Slip ring induction motor power factor control using Fuzzy logic controller

Sivanagappa.V.J [1] Sarumathi.M [2] Sivaranjani.R [3] Soniya.N [4] Sujeetha.A [5,]

1 - Assistant professor, Department of Electrical and Electronics engineering
2,3,4,5 - Student, Department of Electrical and Electronics Engineering
Vivekanandha College of Engineering for Women, Elayampalayam, Namakkal(Dt).

Abstract: Slip ring induction motor plays a vital role where outsized mechanical power and switching speed are important. Speed tuning may be accomplished by slip power control but power factor complications confine the utility of this system. The revised scherbius system implemented in this paper has comprehensive hybrid inverter (poised by six thyristor bridge, added by GTO's across the dc terminals) make use of that to regulate the slip power recovery and also the power factor of the system for all rules. A fuzzy adaptive regulator, centered in a three level regulator assembly to operate the system variables refining drive acts as per the system changes.

Keywords: Slip ring induction motor, slip power control, fuzzy adaptive regulator

1. Introduction

Normally the scherbius scheme have been mostly applied for speed control of slip ring induction motor especially wherever large mechanical power is required, but the power factor complication confines the utility of this system. This paper defines an improved scherbius system accompanied with hybrid inverter, this aid to recover the slip power and also the power factor (Fan Liao et al 1991). The necessity of control system is to produce the inverter firing angles and the GTOs firing pulses consistent with formally executed one, to retain the power factor nearby unity.

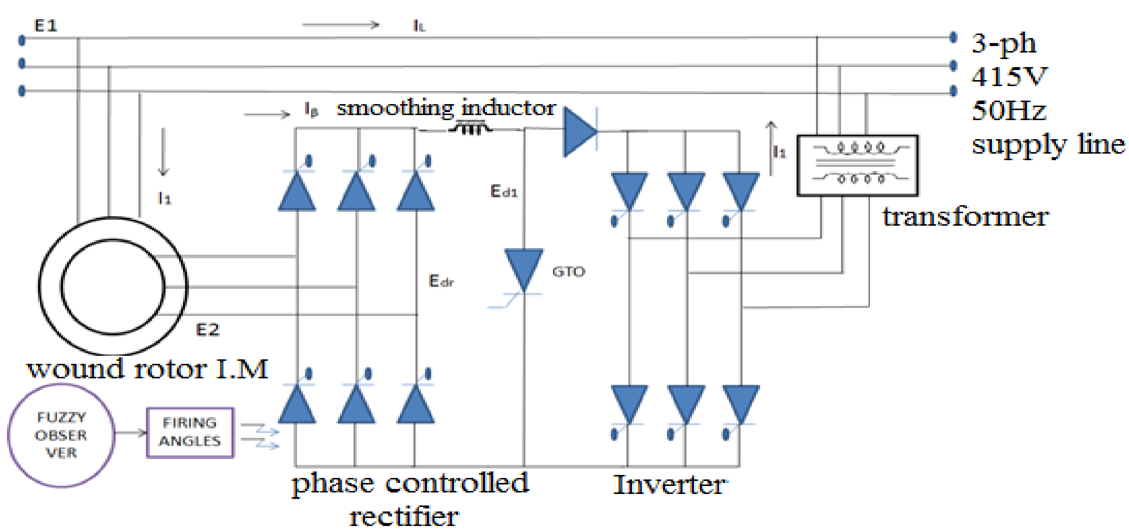


Figure 1. Proposed Slip Power Recovery Drive (SPRD)

When widespread exploration and simulations were done, one important thing was found out that the sophistication of the control structure restrict this system implementation. The additional technical hitches such as unbalance areas and multi variables are also analyzed (S.R. Doradla et al 1988). To rectify these hitches, a three level control structure has been proposed. The linguistic set of fuzzy rules designates each level of control structure. In practice, the three level control structures have so many benefits such as slip power recovery, speed control, dc link current control, safety preferred working norms. Control system is basically used upon fuzzy forth which is poised with data base, having production rules and inference engine (Leonharn, 1985, Krishnan, 2001, Steibler, 2010). By operating a loop type inference engine, the facts confined in a set of rules yield truthful conclusions. The fuzzy forth compiler agree rules of it and dwelling them in a "passive rule set" in such away, in such away, the pertinent rules are house in the "active rule set" which will be demonstrated repeatedly by inference engine (Akpinar, P. et al. 1990). This permits consumption of numerous levels of control which impulses or unfluctuating brain power, if we may perhaps courageous.

