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Constant Torque Operation of Wound Rotor Induction Motor using feedback mechanism in a Rectifier Fed Induction Motor Drive

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Abstract: *This paper sets forth a technique to operate wound rotor induction motor in maximum torque region, using a feedback mechanism using rotor speed and slip.Static rotor resistance control has been used to vary the rotor resistance. The AC output voltage of motor is rectified by a diode bridge and is fed to a parallel combination of IGBT and external resistance. Effective value of rotor resistance is varied by varying the duty cycle of IGBT. Simulation models has been prepared in MATLAB in which a constant maximum torque is generated from standstill(s=1) to* s_{Tmax}*(=0.415) .*
Keywords: *Wound rotor induction motor,diode, IGBT, rotor speed, slip, MATLAB*

I. Introduction

Wound rotor induction motor is of pivotal importance when high staring torque is required and when the driven load requires precise speed control. The doubly-fed induction generator (DFIG) used in onshore wind turbines and motor generator set (MG Set) widely employ wound rotor induction motor. In past, liquid resistance starters (LRS) have been used to control the external resistance of rotor circuit for big induction machines but its setup requires large space .This problem can be easily rectified by employing in power electronic devices like chopper circuit and diode bridge which are compact.

In a wound rotor induction motor at the time of starting the entire external resistance is added to the rotor circuit and as the rotor speeds up, the external resistance is varied in steps so that motor torque tends to remain maximum during accelerating period. Finally, under normal operation the external resistance is fully cut off and the slip rings are short circuited.[1, 2, 4]

II. Models

In past pulse generator has been used to achieve varying rotor external resistance. The Wound Rotor Induction Rotor employing pulse generator is shown in Figure 1for such model

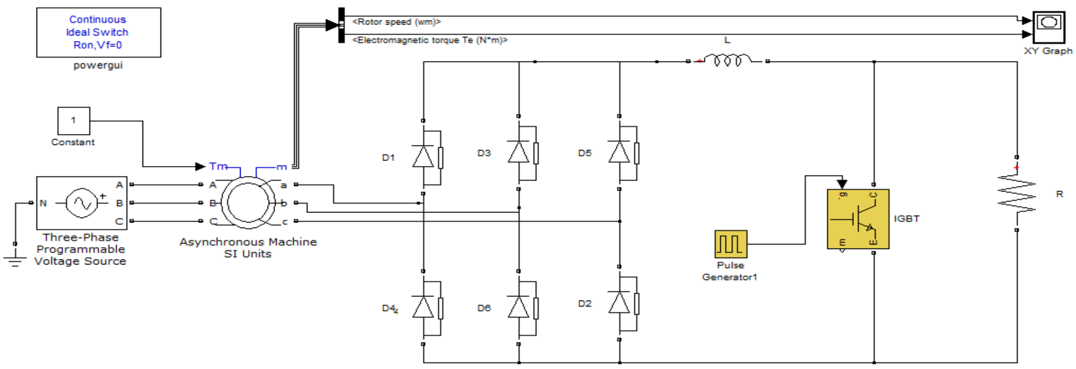

Figure 1: Wound Rotor Induction Motor employing pulse generator

In this model the rectified ac voltage of motor is fed to a parallel combination of resistance R and IGBT. Pulse Generator has been employed to trigger the IGBT.As no feedback mechanism has been employed the duty cycle has to be varied manually to get the desired results thus this model holds very less practical significance.

III. Proposed Models And Implementation

This article discusses about two models which have been simulated in MATLAB to maintain constant maximum torque for motor.

