Slip Energy Recovery of Induction Motor using Converter

S.P.Dhongade
M.Tech(I.D.C.)Final Year
Department of Electrical Engg.
PCE.Nagpur

K.B.Porate, PhD
Associate Professor
Department Of Electrical Engg.
PCE Nagpur

ABSTRACT
Slip ring induction motor is used as a variable speed drive in SERIM scheme. The speed of SRIM can be easily control by simple & primitive method, mechanically variation of rotor circuit resistance. This method of speed control has is very inefficient because the slip energy is wasted in rotor circuit resistance. However, several advantages of this method are as absence of in-rush starting current, availability of full rated torque at starting, high line power factor, absence of line current harmonics, and smooth & wide range of speed control. This wasted power can be utilising by so many techniques are available like chopper control, Static Kramer Drive and static Scherbius drive. This paper deals with the slip energy recovery scheme using power electronic based converter technique of power recovery and energy saving with thyristor control is achieved, the simulation is made in MATLAB environment.

Keywords
Slip ring induction motor,Slip Power recovery.

1. INTRODUCTION
Slip ring induction motors are widely used in industrial applications by varying rotor parameters. Traditionally for the control of SRIM additional rotor resistances have been added .This method is inefficient due to the wastages of power in the rotor circuit [1].This wastage of power can be minimised with the smooth control technique by thyristered circuit of rotor side [2].In this scheme also wastage of power in the rotor circuitry that is slip power .this wastage of power can be utilised by feed back to the input supply during the working of machine that is slip energy recovery. Thyristered rotor circuit comprise of Rectifier, Smoothing reactor, Inverter & Transformer etc. Kramer system &Scherbius system are also suggested for such recovery of energy [3].

This paper deals with the SERD system is simulated in MATLAB environment with the help of power electronic based converter technique of power recovery and energy saving with thyristored control technique is achieved [1].

2. METHODOLOGY
Methodology used in this paper is phase angle control technique to recovery the slip energy.

A.Phase angle control technique

By neglecting the stator and rotor drops , the voltage V_r is given as equation

$$\mathrm{Vr} = \frac{1.35\mathrm{SV_L}}{n_1} (1)$$

Where S= per unite slip, V_L = Stator line voltage,n_1= stator to rotor turn ratio of the machine, again the inverter dc voltage V_i is given in expression (2)

$$Vi = \frac{1.35}{n_2} V_L \cos\propto (2)$$

Where the n_2 = transformer line side to inverter ac side turn ratio &$\propto$ = inverter firing angle. For inverter operation, the range of firing angle is $\frac{\pi}{2} < \propto < \pi$ .since the V_r and $V_i$must be balance. The equation of slip is given in equation (3)

$$S = \frac{n_1}{n_2} \cos\propto (3)$$

Therefore the speed expression can be given as, in equation (4)

$$\omega_r = \omega_e(1 - \cos\alpha) (4)$$

Where ω_e= synchronous speed. Again, neglecting losses, the following power equation can be written as

$$SP_g = V_i I_d (5)$$

$$P_m = (1 - S)P_g = T_e\omega_m (6)$$

$$P_m = T_e\omega_e(1 - S)\frac{2}{p} (7)$$

Where the P_g = air gap power, P_m = mechanical output power, ω_m= mechanical speed , P is the no of pole. Hence the torque equation is given as follow

$$T_e = (\frac{P}{2})\frac{P_g}{\omega_e} (8)$$

$$T_e = (\frac{P}{2})\frac{1.35}{\omega_e}\frac{V_L}{n_1} I_d (9)$$

The equation (9) indicates that the torque is proportional to current I_d. with higher load torque T_L, the machine tends to slow down and current I_d increases so that T_e= T_L. In other words for the fix firing angleof the inverter, the voltage V_i is fixed.

3. SIMULATIONS
Simulation of SRIM for the analysis of Slip energy recovery is developed in MATLAB environment. The SRIM consider for the analysis its specifications are represented in table I. In this study the firing angle of the inverter is taken to be 108° and the corresponding steady state speed 1440 rpm. The simulation block diagram is represented in fig 1. Simulation waveform & the various parameters are noted & shown in fig 2.

