

Slip Power recovery system in Three Phase Slip Ring Induction motor

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ABSTRACT: *The research study takes a look at the impact slip rings power losses of three phase slip ring induction motor. The output slip power losses are more during speed control in two methods which we prefer in present days at Electrical industries and in Electrical Laboratory for speed control purpose. One is Doubly- fed method- The speed of the motor is controlled by three variable rheostat of same rating used at the end of output slip terminals of different phases. Second is converting AC slip power into DC- Instead of mechanically varying the resistance, the equivalent resistance in the rotor circuit can be varied statically by using a diode –bridge rectifier and chopper. This electronic control of rotor resistance is definitely advantageous compared to Rheostatic controlled, but the problem of poor drive efficiency remains the same. To overcome these losses the 3rd method is designed named modified static Kramer drive system a bridge diode rectifier, a cyclo inverter and a step up transformer. The three phase output frequency and voltage of Synchronous power at slip could be stepped up and converted as same input voltage and frequency. This synchronous power is now fed into main supply to the motor. And motor speed could be controlled by using inverter and the problem of poor drive efficiency is increased.*

Keywords: *Power loss due to heat, synchronous power, poor drive efficiency, Insulation, Cyclo inverter, Synchronous frequency.*

I. INTRODUCTION

This research study has the impact of 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) in previous methods. Previous works include the two methods named as Doubly-fed: Machine speed control by rotor rheostat in which when output slip terminals were connected to each other with any coil when the motor was at full load. The speed of the rotors was controlled by these variable rheostat of same rating used at the end of output slip terminals of different phases And the second method is Speed control by converting ac into dc and varying a rheostat: instead of mechanically varying the resistance the equivalent resistance in the rotor circuit can be varied statically by using a diode bridge rectifier and chopper. This electronic control of rotor resistance is definitely advantageous compared to rheostatic control method, but the problem of poor drive efficiency remains the same.

The contribution of this paper is to overcome the losses which occur in previous methods. The slip power or synchronous power is converted into dc by diode bridge rectifier and the DC voltage is converted into AC by line commutated inverter and fed back to supply. As the slip power can flow only in one direction, modified static Kramer drive offers speed control below synchronous speed only and improves overall poor drive efficiency of the system.

II. METHODS

There are two previous methods 2.1 and 2.2 which we use nowadays to control the speed of the slip ring induction motor and method 2.3 is developed to reduce the slip energy losses and to improve overall poor drive efficiency of the system.

External Resistance control by using three Rheostats (Doubly- fed machine speed control by rotor rheostat):-

A simple and primitive method of speed control of a wound rotor induction motor is by mechanical variation of the rotor circuit resistance at output slip terminals. When external resistance initially having zero resistance is shorted with the slip rings, the Inherent torque slip curve of the machine gives a speed corresponding to point at the rated load torque. As resistance is increased the curve becomes flatter, giving less speed until the speed becomes zero at high resistance, when output slip terminals are connected to each other

with any coil the motor works on full load so to control the speed of the motor we use a variable rheostat at the end of output slip terminals. By varying the rheostat the speed of the motor can be controlled. In addition this method of speed control is very inefficient because slip energy is wasted in the rotor circuit resistance like losses of power into heat. The scheme is hardly used now-a-days.

2.2 Speed control by converting ac into dc and varying rheostat:

Instead of mechanically varying the resistance the equivalent 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 power supply, but in the rotor power circuit the slip voltage is rectified to dc by the diode rectifier .The dc voltage is converted to current source by connecting a large series inductor then it is fed to IGBT shunt chopper with shunt resistance shown. When the IGBT is off the resistance is connected in the circuit and the dc link current flows through it. On the other hand if the device is ON, the resistance is short-circuited and current is bypassed through it. It can be shown that the equivalent resistance formula between points A and B .Therefore the developed torque and the speed can be controlled by the variation of the duty cycle of the chopper. This electronic control of rotor resistance is definitely advantageous compared to rheostatic controlled, but the problem of poor drive efficiency remains the same. This scheme has been used in intermittent speed controlled application in limited speed range, where the efficiency penalty is not a great concern.