1. Application of feedback mechanism to vary duty ratio using no inductor (Figure 2).

2. Application of feedback mechanism to vary duty ratio using inductor as a filtering device (Figure 3).

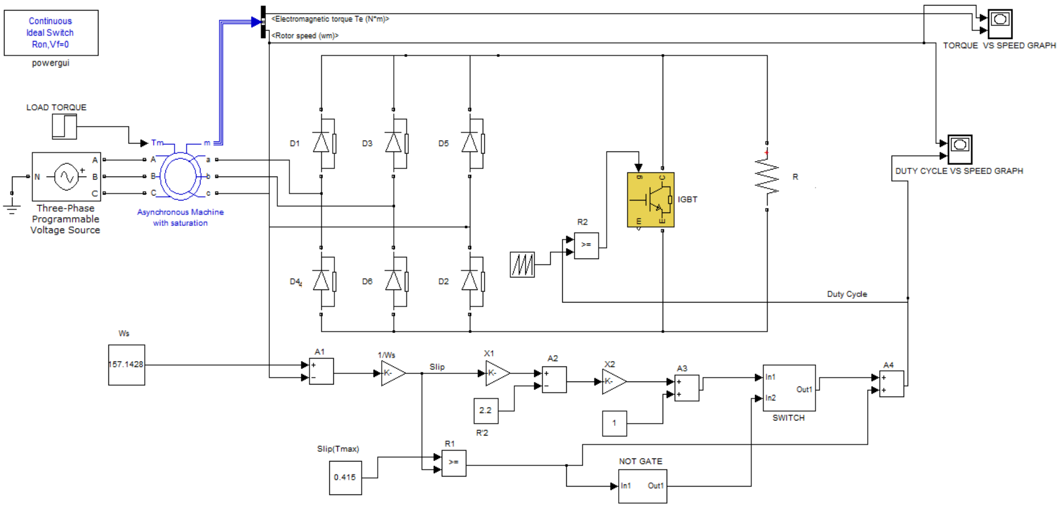

Figure 2:Model 1 for constant torque operation of wound rotor employing feedback control

This method employs in two feedback mechanism of rotor speed and slip to maintain a constant torque upto s_{Tmax} of wound rotor induction motor .The feedback mechanism has been prepared using following equations [1]:

$$s_m = \frac{R_r{}'}{\sqrt{R_s^2 + (X_s + X_r')^2}} \qquad (1)$$

With an external resistance whose stator referred equivalent resistance is Re

$$s_m = \frac{R_e + R_r{}'}{\sqrt{R_s^2 + (X_s + X_r')^2}} \qquad (2)$$

$$R_e = 0.5R(1-\delta)a^2 \qquad (3)$$

For maximum torque to occur at standstill i.e. s=1,δ=0 and
$R_e = 0.5Ra^2$(4)

Where

s_m	Slip	Rr'	Rotor resistance referred to stator side
X_s	Stator Reactance	X_r'	Rotor reactance referred to stator side
R_s	Stator resistance	δ	Duty Cycle
A	Stator to rotor turns ratio	R_e	Stator referred external resistance

In feedback mechanism rotor speed is fed to the negative terminal of add block A1and rotor synchronous speed i.e. 157.14 rad/sec is fed to the positive terminal from constant Ws block toadd block A1.The output of add block A1 gives us the difference of the rotor speed and synchronous speed. The difference in speed is multiplied by a gain which has value same as reciprocal of synchronous speed (1/Ws) which gives us the slip of the motor. The slip value is multiplied by gain of X1 block whose value is $\sqrt{R_s^2 + (X_s + X_r')^2}$ and it gives us the value of effective rotor resistance i.e. R_e +R_r'. The output of X1 block is fed to positive terminal of add block A2. R'2 blockcontaining value of Rr' is fed to the negative terminal of add A2 block. The output of add A2 block gives us the value of external rotor resistance referred to stator side i.e. $R_e = 0.5R(1-\delta)a^2$ .R_e is fed to X2 block whose value is equal to negative of reciprocal of 0.5Ra^2i.e. (-1*1/0.5Ra^2).At this point it's imperative to understand that how the value of R i.e. external resistance introduced into rotor circuit is calculated. We have designed our model in such a way that the breakdown torque is produced from standstill. Hence for maximum torque to occur at standstill when s_m=1 and δ=0 following equation holds .Motor parameters mentioned in appendix have been substituted in the equations:

Using equation (2) we have,

$$1 = \frac{R_e + 2.2}{\sqrt{1.46^2 + (2.56 + 2.55)^2}}$$

R_e =3.11ohms

Using equation (3) we have,
$3.11 = 0.5R1.33^2$
R=3.505ohms

The output of X2 block is fed to positive terminal of add block A3 and a constant value to 1 is fed to another positive terminal of add block A3. The output of add block A3 gives us the value of δ i.e. duty cycle. The output of add block is fed to Inp 1 of SWITCH subsytem.

At this point we would like to re-emphasize that our calculations are valid only for machine running at maximum torque. Thus once the condition of δ=1 has been reached there would be no effect of external rotor resistance . The boundary condition for slip has been calculated using equation (2).
At boundary condition value of external resistance Re is zero as δ=1

$$s_m = \frac{2.2 + 0}{\sqrt{1.46^2 + (2.56 + 2.55)^2}}$$

$s_m = 0.415$

The constant value 0.415 fed to the relational operator R1 which is the value of slip at which value of duty cycle becomes one and there is no effect of external resistance. The relational operator R1 compares the constant value 0.415 with the rotor slip fed to other terminal of relational operator R1. When external resistance is in picture output of relational operator is low because 0.415 would be less than value of calculated slip , but once duty cycle, i.e. δ=1 is reached slip decreases below 0.415 and output of relational operator R1 turns high. The output of relational operator R1 is further fed to In1 of NOT GATEsubsystem.