2. Induction Motor Model

The fourth-order state-space model and second-order system are used to represent the corresponding electrical part and mechanical part. the prime signs in the machine equations given below is indicate this.

Electrical system of equations

$$V_{qs} = R_s i_{qs} + d/dt\Phi_{qs} + \omega\Phi_{ds} \tag{8}$$
$$V_{ds} = R_s i_{ds} + d/dt\Phi_{ds} - \omega\Phi_{qs} \tag{9}$$
$$V'_{qr} = R'_r i'_{qr} + d/dt\Phi'_{qr} + (\omega\text{-}\omega r)\Phi'_{dr} \tag{10}$$
$$V'_{dr} = R'_r i'_{dr} + d/dt\Phi'_{dr} + (\omega\text{-}\omega r)\Phi'_{qr} \tag{11}$$

Where,

$$\Phi_{qs} = L_s i_{qs} + L_m i'_{qr} \tag{12}$$
$$\Phi_{ds} = L_s i_{ds} + L_m i'_{dr} \tag{13}$$
$$\Phi'_{qr} = L'_r i'_{qr} + L_m i_{qs} \tag{14}$$
$$\Phi'_{dr} = L'_r i'_{dr} + L_m i_{ds} \tag{15}$$

$$T_e = 1.5\, p(\Phi_{ds} i_{qs} - \Phi_{qs} i_{ds}) \tag{16}$$

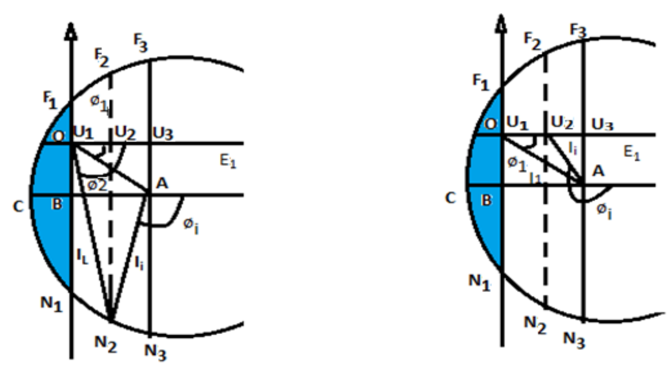
Mechanical system of Equations

$$\frac{d}{dt}\omega_m = \frac{1}{2H}(T_e - F\omega_m - T_m) \tag{17}$$

$$\frac{d}{dt}\theta_m = \omega_m \tag{18}$$

3. Proposed Slip Recovery Drive

The amendment of electrical variables concerned in the proposed system can be achieved by the use of power converters which has more or less multifarious set of pictures by the proper control. The system uses a hybrid converter due to the generation and consumption of reactive power. Obviously, the firing angle of thyristor and the duty cycle of the GTOs will fix the speed control it is acknowledged that the machine torque is directly proportional to dc link current with full range of speed control. The analysis of the phasor diagram is shown. The position of the stator, inverter and the line current as a function of inverter firing angle and the GTOs duty cycle or revealed in the phasor diagram.



(a) (b)

Figure 3. Phasor diagram

This illustration in Fig 2 use I_1 has a stator current with the phase angle of θ_2 lagging, I_2 has an inverter current fed back to the line with phase angle of θ_1 and I_{L1} is the total lag current. The curvature N_1-N_3 denotes the fundamental line current position which is obtained with a standard sub synchronous cascade. This section U_1-U_3 indicates the locus of the line currentI_{L1} for a unit displacement factor. During all the operating conditions the line current I_{L2} should flow along the segment which is the foremost in this paper. The DC link current goes to zero in this region which is represented as cross-hatched area. This shows that rectifier voltage E_{dr} is smaller than inverter voltage. Consider that the stator current remains constant, the area enclosed by F_1,F_3,N_3,F_1 which indicates the locus of the total line current I_{L1} for all variations of duty cycle and firing angle. Angular position of I_{L1} controls the firing angle the inverter and the amplitude is controlled by duty cycle. The semicircle F_3, F_1, C, N_1, and N_3 indicates the position of the inverter current for duty cycle which is equal to zero. For a given inductive power factor of induction motor, the firing angle of the inverter is more or less 120˚ and the duty cycle of the GTO is equal to zero. Thus the line current I_{L1} is greater than the current in the stator.

