Microprocessor based Slip Power Recovery system in Induction Motor

Rushabh DodkeMayur Karpate
Dept.Electrical EngineeringDept.Electrical Engineering
KDK College of Engineering K D K College of Engineering
NagpurNagpur
rushabhdoke10@gmail,com   mayurkarpate@gmail.com

Sharayu BhadNikita Vyawahare
Dept.Electrical EngineeringDept.Electrical Engineering
K D K College of EngineeringK D K College of Engineering
Nagpur Nagpur
sharayu1195bhad@gmail.com   nikitavyawahare6@gmail.com

Prof. P.P. Titarmare
Dept.Electrical Engineering
K D K College of Engineering
Nagpur

***Abstract*—Induction motors are the most commonly used motors in industrial motion control systems. Earlier, the nature of industrial applications of the induction motors were of constant speed mechanical drives due to difficult speed control systems but the recent advancement in power electronics components have the way for the development of power electronics based variable speed induction motor drives replacing dc drives..The slip power recovery scheme comprising Static Kramer Drive provides speed control of slip ring induction motor below synchronous speed.**

Key Word- Slip power recovery, power losses, poor drive efficiency

INTRODUCTION

Induction motor drives with control of speed have huge applications in the modern industrial set up. More than 75% of the load today in the industry of any country consists of induction motor drives. Wound rotor induction motor drives have found great applications due to the availability of slip power easily available from slip rings and can be utilized . High performance induction motor drive application requires low cost, high efficiency and simple control circuitry for the complete speed range. Nowadays, slip power recovery drives (SPRD),the principle of slip power recovery drive particularly to reduce the power losses at output terminals of slip ring induction motor due to the output. Slip power losses are more during speed control due to use of variable resistance (Rheostat) .

To reduce this losses the three methods are used first is doubly-fed machine speed control by motor resistance method and second is speed control by converting AC to DC but we are used static Kramer drive system to overcome slip losses and increase the efficiency of the drive .

METHODS

There are two method which are used for the speed control of the slip ring induction motor.

(1)Doubly- fed machine speed control by rotor resistance :-

This method is simple of speed control of a wound rotor induction motor is by mechanical variation of the rotor circuit resistance at output slip terminals . By varying the rheostat the speed of the motor can be controlled. But this method is very inefficient because slip energy is wasted in the rotor circuit resistance . This system is not in used very much.

(2) Speed control by converting AC to DC :-

In this method the external resistance in the rotor circuit can be varied statically by using a diode –bridge rectifier and chopper as usual the stator of the machine is connected directly to the line supply. The dc voltage is converted to current source by connecting a large series inductor then it is connected shunt resistance .When the IGBT is ON the resistance is short circuited and the current is bypassed through it. On the other hand if the IGBT is OFF the resistance is connected in the circuit and current flow through it .So the developed torque and the speed can be controlled by the variation of the duty cycle of the chopper. But in this method the problem of poor drive efficiency is same . Therefore this method has been used where the efficiency is not great concern .

(3) Modified Static Kramer Drive System :-

In this method the slip power recovery scheme for Induction Motor speed control . The slip power recovery (SPR) drive is an external system connected to the rotor circuit in place of the external resistors.The SPR provides speed and torque control like resistors but can also recover the power taken off the rotor and feed it back to the power system to avoid energy waste.

In an SPR drive consists of two interconnected power converters . The slip power recovery drive that permits only a sub-synchronous range of speed control through a converter cascade is known as a modified static Kramer drive. In this modified static kramer model circuit some modifications are there at the output. The slip terminal are connected to the drive rectifiers that converted three phase ac slip power into dc and an inductor is connected in series and the current through the inductor is applied to the inverter that convert dc in to the form of 3 phase ac voltage . With the use of inverter the speed of the slip ring motor can be controlled easily by changing firing angle of the microprocessor devices. In all methods the output voltage and frequency amplitude of IM is changed and less than the input voltage and frequency due the slip .So to set the voltage and frequency of output. The output voltage is given to the step up transformer that increases the amplitude of voltage .For the variation of firing angle in inverter frequency is changed .After that the feedback power given to the main supply. Hence we can reduce all losses due to slip and the speed of motor can also be controlled easily by the drive system. The speed and current feedback signals are obtained by connecting tachogenerator to the motor shaft . After digitizing, these signals are fed to the microprocessor where they are compared with respective reference signals. The firing pulses generated by the microprocessor are fed to the inverter through driver circuit.