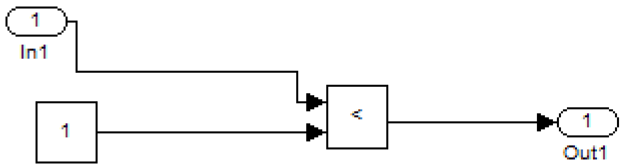

Figure 3:NOT GATE Subsystem

In NOT GATEsubsystem In1 is the output of the relational operator R1. When output of relational operator R1is high output of NOT GATE subsystem becomes 0.The output (Out1) of NOT GATE subsystem is fed to second input terminal In2 of SWITCH block subsystem.

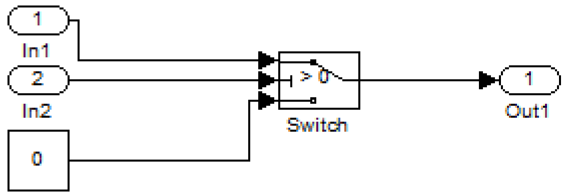

Figure 4:SWITCH block subsystem

If input to second terminal of SWITCH subsystem is high it means that switch would operate with terminal 1 configuration related to In1. The output of switch,which would be duty cycle δ in this case is fed to add block A4. A second input from relational operator R1 is fed to other positive terminal of add block A4. In this particular case the value of input from relational operator would be zero. Thus the output of add block A4 would be duty cycle which is further fed to 1stterminal of Relational Operator R2. The other terminal of relational operator is fed with a saw tooth pulse generated with the help of repeating sequence block which will produce repeated pulses of the duty cycle. Whenever value of terminal 1 would be greater than terminal 2 a gate pulse would be given to IGBT which will turn the power semiconductor device into action.

On the other hand if input to second terminal of SWITCH subsystem is low it means that switch would operate with terminal 3 configuration. The output of switch in this case would be 0 i.e. fed from a constant block .The output of switch is further fed to add block A4. A second input from relational operator R1 is fed in other positive terminal of add block A4. In this particular case the value of this signal would be 1. Thus the output of add block A4 would be 1 which is further fed to 1st terminal of Relational Operator R2. The other terminal of relational operator R2 is fed with a saw tooth pulse generated with the help of repeating sequence block. In this case the output of relational operator would be set at 1.The same is desired because at last we want the value of external rotor resistance being realized by the circuit to reduce to zero so that motor can operate with maximum efficiency for a given load.

