# SPEED CONTROL

OF

# A THREE PHASE INDUCTION MOTOR

BY MEANS OF

# ANTI PARALLEL THYRISTOR / DIODE CONFIGURATION

A THESIS

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The thesis deals mainly with one of the most economical method of control, which uses anti-parallel thyristor/diode configuration in stator side. The system has been built and realized experimentally.

The thesis contains six chapters as follows :

The first chapter is an introduction to the classical methods and the modern techniques of speed control of induction motor. Principles and assumptions on which the analyses of the thesis are based, are explained in this chapter.

Chapter two presents the analysis of the system using anti-parallel thyristor pairs in the stator side.The relation between the firing angles and extenction angles is also studied. The analysis of the system using anti-parallel thyristor/diode are given in chapter three by two different approaches. This chapter contains also a complete analysis of harmonic contents of the motor current and voltage.

Chapter four presents a design of a modern firing circuit required for the used thyristors. The firing circuit is built using the technique of integrated circuits. This chapter refers also to the design of the needed stabilized power supplies.

Chapter five includes the experimental results containing the performance characteristics of the system in different modes of operation.

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Chapter six contains the conclusion of the main results and recommendation of research work.

# LIST OF SYMBOLS

## Chapter (2) :

$Y_o$ : : The magnetizing admittance of the induction motor.

$r_1$, $x_1$ : The resistance and reactance of the stator winding.

$r_2'$ , $x_2'$: The resistance and reactance of the rotor winding referred to the stator.

S : The slip.

$R_{eq}$, $X_{eq}$: The equivalent resistance of the induction motor.

$\phi$ : The phase difference between the phase voltage and current.

$\alpha$ : The firing angle of the thyristor.

$\gamma$ : The hold off angle of the thyristor.

$\beta$ : The extinction angle of the thyristor.

$\tau$ : The hole interval.

$\tau_c$ : The period of 3-ph state.

$\tau_n$ : The period of 2-ph state.

$\tau_o$ : The period of 0-ph state.

$\bar{u}$ : The Park-vector of the applied supply voltage (phase).

$\bar{i}$ : The Park-vector of the phase current.

U : The pick value of the supply voltage(phase).

I : The pick value of the phase current.

T : The time constant of the equivalent circuit of the induction motor.

$_s$ : The synchronous angular velocity of the supply voltage.

Im : The imaginary part of the equation.

Re : The real part of the equation.

## Chapter (3) :

$u_d$, $u_q$ : The direct and quadrature components of the supply voltage Park-vector respectively.

$i_d$, $i_q$ : The direct and quadrature components of the current Park-vector repectively.

$I_{do}$, $I_{qo}$ : The initial values of ($I_d$), ($I_q$) respectively.

$t_e$, $t_c$ : The initial and final instants of the 3-ph state respectively in 3-2ph mode of operation.

$t_1$ : The final instant of the 2-ph state in 3-2ph mode of operation.

$t_f$, $t_o$ : The initial and final instants of the 3-ph state respectively in 2-0 ph mode of operation.

$t_2$ : The final instant of the 0-ph state in 2-0 ph mode of operation.

$\bar{I}_1$ : The fundamental component of the phase current.

$\bar{I}_n$ : The harmonic, of order (n), of the phase current.

R, X : The per-unit values of $R_{eq}$, $X_{eq}$ respectively

$\bar{u}_1$ : The fundament component of the supply voltage.

$\bar{u}_n$ : The harmonic, of order (n), of the supply voltage,

Chapter (5) :

$P_{i/p}$ : The input power to the induction motor

$V_{ph}$ : The phase-value of the applied voltage.

$I_{ph}$ : The phase current.

i/p P.F.:The input power factor of the induction motor.

$Q_{i/p}$ : The input reactive power to the induction motor.

$V_{th}$ : The thyristor voltage.

T : The output mechanical torque of the induction motore.

N : The speed of the induction motor.

$P_{o/p}$ : The output power of the induction motor.

$\eta$ : The efficiency of the induction motor.

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# CHAPTER (1)

## INTRODUCTION

The d.c. machine finds wide application in variable speed drives because its speed can be efficiently controlled by adjusting its voltage. It does, however, have the practical disadvantage of employing a commutator and brush-gear, which is relatively expensive and requires periodic maintenance. Moreover, the use of a commutator makes the operation difficult with voltage or currents beyond a certain practical limit. Furthermore, the commutator actually precludes the use of a d.c. motor in certain extreme environmental condition.

The induction motor, on the other hand, does not require a commutator. As a result, it is generally considered less expensive than the d.c. machine. It is much more robust mechanically and therefore much less in need of maintenance.

Apart from its bearing the induction motor has no component exposed to wear. It is almost free from current carrying moving contacts. Moreover, it has a high power /weight ratio especially at high speeds. So the induction motor is the most extensively used of all other types of a.c. motors.

Unfortunately, the speed control of the induction motor is not flexible and is closely dependent on the supply frequency which is not easily varied.