Table I SRIM Specifications

Parameter	**Rating**	**Parameter**	**Rating**
Phase	3 Phase	Stator resistance, R_s	0.7384 ohms
Input capacity	7.5 Kw	Stator inductance,Ls	0.003045 H
Supply voltage	415 volt	Rotor resistance , R_r	0.7402 ohms
Input current	14.2 Amp	Rotor inductance ,Lr	0.003045 H
Frequency	50 Hz	ResistancR_f	0.2 ohms
Poles	4	Inductance L_f	0.039H
stator to rotor turn ratio	0.55	Mutual reactance ,M	0.1241 H
The moment of inertia constant including load ,J	0.0343 $kg.m^2$	Damping coefficient including load , B	0.000503 N.m.sec

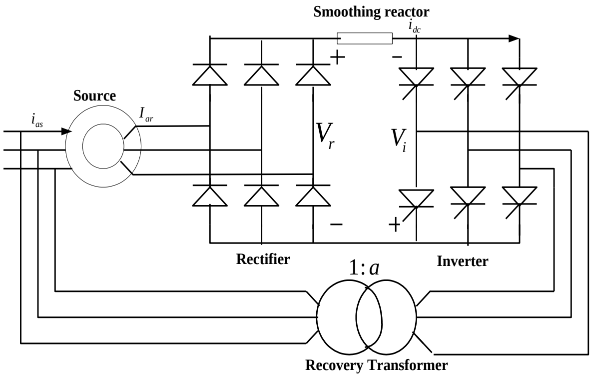
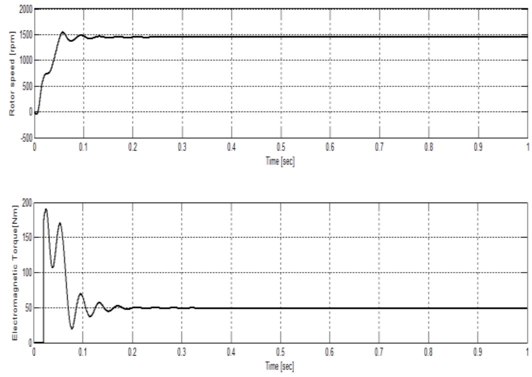


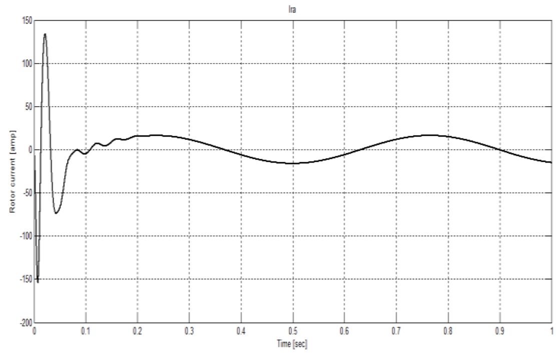
Fig.1. Schematic of Slip energy recovery drive

A slip ring IM is needed .The three phase rotor voltages are rectified with a diode bridge rectifier and fed in to a dc link inductor to smooth out the current. The dc link current is then inverted and fed back to the mains using an interposing transformer.

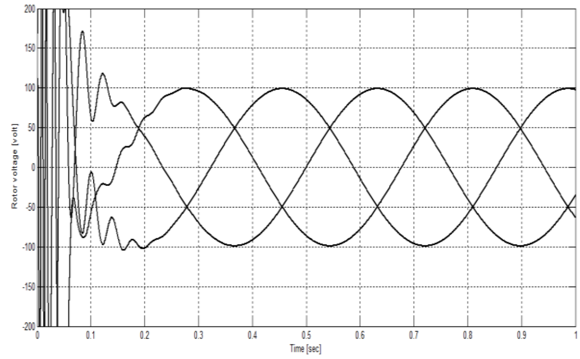
(a)



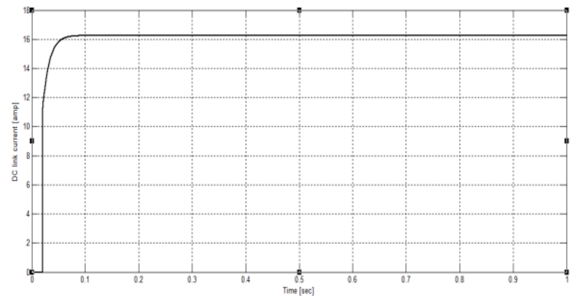
(b)