4. Control Structure

The controller which describes the behaviour of the drive is put into operation by a set of linguistics rules. Normally the response time will be faster than the human operator. Some of the advantages of these approaches are to present the line parameters adaptation, retort optimization and possibility to deal with the unstable region in the control space. There are three levels in the control structure. Each level places a particular task. First level "instinct" which deals with the DC link current control, preventing and safeguarding. The input to this is speed error and the speed error variation. The output to this is increment of the duty cycle. A numerical output value is generated by the centre of gravity criterion through defuzzification. It also gives the protection rules against converter over current and avoid dangerous operating region.

IF Ω IS X1	AND	δΩ IS Y1	THEN	δd IS Z1
IF Ω IS X2	AND	δΩ IS Y2	THEN	δd IS Z2
IF Ω IS X3	AND	δΩ IS Y3	THEN	δd IS Z3
...	....	....	....	....
....	....	....	....	....
IF Ω IS Xn	AND	δΩ IS Yn	THEN	δd IS Zn

Table 1. Rule base for fuzzy logic control

IF
DC_ LINK_CURRENT is Very High
THEN
Decreases_Duty_Cycle Very_much
END-RULE
IF
Firing_Angle is Around_270
THEN
Limit_Duty_Cycle
END-RULE

The second level is responsible for the control of the motor from the lower level which is the reference value and it also manipulates the knowledge about the start condition, acceleration rate. The "mechanical skills" of the drive is achieved in this level. Speed reference, actual speed and duty cycle are the inputs in this level. The inverter firing angle is the output. It also estimates the speed error. The fuzzy inference describing this level has the form.

IF
X_1 IS A_1 OR B_1 OR…
AND
……..
X_k IS A_k OR B_k OR ….

THEN

$y=P_0+ P_1 X_1 +\dots +P_\kappa X_\kappa$

Where,

X_1-X_k	-	Variables of premise that also appear in the consequence
A_1-A_k	-	Fuzzy set with linear membership functions
P_0-P_κ	-	Parameters in consequence
y	-	Variable in consequence whose value is inferred

The final desired output y, inferred from the set of Implications, i s given by:

$$Y = \frac{\sum \mu 1 \,.Y1}{\sum \mu 1} \tag{19}$$

Where μ1 is the membership function of minimum operator. The transient behaviour is created from this structure. The third level is "observer" notices the overall behaviour of the system to decide what is to be done.

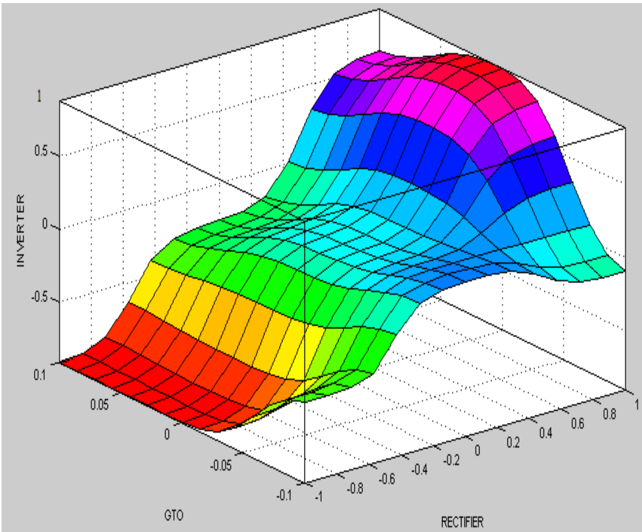


Figure 4. Output of Fuzzy Structure

The "Investigator" is the set of fuzzy conditional statements which adjust the operating point until the preferred criterion is achieved. Next the "Estimator" is used for finding the vector θ so that the performance index T is minimized.