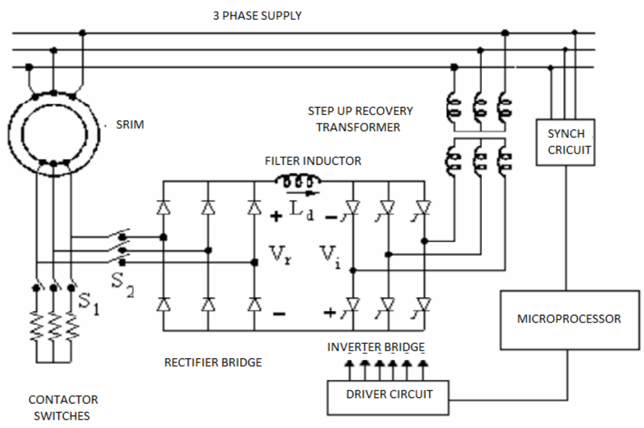
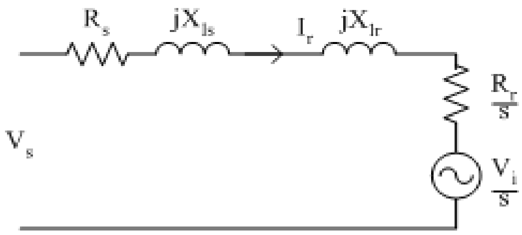


Fig . SLIP POWER RECOVERY SYSTEM

Equation

Considering the equivalent circuit, if the injected voltage is increased, the rotor current will be reduced, resulting in a reduction in the available torque generated by the motor. If there is a load applied to the motor, the rotor will slow down, resulting in an increase in slip. As slip increases, the effective voltage seen by the stator will be reduced (the actual voltage physically induced in the rotor, due to the stator, will increase). As a result, rotor current will increase. This process allows the machine to find a new steady state where the induced rotor current produces enough torque to equal the load torque.

In order to simplify the analysis, assume that the magnetising reactance can be moved to the terminals of the equivalent circuit. (If this is not the case, the stator phase voltage, stator impedance and magnetising reactance can be replaced by a Thevenin source and impedance. Simply replace subscript "s" in the following analysis with subscript "TH").



If the injected voltage is in phase with the rotor current, then the voltages in the equivalent circuit may be written as

$$V_s = \overrightarrow{I_R}\left(R_s + \frac{R_R}{s}\right) + \frac{\overrightarrow{V_i}}{s} + j\overrightarrow{I_R}(X_{Ls} + X_{Lr})$$

$$V_s = \frac{I_r R_r + V_i}{s}\angle\theta_r + I_r(X_{Ls} + X_{Lr})\angle(\theta_r + 90^\circ)$$

$$V_s{}^2 = \left(I_r R_s + \frac{I_r R_r + V_i}{s}\right)^2 + I_r{}^2(X_{Ls} + X_{Lr})^2$$

rearranging, the slip may be found as.

(ii) Power and Torque

The air gap power of the machine may be written as

Breaking this equation into parts, it can be seen that the air gap power is the sum of resistive losses, power recovered through the slip rings and the mechanical power.

$$P_{gap} = 3I_r{}^2 R_s + 3I_r V_i + 3I_r(I_r R_r + V_i)\frac{(1-s)}{s}$$

Using the expression for air gap power, the torque may be written as

$$\tau = 3I_r \frac{(I_r R_r + V_i)}{s\omega_s}$$

Now, substituting the slip expression into the torque expression gives the result that torque is only a function of rotor current, not slip or injected voltage:

$$\tau = \frac{3I_r}{\omega_s}\left[\left(V_s{}^2 - I_r{}^2(X_{Ls} + X_{Lr})^2\right)^{1/2} - I_r R_s\right]$$

The expression above means that for a given torque, the rotor current will always be the same, independent of speed. Analysing the torque equation, this in turn means that for a given constant value of torque

$$\frac{(I_r R_r + V_i)}{s}$$

will be constant. The injected voltage required to adjust the slip at a given load can be found from this expression.

(iii)No-Load Condition

Consider again the expression for slip:

$$s = \frac{V_i + I_r R_r}{\left[\left(V_s^2 - I_r^2 (X_{Ls} + X_{Lr})^2\right)^{1/2} - I_r R_s\right]}$$

If the torque is zero, then the rotor current will also be zero and at zero torque, the slip is given by

(iv) Efficiency

Since some of the power supplied to the motor is recovered from the rotor circuit, the efficiency cannot be calculated as simply output power over input power. Instead, in a slip energy recovery drive the efficiency is

$$\eta = \frac{P_{out}}{P_{in} - P_{recovered}}$$

(v) Static Kramer Drive

A static kramer drive is a method to obtain an injected voltage that is in phase with the rotor current. The schematic circuit for a static kramer drive is shown below

