harmonics are the differences in the position of stators and rotor slots and the mmf phase harmonics. These losses are related to the specific motor frequency and can be predicted to rise with the increase in the fundamental motor frequency.

High Frequency Time Harmonic Losses

An significant problem in today's electronic power management is the impact of time-harmonic frequency rise on harmonic motor losses. There are also valid explanations for control and motor acoustic noise, which justify for the strong inverter frequency of the carrier. Contrary to these claims, large engine losses may be induced by the carriers' large time harmonic frequency.

Rewinding

If the engine dies, fast repair and replacement are primarily two methods of avoiding output losses in front of engine customers. Excellent materials will reach optimum performance as in the previous stage, but the bad rewind contributes to higher energy usage and a shorter life due to higher ambient temperatures.

After rewinding the induction machine performance and power factor will greatly effect. The producer and consumer can then retain an appropriate register with no loss of load and pace during selling and buy. These reports may be valuable for rewinding effect measurement.

Unbalance Supply Voltage

While supplied by unequalled terminal voltages, induction motor output (speed and torque profile) is adversely affected. The accessible 1950 literature indicates that researchers concentrated on 3-fold induction motor output in voltage imbalances in relation to total current drawn, current imbalance factor, torque ripples, productivity and factor loss, rate loss, overheating isolation damages or computer failure factor [39].

Equal magnitudes and phase angle of 1200 in three stages, reflect the 3-fold mechanism in equilibrium. Every divergence from the parameters specified contributes to a system mismatch. The statistical concept of imbalance can be presented according to various criteria, including the Association of National Electrical Manufacture (NEMAs), the College of Electrical and Electronic Engineers (IEEE's) and IECs.

Voltage Sags

The RMS voltage drop in the associated power grid for short term is known as a "voltage decline." This issue in power quality is primarily attributed to machine failures. This is also likely due to loose links and the immediate start of heavy loads (the broad starter motor draws a strong in-rush current). For this phenomenon, the IEC term is "dip." Voltage decay triggers significant process problems and often vulnerable electrical loads sometimes go or shut down, which contributes to low quality items and severe production savings as well as a spike in engine temperature.

Parameter Variation

Both education and researchers performed a large amount of efficiency tests in order to monitor AC drives and DC drives effectively and precisely. The study brings them to the vector control principle. AC drive vector control is somewhat close to individual torque and flux control. The high efficiency of an induction engine can be accomplished by vector power. The methods of vector control are very susceptible to the variance of system parameters. However, with temperature and magnetic core saturation the motor parameters change. Computer flux is calculated offline in the direction of vectors by parameters that may be mistake attributable to parameter variations. If the vector controller does not change the error, the system output can be degraded by steady state error and transient speed and torque oscillations.

V. MODELING OF INDUCTION MOTOR DRIVE

The mathematical model of the drive mechanism comprises the induction engine model, PWM inverter models, PI speed controls and comprehensive engine and inverter failure models. The modelling expectations of the drive method are as follows.

1) The inductive motor's three-phase stator windings are balanced and generate Magneto Motive Force (MMF) spread sinusoidally in vacuum.
2) The DC link voltage accessible at inverter input terminals is considered to be free of ripple.
3) The three-phase sinusoidal currents moving through the engine are often presumed clear of ribbons.
4) Inverter and converter flipping transients are ignored.
5) Between switching system change times is small.
6) Three-phase converter input currents are sinusoidal

VI. CONCLUSION

The induction motor can be operated by increasing the frequency with the V / f ratio control system. But in this situation, if we adjust the frequency, the voltage still adjusts on the secondary side. The amount of supply voltages is also minimal relative to high speeds at low levels. The supply voltage decreased automatically to preserve a steady V / F ratio. The torque is thus minimized since the torque is directly equal to the voltage square. This is also not an effective speed control system. We may therefore say that we can adjust the resistance of the induction motor speed function. In this step, we can raise the rotor resistance to reach the optimum starting torque. But the copper loses in the running state are raised because of high resistance. The performance of the motor is thus limited. We may therefore assume that it does not play a major role in speed regulation and we must search for more methods.

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