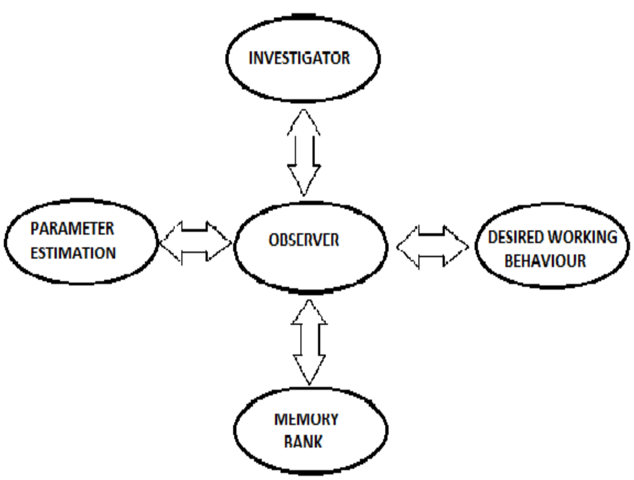


Figure 5. Flow Diagram of fuzzy observer

5. Experimental Parameters

Table 2. Parameters of Induction motor

Parameters	**Values**
Type	Slip ring
Phase	3
Voltage	410v
Current	7.5A
Speed	1440rpm
Capacity	3.0hp
Connection	Y-Y

6. Simulation Results

The function of the simulation was to determine if it is possible to sustain unity displacement factor under all conditions of load and speed, by judicious adjustment of the inverter firing angle and GTO's duty cycle. a simulation is done by matlab/ simulink. A 3 hp, 410 V, 50 Hz wound rotor induction motor has been used for the simulation. Theoretically, through the study of presented diagram, for a certain mechanical power which is required by the load and line current represented by the N_2-F_2.The operational point N_2 has only to remain this line and desired goal will be reached.

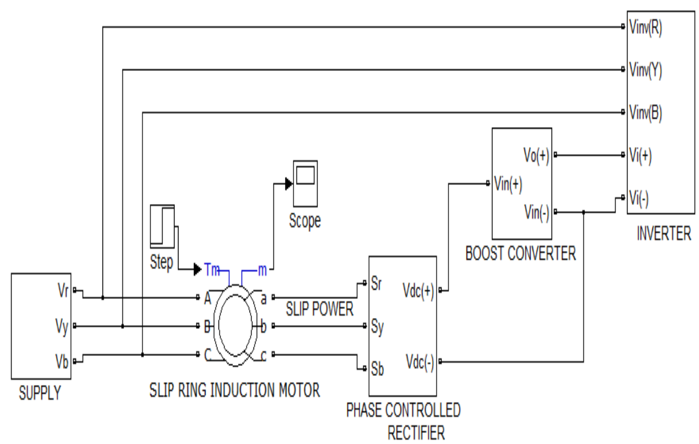


Figure 6. Simulation of proposed scherbius drive System

It represents the simulated output of the phase controlled rectifier and the fig shows the output voltage and output current attained from the phase controlled rectifier. Slip power from the rotor is taken as an input to the rectifier and the output voltage from the rectifier has the magnitude of 168V.

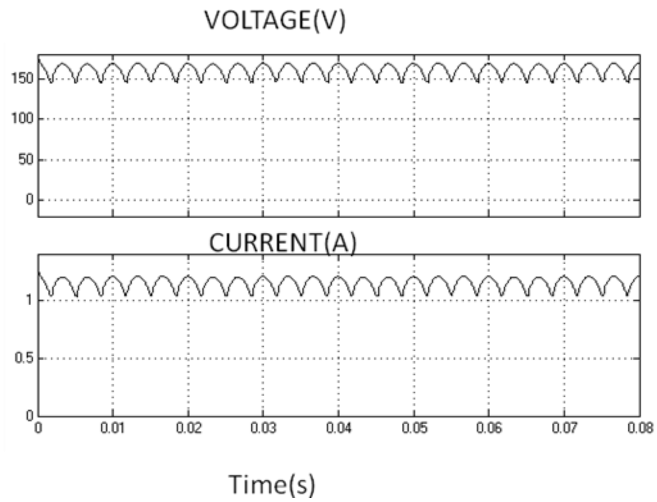


Figure 7. Simulation output of Phase controlled Rectifier

It shows the simulated output voltage from the boost converter. The boost converter enhances the voltage feed from the phase controlled rectifier. It increases the voltage magnitude from 168V to 400V.