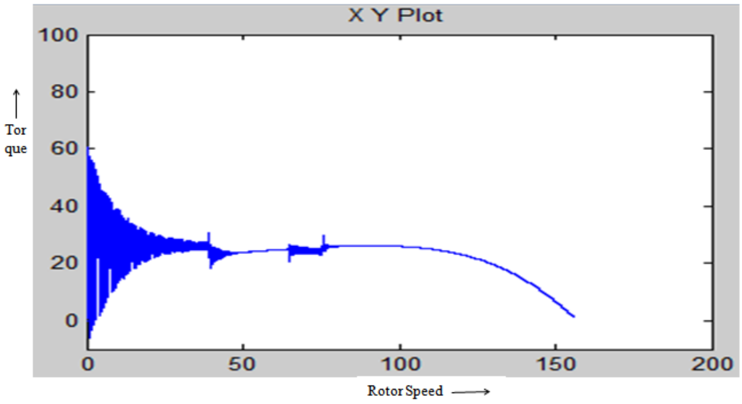

Figure 5:Torque V/S Rotor Speed

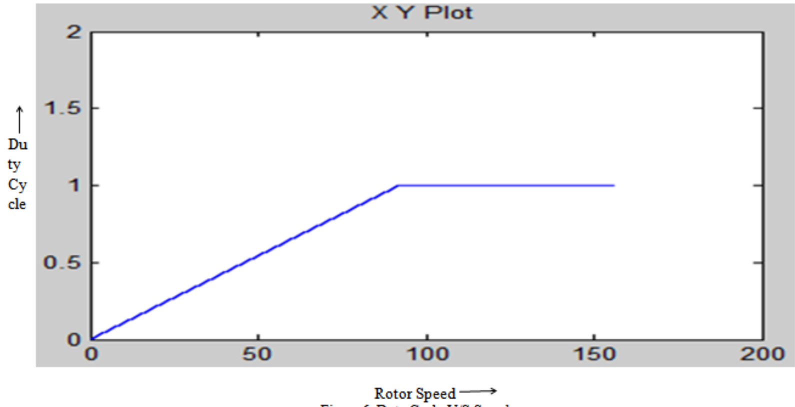

Figure 6: Duty Cycle V/S Speed

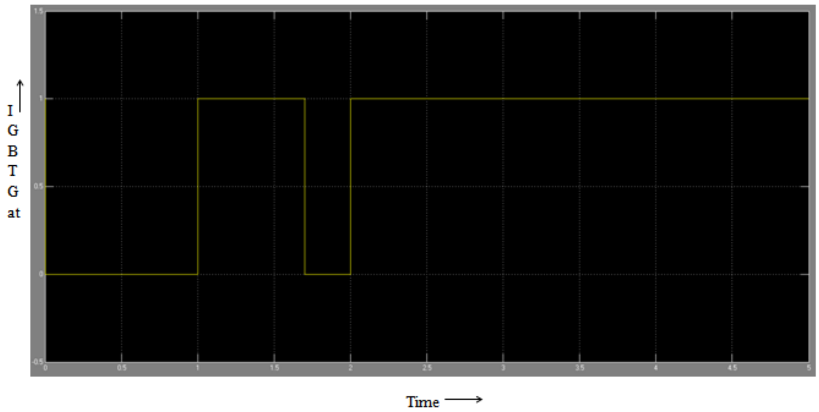

Figure 7:IGBT Gate Pulses

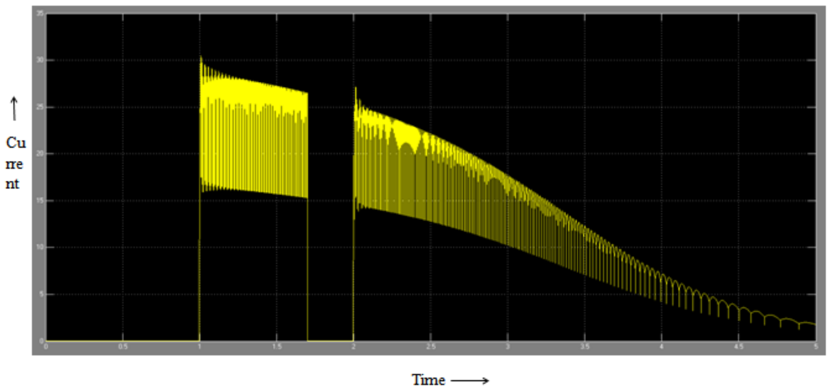

Figure 8:Current flowing in IGBT

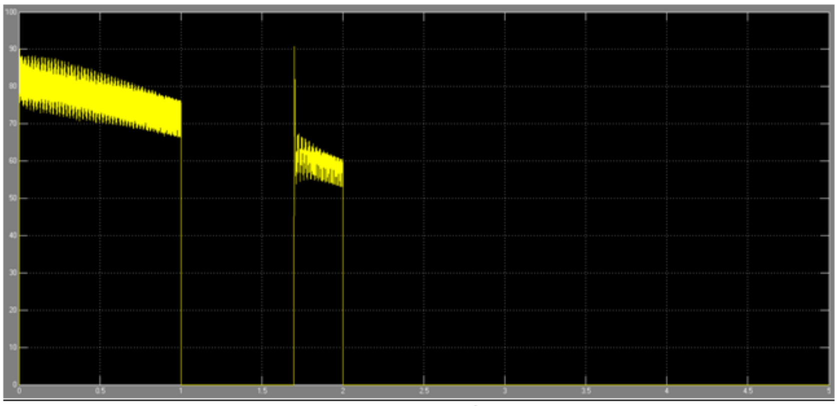

Figure 9:Voltage across IGBT

Model 2:Application of feedback mechanism to vary duty ratio using inductor as a filtering device.