## 1.1 Classical methods of speed control of the induction motor:

Various means for controlling the speed of a.c. induction motor connected to fixed frequency supply have been deviced. Although these classical methods are satisfactory within their own limitation, they are either inefficient or not generally applicable to a drive which is required to provide a high performance over wide range of load and speed. Some of these classical methods are the following:

### 1.1.1 Rheostatic control :

This can be applied only to motors with wound rotors, Resistance is included in the rotor circuit and the speed depends on the amount of the additional resistance per phase. Actually, the percentage slip is equal to the percentage rotor coppor loss. If the motor is working at a constant torque, the current will be sensibly constant, and the drop of speed below the synchronous speed will be proportional to the extra resistance per phase. Therefore there is a wast of power using this method of control especially if speeds much below the synchronous speed are required. A further disadvantage is that with automatic speed control, a servo motor is used to vary the external resistances,

### 1.1.2 Changing the number of poles :

By changing the number of poles, the synchronous speed and consequently the rotor speed is varied. The simplest arrangement uses a separate winding for each speed which is related to suit the particular application. Speeds in the ratio 2 : 1 (or 3:2) can be obtained by single winding. The connections of stator coils can be arranged to give either constant torque or constant power at the two speeds.

### 1.1.3 Cascade connection:

This method is useful to control the speed of a wound rotor induction motor. That motor is mechanically coupled to an auxiliary one of the same type or squiral caged rotor type. The stator of the main motor is connected to the supply. The auxiliary motor receives its power from the rotor of the main motor. If the auxiliary motor is wound rotor type that power is delivered either to its stator or rotor sides as shown in Fig. 1.1 . The e.m.f. of the auxiliary motor is injected into the rotor of the main motor causing the speed to vary considerably below the synchronous speed.

Let ($P_1$, $P_2$) are the numbers of the pole pairs of the main and auxiliary motor respectively, ($S_1$, $S_2$) are the respective fraction slips, and (f) is the line frequency. Then:

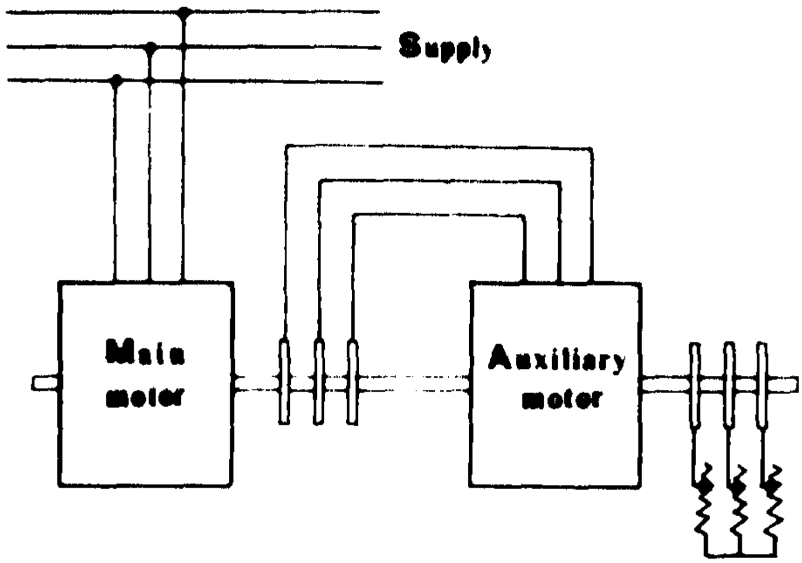


Fig. 1.1-a Speed control by means of Cascade, rotor to stator, connection.

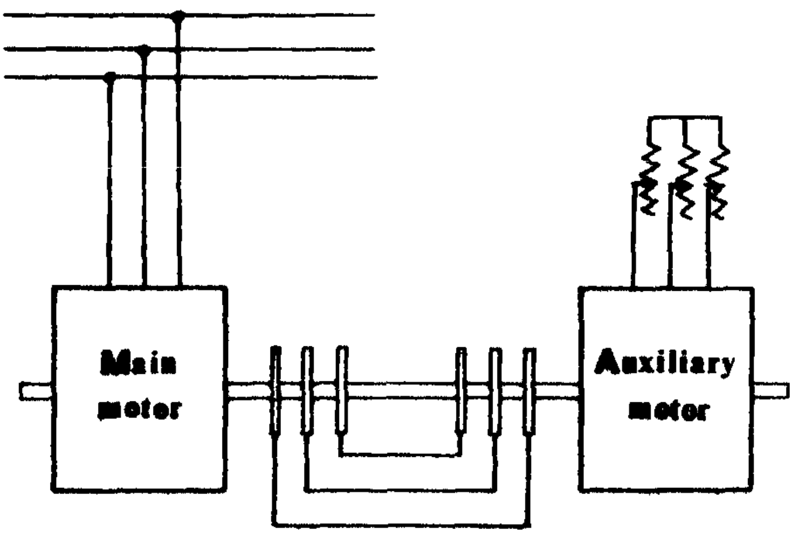


Fig. 1.1-b Speed control by means of cascade, rotor to rotor, connection.