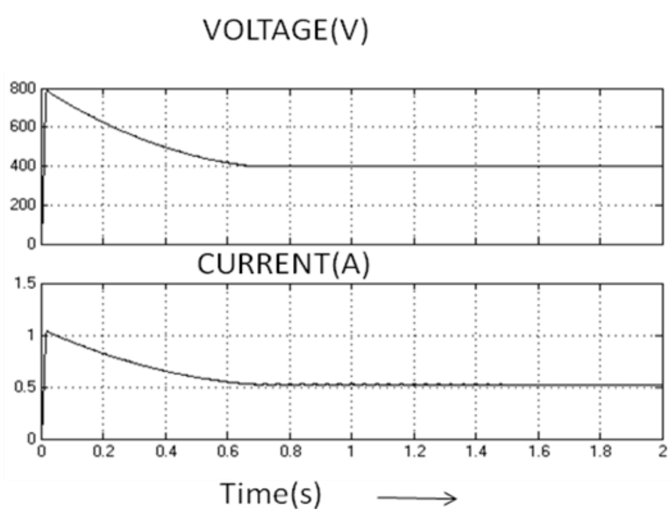
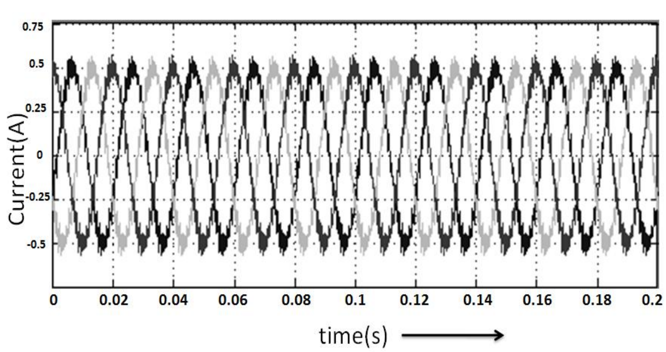