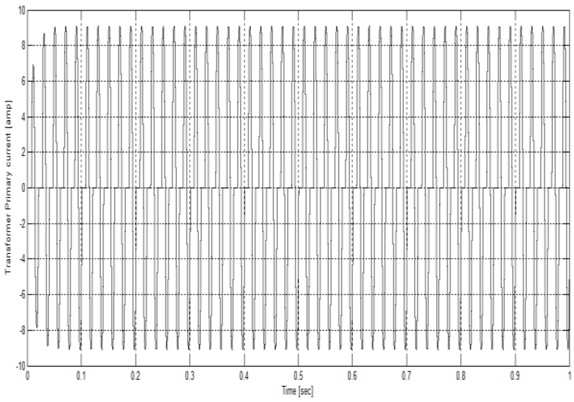
(c)



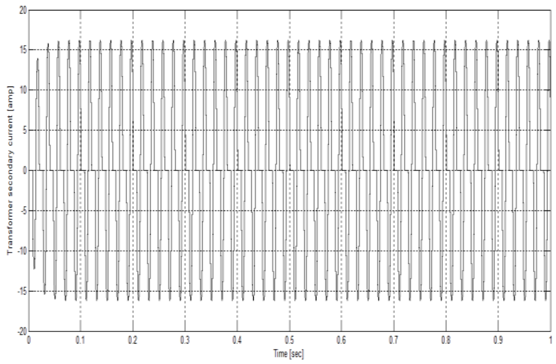
(d)



(e)



(f)



(g)

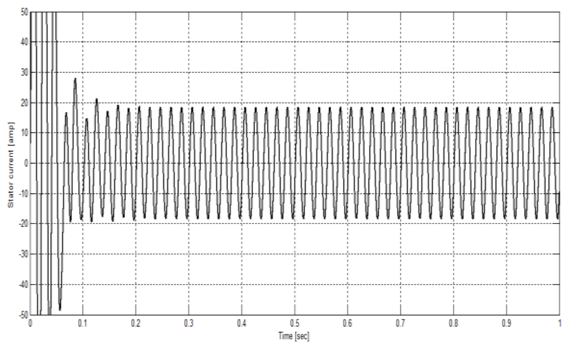


Fig 2. Waveform of : (a) Rotor speed and torque,(b) Rotor current ,(c) Rotor Voltage ,(d) DC Link Current, (e) TransformerPrimary current, (f) Transformer Secondary current, (g) Stator current.

A. *Rotor Speed and Electromagnetic Torque.*

Simulation is carried out up to 1 sec. , we get the rotor speed and electromagnetic torque waveform shown in Fig 2(a). During starting Rotor speed rises up to 1540 rpm then settle down to 1440 rpm at 0.2 sec. and the Electromagnetic torque during starting rises to 190 Nm and then settle down to rated value of machine that is 49 Nm at 0.2 sec.

B. Rotor Current and Voltage.

Rotor current waveform is shown in Fig. 2 (b). Rotor phase current are obtain by the sum of the currents of three phase rectifier bridge legs. Three phase bridge rectifier is used here to eliminate the harmonic.Fig.2(c) shows the rotor voltage. Initially the rotor voltages vary largely and it settle down at 0.2 sec.

C. *Dc Link current*

Dc link current is the output of the rectifier circuit. The dc link current waveform is shown in fig 2 (d).and the nature of DC link current is smooth dc because of use of smoothing reactor.

D. Transformer Current.

The Transformer primary and secondary current waveform shown in fig. 2 (e) & 2(f) .The nature of the transformer current is sinusoidal on both the side.

E. Stator Current.

Fig 2 (g) present the stator phase current and During starting stator phase current is high up to 0.1 sec after that it settle down at 0.2 & the nature of the waveform is close to sinusoidal & this is the sum of the motor magnetising current and Rotor phase current.