Modified Static Kramer Drive System:-

This method is used as Slip-power-recovery scheme for Induction Motor speed control. Figure number 1 shows the connection for modified static kramer drive. The slip power for an induction motor is positive for Sub-synchronous speed because slip is positive. But it is negative for super-synchronous, speed slip frequency – adjustable voltages are inserted in the rotor circuit for induction motor speed control. The slip power can either be returned to the supply or added to the motor shaft output. Instead of wasting the slip power in the rotor circuit resistance, it can be converted to 50 hz. AC supply and pumped back to the line. The slip power control drive that permits only a sub- synchronous range of speed control through a converter cascade is known as a modified static Kramer drive, so we use modified static Kramer drive system .It is different from original static Kramer drive where rotating machines were used for slip energy recovery. The static – Kramer drive has been very popular in large power pump and fan-type drive, where the range of speed control is limited near but below the synchronous speed .the drive system is very efficient and the converter power-rating is low as mentioned already because it has to handle only the slip power. Infect the power rating becomes lower with the more restricted range of speed control. The additional advantages which are that the drive system has DC machine like characteristics and the control is very simple. These advantages largely offset the disadvantage of one rotor induction machine.

“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 controlled 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 cyclo 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 machine air-gap flux is established by the stator supply and it practically remains constant if stator drops and the supply voltage fluctuation are neglected .ideally, the machine rotor current is a six stepped wave in phase with the rotor phase voltage if the DC link current is considered harmonic-free and commutation overlap angle of the diode rectifier is neglected.

2.3.1 Speed control in modified static Kramer drive:

A speed control system of a modified Kramer drive is shown in figure 3 shows its typical performance. Figure 2 shows the relation of speed, dc current and firing angle variations with rest to time. As explained before, the drive has the characteristics of a separately excited dc motor, and therefore the control strategy is similar to a phase control rectifier dc drive. With essentially constant air gap flux, the torque is proportional to dc link current, which is controlled by an inner feedback loop. If the command speed W_r is increased by a step as shown in figure 3, the motor accelerate at a constant developed torque corresponding to the DC link current

limit set by the speed control loop. The inverter firing angle initially decreases with high slope to establish DC link current and then gradually decreases as speed increases. As the actual speed approaches the command speed, the dc link current is reduced to balance the load torque at a certain firing angle at steady state. As the speed command decreases by a step, DC link current approaches zero and the machine slows down by the inherent load braking effect. During deceleration, the firing angle increases continuously so that the inverter voltage balances the rectifier voltage. Then, as speed error tends to be zero at the steady state I_d is restored so that the developed torque balances with the load torque the air gap flux during the whole operation remains approximately constant, as dictated by the stator voltage and frequency. As mentioned before, the maximum speed should be slightly less than the synchronous speed so that the DC link current can be established with finite rectifier voltage.

2.3.2 Power factor improvement:

As discussed above, the method number 2.1 and method 2.2 is characterized by poor line power factor. The power factor can be improved by a scheme called modified static Kramer drive with less number of commutators. The scheme is somewhat analogous to a primitive Kramer system, where a dc motor is coupled to the induction motor shaft and is fed by the rectifier slip power through a diode rectifier.

III. INDENTATION AND EQUATION

Torque Expression:

Figure 4 shows the torque-speed characteristics of slip ring induction motor in modified static Kramer drive system.

The average torque expression in terms of inverter firing angle is derived resulting in:

$$T_e \approx 3 \left(\frac{P}{2} \right) \frac{V_s^2}{\omega_e R_r} \left[\frac{|\cos \alpha| \left(\frac{s^2}{n_1} - \frac{|\cos \alpha|}{n_2} \right)}{sn_2} + s \left(\frac{s}{n_1} - \frac{|\cos \alpha|}{sn_2} \right)^2 \right]$$

Where V_s =Supply voltage.

n_1 =Stator-to-rotor turn ratio.

n_2 =Transformer line side-to-inverter ac side turn ratio.