Figure 8. Simulation output of boost converter



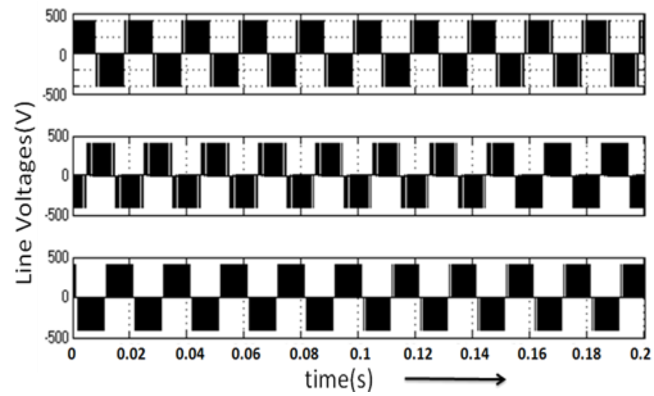


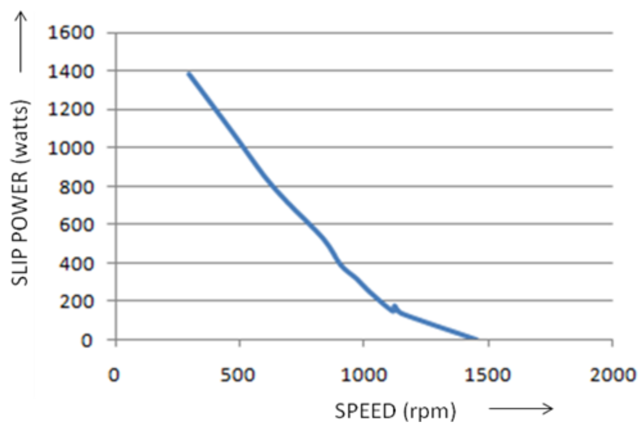
Figure 9. Simulation Output of Inverter

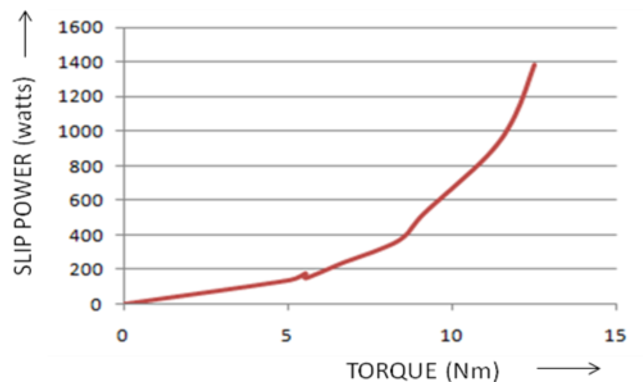
It shows the output voltage and output current obtained from the inverter which is fed to the line and the power factor is preserved as unity throughout the operation facilitated by the fuzzy control. The inverter firing angle and the duty cycle of the GTO are proscribed by fuzzy techniques.

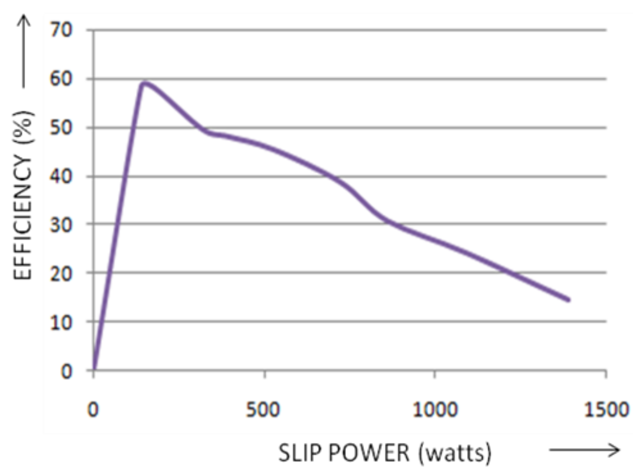
Figure 10. Shows the testing setup of the slip power recovery system. The experiment is conducted for attaining the slip power from the rotor and it is transformed into DC voltage facilitated by diode bridge rectifier. From the testing, characteristics of slip power versus torque, efficiency and speed are obtained.

7. Experimental Verification

Figure 10. Experimental Setup







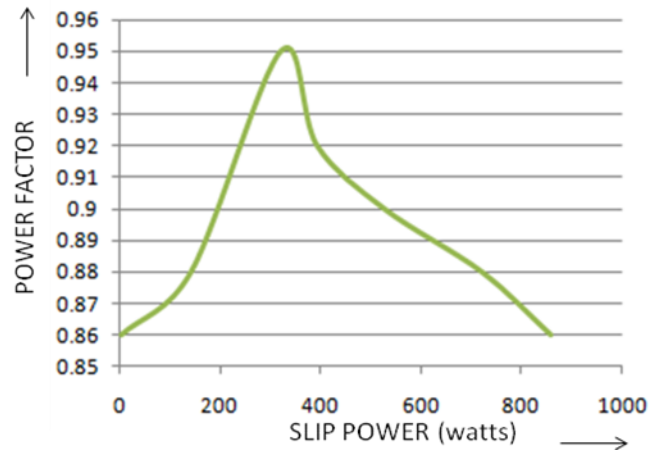


Figure 11. Various drive characteristics

8. Conclusions

The engineering and design aspects of the modified slip power recovery system using fuzzy control for improving power factor and controlling the speed of the wound rotor induction motor has been proposed in this paper. Nearly 15% of power i.e. 335W of power from the slip has been utilized. It has been shown that the efficiency of the modified slip power recovery system is nearly equal to the efficiency of the existing slip power recovery system while the power factor of the modified slip power recovery system has been improved to 0.95 significantly. The fuzzy logic controller giving the faster response to the system.

Appendix

Parameters: Stator resistance = 4.8 Ω; Rotor resistance = 4.2 Ω; Stator leakage reactance = 9.5 Ω; Rotor leakage reactance = 9.5Ω; Magnetizing reactance =185 Ω; Stator to rotor turn ratio = 5.
Other Parameters of the drive system: Turns ratio of recovery transformer (inverter to line side) = 0.2; Resistance of smoothing inductor = 2 Ω; Inductance of smoothing inductor = 0.025 H