A. EstimationOf Result

Estimation of energy recovered is calculated as follows.

Output voltage of rotor(line) = 70.71 volt

Output current of rotor (line) = 11.31 Amp

Power factor = 0.85

The rotor power= 1.177 kwatt

Assuming the machine is working for 10 hrs, energy=1.177*10 = 11.777 kwhrs

4. RESULT

The various waveform of SERD has been obtained by using the phase angle controlled technique, that model simulating in MATLAB environment. The total power recovery is 15% of the rated machine. Machine is loaded for 10 hr. then 15% energy0f rated machine is recovered**.**

5. CONCLUSION

In this paper, SRIM is presented, for energy saving purpose. The waste slip energy in the rotor circuit resistance is recovered. The transformer is also use between the inverter and main supply for improvement of the operation of the drive, although the power factor. Slip power recovery is also helpful for speed control of induction motor by varying the firing angle of the inverter and minimisation of the losses.

6. ACKNOWLEDGMENTS

Our thanks to the experts who have contributed towards development of the template.

7. REFERENCES

[1] Jawed Faiz,H. Barati, and EyupAkpinar, "Harmonic Analysis and Performance Improvement of Slip Energy Recovery Induction Motor Drives," *IEEE Transactions on Power Electronics,* vol. 16, NO. 3, pp 410-417, May 2001

[2] W. S. Zakaria, A. A. Shiiltout& S. *E.* Alrvash, "A Novel Double-Circuit-Rotor Balanced Induction Motorfor Improved Slip-Energy Recovery Drive Performance Part I1 : Experimental Verification & Harmonic Analysis", *IEEE Transactions on Energy Conversion,* vol. 11, No. 3, pp 563-569 ,September 1996.

[3] Lavi, & R. J. Polge, "Induction Motor Speed Control with Static Inverter in the Rotor", *IEEE Transactions On*

Power Apparatus And Systems, VOL. PAS-85, NO. 1,pp.76-84, January, 1966

[4] L.Refoufi&P,Pillay, "Harmonic Analysis Of Slip Energy Recovery Induction Motor Drives", *IEEE Transactions on Energy Conversion,* Vol. 9, No. 4, pp 665-672,December 1994.

[5] E. Akpinar, P. Pillay& A. Ersak, "Starting Transients In Slip Energy Recovery Induction Motor Drives- Part 1: Formulation And Modeling*" IEEE Transactions on Energy Conversion*, Vol. 7. No.1,pp.238-244 March 1992.

[6] E.Akpinar and P. Pillay, "Modeling and Performance Of Slip Energy Recovery Induction Motor Drives", *IEEE Transactions on Energy Conversion,* Vol. 5, No.1, pp 203-210,March 1990.

[7] M. Ramamoorthi, and NS Wani,"Dynamic Model for Chopper Controlled Slip-Ring Induction Motor" *IEEE Trans. On Industrial Electronics and control Instrumentation.* Vol. IECI-25 , no. 3, pp 260-266, Aug.1978.

[8] B.K. Bose, *Advance Power Electronics and AC Drive*. Englewood Cliffs, NJ: Prentice-Hall, 1988.

[9] Jagendrasingh, Swati Rani,&Rohini, " Slip Power recovery system in Three Phase Slip Ring Induction motor", *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE).*

[10] H.Azizi, A.Vahedi& M.A.S Masom, "Study of Slip Energy Recovery of Induction Motor Drive Using Matlab/SimuIink",pp 563-569

[11] M. T. Outeiro , E. S. Saraiva , "Harmonics on the Electromagnetic Torque of a Slip Energy RecoverySystem with Two Thyristor Bridges and no DC Coil"pp. 1-8.

[12] J.D. Van Wyk, "Variable-speed a.c. drives with slip-ring induction machines and a resistively loaded force commutated rotor chopper",Electric Power Applications, October 1979, Vol. 2, No. 5,pp.149-160

[13] Dhaval D. Mer, Rakeshkumar A. Patel & Manish G.Prajapati, "Comprehensive Study of Speed Control And Power Loss Analysis Using Rotor Resistance And Slip Power Recovery Method", *International Journal Of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering,Vol. 2, Issue 3,* March 2014.