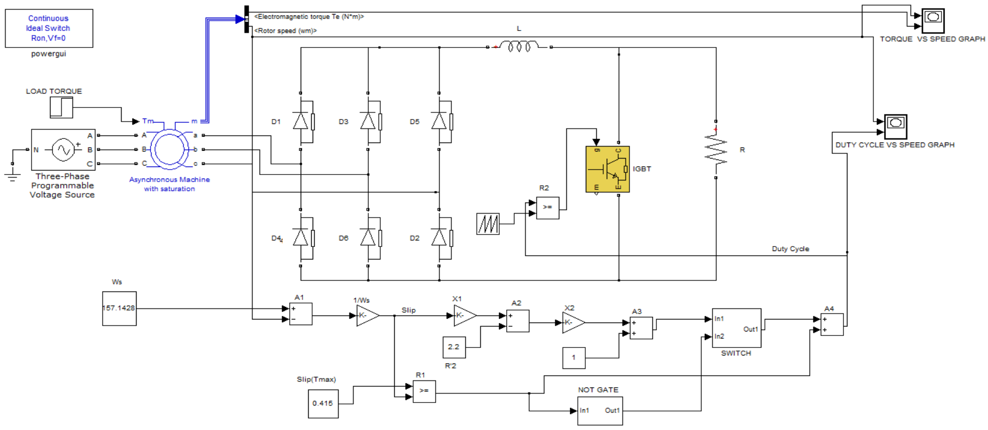

Figure 5: Model 2 for constant torque operationof wound rotor employing feedback control and inductor for rectification

The working of this model is similar to the model discussed above, only difference being that an inductor L has been used in the secondary rotor circuit for filtering purpose.