Nomenclature

R_s, L_{ls}	Stator resistance and leakage inductance
R'_r, L'_{lr}	Rotor resistance and leakage inductance
L_s, L'_r	Total stator and rotor inductances
V_{qs}, i_{qs}	q axis stator voltage and current
V'_{qr}, i'_{qr}	q axis rotor voltage and current
V_{ds}, i_{ds}	d axis stator voltage and current
V'_{dr}, i'_{dr}	d axis rotor voltage and current
ω_m	Angular velocity of the rotor
Φ_{qs},Φ_{ds}	Stator q and d axis fluxes

Φ'_{qr}, Φ'_{dr}	Rotor q and d axis fluxes
Θ_m	Rotor angular position
T_e	Electromagnetic torque
T_m	Shaft mechanical torque
J	Combined rotor and load inertia coefficient. Set to infinite to simulate locked rotor.
H	Combined rotor and load inertia constant. Set to infinite to simulate locked rotor.
F	Combined rotor and load viscous friction coefficient

References

[1] Fan Liao, Ji Sheng, and Thomas A. Lipo, Fellow, IEEE: A New Energy Recovery Scheme for Doubly Fed, Adjustable-Speed Induction Motor Drives,Vol. 21, No. 4, July/August 1991.

[2] S.Tunyasrirut,J.Ngamwiwit,T.Furuya and Y.Yamamoto: Fuzzy Logic Controlled Inverter-Chopper for High-performance of Slip Energy Recovery System.

[3] M. S. Vicatos J. A. Tegopoulos, l. Fellow, IEEE :Doubly-Fed Induction Motor Differential Cascade Part I - Configuration And Analysis In The Steady State -Vol. 14, No. 3, September 1999.

[4] Isik Adirci, Okhan akçam, and Uammer ermis: Effects Of Instantaneous Power-Supply Failure On The Operation Of Slip-Energy Recovery Drives -vol. 20, no. 1, march 2005.

[5] Nikhil Mishra, Ankit Dixit, S.M. Tripathi and K.S.Verma:A Survey On Slip Power Recovery DrivesJournal Of Natural & Physical Sciences- Vol. 24, No.1, pp.21-28 (2011) ISSN 097-3799.

[6] P.Pillay University of New Orleans Algeria (Dept. of Elec. Eng.) L.Refoufi lnstitute National D'Electricite Calculation Of Slip Energy Recovery Induction Motor Drive Behavior Using The Equivalent Circuit

[7] Krishnan, R., 2001, .Electric Motor Drives, Modeling and Analysis. Prentice Hall, Inc.

[8] S.R. Doradla, S. Chakravorty and K.E. Hole, "A New Slip Power Recovery Scheme with Improved Supply Power Factor., *IEEE Trans on Power Electronics,* Vol 3, No 2, April 1988, pp 200-207.

[9] Akpinar, P. and Pillay P., 1990, .Modeling and performance of slip energy recovery induction motor drive. IEEE Trans. on Energy Conversion, Vol. 5, No. 1, pp. 203-210.

[10] Papathanasiou S. A., Papadoupolous M. P., 1998, .Commutation angle analysis of slip energy recovery drive. *IEEE Trans. On Energy Conversion,* Vol. 13, No. 1, pp. 21-26.

[11] Faiz, J., et al., 2001, Harmonic analysis and performance improvement of slip energy recovery induction motor drive. IEEE Trans. on Power Electronics, Vol. 16, No. 3, pp. 410-417.

[12] Tunyasrirut S.,et al., 2008, .DSP based modified slip energy recovery drive using a 12-pulse converter and shunt chopper for speed control system of a wound rotor induction motor. Electric Power System Research, Vol. 78, No. 6, 861-872.

[13] Tunyasrirut S.,et al., 2008, .DSP based modified slip energy recovery drive using a 12-pulse converter and shunt chopper for speed control system of a wound rotor induction motor. Electric Power System Research, Vol. 78, No. 6, 861-872.

[14] Lavi, A. and Polge, R.J., 1966, .Induction motor speed control with static inverter in the rotor. IEEE Trans. on power apparatus and systems, Vol. PAS- 85, No.1, pp.76-84.

[15] Dick, B., 2009, .Wound Rotor Slip Power Recovery Drive Experience and Applications. Cement Industry Technical Conference Record, 2009 IEEE, Vol. 1, No.1 , pp.1-4.

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

[17] Dubey, G.K., 2008.Power semiconductor controlled drives., PHI. Edition.

.