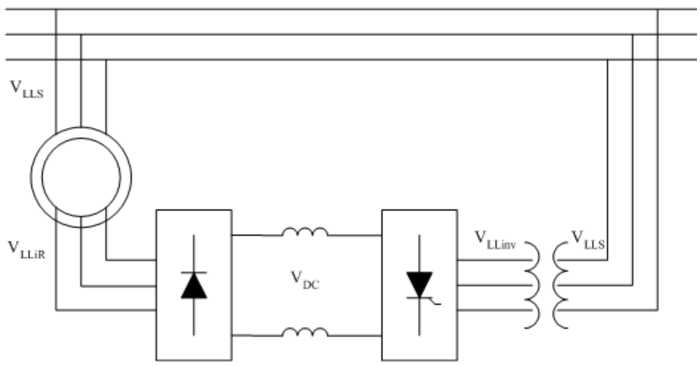


Fig .Static Kramer Drive

The voltage at the slip rings is forced to be in phase with the rotor currents by the diode rectifier. The magnitude of the slip ring voltage is set by the DC link voltage, which is in turn set by the inverter connected back to the AC supply. In the diagram above and the analysis presented, the inverter used is a thyristor converter. However, a PWM inverter can also be used.

(vi) Simple Analysis

This simple analysis of the static kramer drive illustrates the operation of the drive. It neglects the voltage drops in the drive and any possible commutation overlap in the diode rectifier.

The voltage at the input to the diode rectifier is given by

$$V_{LLiR} = \sqrt{3}\,\frac{V_i}{a_{eff}}$$

and the dc link voltage can be found from the diode input line-line voltage as

$$V_{DC} = \frac{3\sqrt{2}}{\pi} V_{LLiR}$$

Considering the thyristor converter, this circuit can be thought of as a thyristor rectifier connected in reverse, and the DC link voltage is related to the line-line inverter voltage as

$$V_{DC} = -\frac{3\sqrt{2}}{\pi} V_{LLinv} \cos\alpha = \frac{3\sqrt{2}}{\pi} V_{LLinv} |\cos\alpha|$$

Substituting the above expressions, the voltage injected into the rotor can be calculated as

$$V_i = \frac{a_{eff}}{\sqrt{3}} \frac{N_{inv}}{N_{Line}} V_{LLS} |\cos\alpha|$$

In the case that the inverter line-line voltage is connected to the supply through a transformer, as shown in the diagram above, the injected voltage can be related to the supply voltage as

$$V_i = \frac{a_{eff}}{\sqrt{3}} V_{LLinv} |\cos\alpha|$$

Using this simplified analysis together with the slip energy recovery torque equations, the thyristor firing angle required for a particular torque at a particular speed can be found. If necessary, more detailed analysis can be carried out by repeating the above process, but including device voltages and commutation overlap.

(vii) Torque-Speed

Because the slip ring voltage is derived using a diode bridge, the torque speed curve for a motor operated using a static kramer drive does not produce a negative torque as soon as the speed exceeds the no-load speed. If the slip is too low for a given injected voltage, the voltage induced in the rotor circuit by the stator will have a lower magnitude than the DC link voltage. As a result, no rotor current will flow and the torque will be zero.

HARDWARE REQUIREMENT

Sr. No.	Name of equipment	Specification
1.	dsPIC33	3.3 V
2.	Rectifier	50 V
3.	Capacitor	1000uF, 100uF, 10uF, 0.1uF,
4.	Resistor	1k, 10k, 330, 47
5.	Crystal	10MHz
6.	Transformer	30/415 V

7.	LED	2.5 V
8.	Driver Circuit (7407 Buffer)	5 V
9.	IGBT	1200 V
10.	Opto-coupler (TLP 250)	30 V
11.	Voltage Regulator (LD33CV)	3.3 V

ACKNOWLEDGMENT

I would like to express my deep gratitude to P.P. Titarmare (Prof. at RTMNU University) for his patient guidance, enthusiastic encouragement and useful critiques of this research work. My grateful thank is also extended to my mates Rushabh, Mayur, Sharayu, Nikita for their help in doing induction motor data analysis and helped me to perform experiment.

I would also like to extend my thanks to the technicians of the laboratory of the Electrical department for their help in offering me the resources in running the program.

Finally, I wish to thank my parents for their support and encouragement throughout my study.

REFERENCES

[1] B. K. Singh and K. B. Naik, “Steady State Modelling and Performance Analysis Static Slip Energy Recovery Controlled Slip Ring Induction Motor Drive” proceedings of the internationalmulticonference of engineers and computer scientists 2009 vol II IMECS 2009,March18-20,2009 HongCong.

[2] Shiv Kumar, Ajay Kumar, Himanshu Gupta, “Comprehensive Analysis Of Slip Power Recovery Scheme” IJIRT Volume 2 Issue 1 ISSSN:2349-6002 JUNE 2015.

[3] Ajay Kumar, S. K. Agrawal, L. M. Saini, and Ashwani Kumar, “Performance analysis of a microcontroller based slip power recovery drive” International Journal of engineering, science and technology volume 3, No.3, 2011.

[4]Jagendra Singh, Swati Rani, Rohini, “Slip Power Recovery System In Three Phase Slip Ring Induction Motor” IOSR Journal of electrical and electronics Engineering(IOSR-JEEE)-2014.