A NOVEL METHOD FOR SPEED CONTROL OF SWITCHED RELUCTANCE MOTOR BY FUZZY PI CONTROLLER

D.SRI LAKSHMI,
ASSISTANT PROFESSOR
ANIL NEERUKONDA COLLEGE OF ENG
srilakshmi.eee@anits.edu.in

KVR SWATHI, (PHD)
ASSISTANT PROFESSOR,
ANIL NEERUKONDA COLLEGE OF ENG.
wathi.korukonda22@gmail.com

Abstract: This paper presents a speed control of switched reluctance motor using fuzzy PI controller. Depending on the non linear model of the SRM with negligible mutual inductances and the torque depending on the rotor position of the motor, the subsystems are modeled using MATLAB/SIMULINK. The fuzzy PI controller is robust to sudden changes in reference speed and shows its effect on transient response and decreases the steady state error. This paper provides a better control on the speed of the SRM when compared with conventional PI controller.

Keywords: switched reluctance motor, current control, fuzzy PI controller

I. INTRODUCTION

Switched reluctance motor is the simplest of all electrical machines. Only the stator has windings. The rotor contains no conductors or permanent magnets. It consists simply of steel laminations stacked onto a shaft. It is because of this simple mechanical construction that SRM is of low cost, which in turn has motivated a large amount of research on SRMs in the last decade. In speed control of SRM, it consists of switched reluctance motor, converter and a controller.

II. MATHEMATICAL REPRESENTATION OF SRM PHASE

The equivalent circuit for the SRM can be derived neglecting the mutual inductance between the phases a. The applied voltage to a phase is equal to the sum of the resistive voltage drop and the rate of the flux linkages and is given by

\[ U_k = R_k i_k + d\phi_k(\theta, i_k)/dt \quad K=1,2,\ldots,p \] (1)

Where \( \phi_k \) is the flux linkage, \( U_k \) is the terminal voltage of phase k, \( R_k \) is the phase winding resistance, \( i_k \) is the phase current and \( \theta \) is the rotor angle.

Flux linkage \( s \) depends upon the inductance and electric current in electromagnetic circuit of a SRM phase and given by

\[ \phi_k - \phi_k(\theta, i_k) = L_k(\theta, i_k) i_k \quad K=1,2,\ldots,p \] (2)

Where \( L_k \) is the inductance of the phase k, given in literature[1,2,3,4,5,6,7,8].

\[ L_k(\theta, i_k) = L_{k0} + \sum_{n=1}^{N_p} a_n \cos(N_p \theta + \pi) \quad n=0,1,2,\ldots,N_p \] (3)

Where \( N_p \) is the number of rotor poles. Now, if two first two terms are considered then the above equation becomes

\[ L_k(\theta, i_k) = L_{k0} + L_{k1} \cos(N_p \theta + \pi) \] (4)

Where

\[ L_{k0} = L_{k0}(i_k) + L_{k1}(i_k) \]

\[ L_{k1} = \frac{2}{L_{k0}(i_k) + L_{k1}(i_k)} \]

(5)

Where \( L_{k0}(i_k) \) is the aligned position inductance and \( L_{k1}(i_k) \) is the unaligned position inductance and is assumed to be constant.

The phase torque[3,4,8] is given by

\[ T_k = -\frac{N_p}{4} \sum_{n=1}^{N_p} a_n \cos(N_p \theta + \pi) \] (6)

The dynamic equation can be expressed as

\[ \omega = \frac{d\phi}{dt} \] (7)

and

\[ T_e = J \frac{d\omega}{dt} + D \frac{d\omega}{dt} + T_L \] (8)

Where \( T_e \) is electromagnetic torque, \( T_L \) is load torque, \( \omega \) is angular velocity, \( J \) and \( D \) are moment of inertia and coefficient of friction respectively.
III. DYNAMIC MODELLING OF THE SWITCHED RELUCTANCE MOTOR USING MATLAB/SIMULINK

On basis of nonlinear model of SRM, dynamic model of SRM for the speed controller is developed with the help of MATLAB/SIMULINK. The schematic diagram for the speed control of SRM is as shown in fig.:1:

The simulation model for the phase of the SRM is shown in fig.3. The inputs to the current calculation block is rotor position angle and phase current where output is phase current. Using equations (2), (3), (4), (5), we calculate the phase current by using MATLAB function compiler. The torque calculation block consists of phase current and rotor position angle as inputs with torque as output. The torque of each phase is obtained by using equations (6), (7), (8). The total torque is the sum of individual phase torques.