P=Number of poles.

I_{r1} =Fundamental component of rotor current.

R_r =Rotor resistance.

S=Slip.

ω_e =Synchronous speed.

Figures and Table

Table : Showing the Data analysis of 3-phase, 420 V, 4-pole, 50 Hz, star-connected Slip Ring Induction Motor controlled by means of modified static kramer drive with operating speed of 1000 rpm .Transformer has phase turn ratio from L.V. to H.V. as 0.4

Per phase Stator voltage (in volts)	Slip	Load Torque (In Nm)	Firing angle (In degree)	Power fed back to supply (In watt)	Power Output (In Watt)	Loss in Inductor (In Watt)	Rotor Ohmic Loss (In Watt)	Stator Ohmic Loss (IN Watt)	Input Power (In Watt)	Efficiency (In %)	Motor Speed (In rpm)
242.5	0.333	312.5	131.81	16363.31	32724.92	117.03	468.13	224.70	33534.78	97.58	994.3

Figures:

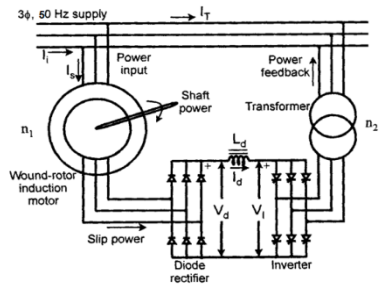


Figure-1
Modified static kramer drive

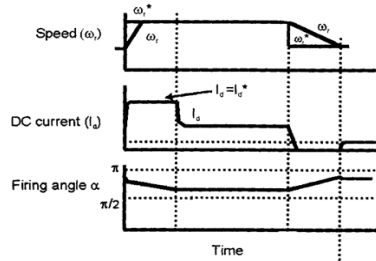


Figure-2

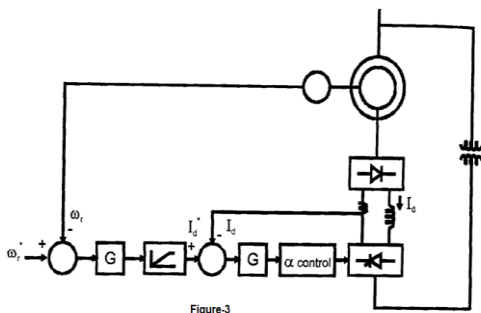


Figure-3
Speed Control of a modified Static Kramer Drive

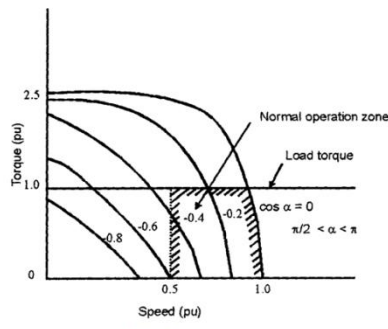


Figure-4

The torque-speed curves at different firing angles of the inverter

IV. CONCLUSION

In this study, a methodology has been put forward in design of three phase wound rotor motor. The wasted slip energy in the rotor circuit resistance like losses of power into heat is removed which occurred in Doubly-fed method. The power drive efficiency is increased in Modified Static Kramer Drive Method. This method is used in intermittent speed controlled application at any speed range.

With the use of three phase star-delta connected transformer in the synchronous power line. The slip data output is transformed as primary star connected supply. Hence for better insulation purpose, this drive is more effective. With the use of inverter the speed of the motor is controlled in a very easy and safe manner. The drive system is very efficient and the converter power rating is low, because it has to handle only the slip power. The drive system has dc machine-like characteristics and the control is very simple.

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