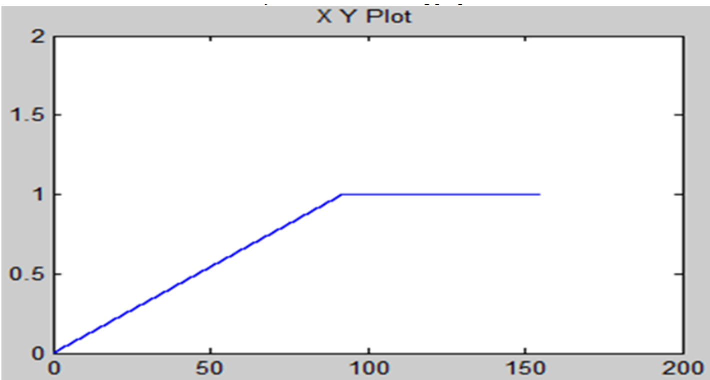

Figure 11:Torque V/S Speed Graph

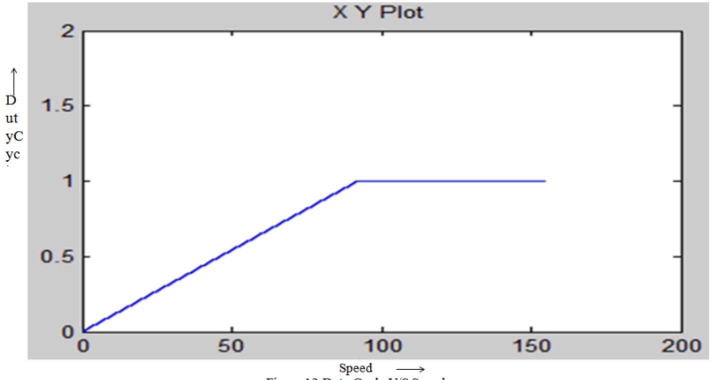

Figure 12:Duty Cycle V/S Speed

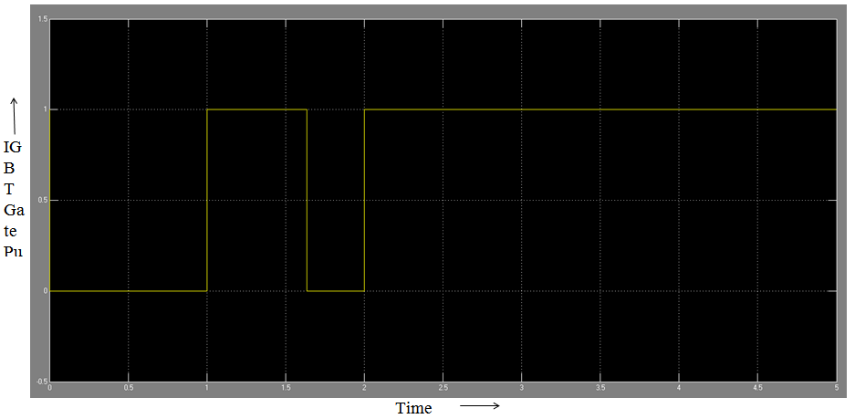

Figure 13: IGBT Gate Pulses

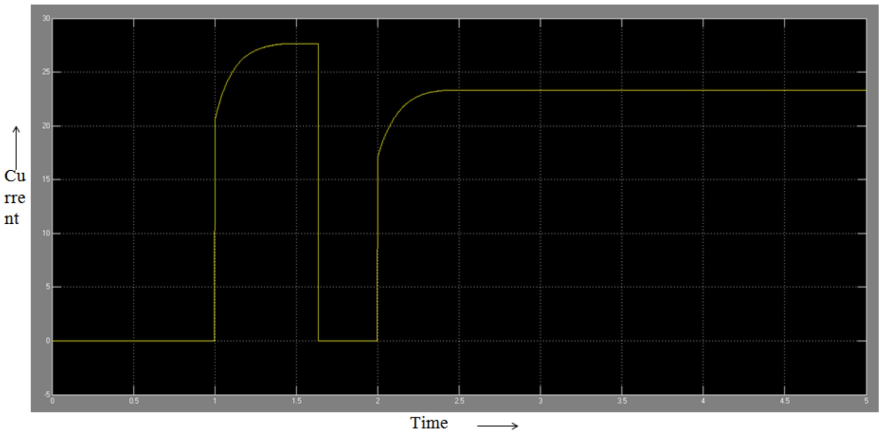

Figure 14: Current flowing through IGBT

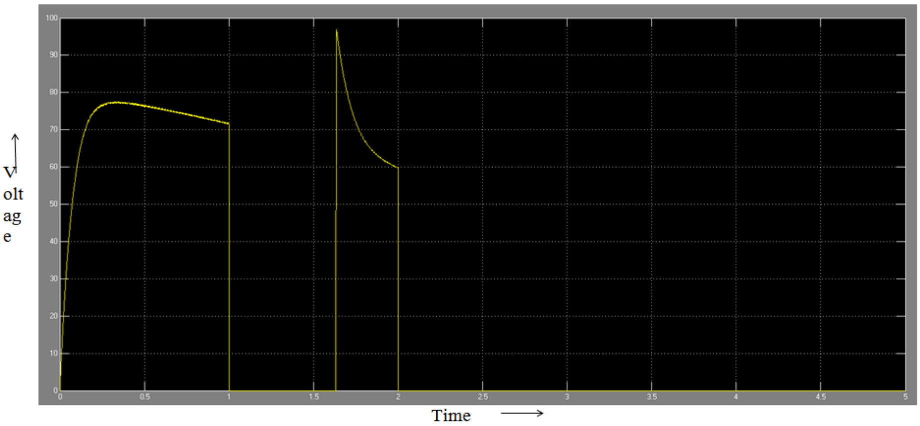

Figure 15: Voltage across IGBT

IV. Conclusion

An automatic controller to run the wound rotor induction motor at maximum torque from standstill slip(s=1) to slip (s_{Tmax}=0.415) has been successfully simulated using two circuits with help of MATLAB.The first model(Figure 2) and second model (Figure 3) employs a feedback mechanism to maintain maximum torque of motor.The second model uses an inductor in the secondary rotor circuit which acts a rectifier and reduces the harmonic distortions in torque curve which were prevalent in the first model.The graph between duty cycle and motor speed has been successfully plotted and observed to be linear which reaffirm that the motor has been operating at maximum torque.

Appendix-A

Specifications of the Wound Rotor Induction Motor [3]
V_L= 240 V
I_L= 5.72 A
Pole pairs= 2
Frequency= 50 Hz
P_{out}= 2.40 HP,Δ-Δ connection
R_s= 1.46 ohms
X_s= 2.56 ohms
X_m= 92 ohms
a=1.33
R_r'= 2.2 ohms
$X_{r'}$= 2.55 ohms

References

[1] Gopal K. Dubey, "Fundamentals of Electrical Drives", Narosa Publishing House Pvt. Ltd., 2001
[2] PS Bimbra, "Electrical Machinery", Khanna Publishers, 2010
[3] Control of Wound Rotor Induction Motor Using Thyristors in the Secondary Circuits,IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 32, NO. 2, MARCWAPRIL 1996
[4] Comparative Study of Speed Control of Induction Motor Using PI and Fuzzy Logic Controller, Anmol Aggarwal, J. N. Rai, Maulik Kandpal, IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 2 Ver. I (Mar – Apr. 2015), PP 43-52