A. MOTOR PHASE WINDING BLOCK

Motor phase winding block is the important part of the whole system simulation. It shows the existing properties of SRM. In this, all three phases are assumed to be identical, therefore the modelling procedure of them are almost same, though have a little difference in their modulo block. Detailed implementation .The function of modulo block is to work out the angle of rotor position angle relative to reference zero angle in a electric cycle. For a 3-phase 6/4 SRM, the phase inductance has a periodicity of 90 degrees. Therefore, it is convenient to transform the rotor position angle coming from the mechanical equation to 90 degrees. Hence, this modulo is realized by virtue of rem function.

SWITCH RELATIONS OF 3-PHASEWINDINGS

<table>
<thead>
<tr>
<th>Position angle</th>
<th>switching on phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ~ 10</td>
<td>C, A</td>
</tr>
<tr>
<td>10 ~ 30</td>
<td>A</td>
</tr>
<tr>
<td>30 ~ 40</td>
<td>A, B</td>
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<tr>
<td>40 ~ 60</td>
<td>B</td>
</tr>
<tr>
<td>60 ~ 70</td>
<td>B, C</td>
</tr>
<tr>
<td>70 ~ 90</td>
<td>C</td>
</tr>
</tbody>
</table>

The simulation model for the phase of the SRM is shown in fig.3. The inputs to the current calculation block is rotor position angle and phase current where output is phase current. Using equations (2), (3), (4), (5), we calculate the phase current by using MATLAB function compiler. The torque calculation block consists of phase current and rotor position angle as inputs with torque as output. The torque of each phase is obtained by using equations (6), (7), (8). The total torque is the sum of individual phase torques.

B. CURRENT CONTROL BLOCK

Current control is achieved with current switching control of the converter. In this, the current error is computed from which the switching is generated depending on its relationship to the current breadth. The reference current $I_{ref}$ will be compared to the motor phase current $I$. It is assumed that the power devices in the converter are ideal, hence their voltage drops and switching times are neglected.
IV. SPEED CONTROLLER BLOCK

The fuzzy logic controller is robust to sudden changes in reference speed, but has a significant study on steady state error. The fuzzy logic controller reduces the steady state error. The inputs to fuzzy logic controller are Speed error and change in speed error.

The output variables are $K_p$ and $k_i$ of the PI controller. Hence the current is calculated using these values. Depending on the range of speed error and precision of regulating speed, we deal with the input variables and the Madani method is used and COA method of defuzzification is used. The linguistic variables of the input and output fuzzy regions are negative large (NL), negative medium (NM), negative small (NS), zero (ZE), positive small (PS), positive medium (PM), positive large (PL).

These rules are taken as follows. If error and change in error is negative then output is negative. If error and change in error is positive then output is positive. If error is negative and change in error is positive then output us negative.

The fuzzy rules for the fuzzy PI controller are as follows:

<table>
<thead>
<tr>
<th>$\Delta \omega_t$</th>
<th>NL</th>
<th>NM</th>
<th>NS</th>
<th>Z</th>
<th>PS</th>
<th>PM</th>
<th>PL</th>
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<tbody>
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<td>Z</td>
<td>PS</td>
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<tr>
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The fuzzy pi controller for the switched reluctance motor can be designed using fuzzy logic toolbox in MATLAB. The conventional PI controller is also designed using MATLAB/SIMULINK. The simulation results of speed for both conventional PI controller and fuzzy PI controller are obtained with load disturbance of 5N.m at 0.1 sec.

Fig. 6 simulation result of speed for conventional PI controller with reference speed of 1000RPM

Fig. 7 simulation result of speed for fuzzy PI controller with reference speed of 1000RPM

V. CONCLUSIONS

In this paper, the speed control for the switched reluctance motor using effective dynamic modelling of the SRM is given. This model consists of number of subsystems and hence can be modified easily. The fuzzy PI controller shows its effect on the transient state of the SRM and steady state error is reduced.

VI. APPENDIX

number of stator poles=6, number of rotor poles=4, number of phases=3, reference speed=1000RPM, DC link voltage=120V, $R=0.075\Omega$, $L_{min}=22e^{-3}$H, $a_1=4.95$, $a_2=-1.3$, $a_3=0.16$, $J=0.08$ kg.m$^2$, $D=0.0183$. 
VII. REFERENCES


VIII. ABOUT AUTHORS

First Author:

D. SRI LAKSHMI received her B.Tech degree from JNTU College of Engineering, Visakhapatnam, currently pursuing ME degree in ANITS College of Eng., Visakhapatnam, Andhra Pradesh, India. Areas of interest are control systems design, present working as assistant professor, Dept of EEE, ANITS.

Second Author:

KVR SWATHI received his B.E. degree from ANITS, India in 2005, his M.E. degree from Andhra University, India, and is currently pursuing his Ph.D. degree in GITAM University, Visakhapatnam, India on Bearingless SRM. Her areas of interest include power electronics control and design and advanced control systems. Presently she is with ANITS college of Engineering as assistant professor.