COMPARISON OF DIFFERENT CONTROL METHODS IN SWITCHED RELUCTANCE DRIVE SYSTEM

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Abstract— Different Control methods used in Switched Reluctance motor is compared in this paper, mainly three controlling methods are used to reduce the torque ripple at different levels, increased output torque power, maximum efficiency even in different speed range. The controlling methods used are i) Current Chopping Control (CCC) ii) Torque Sharing Function Control (TSF) iii) Direct instantaneous Torque Control (DITC). Each Controlling methods have a specific salient features for example high output torque compared to TSF and DITC is obtained by using Current Chopping Control (CCC). For high speed operation TSF can reduce the torque ripple but for low speed operation it fails. DITC can reduce the torque ripples even at low speed operation. In this paper, in order to understand its inherent characteristics the Controlling methods were experimented and the performance of those method is compared based on the torque ripple and the output torque power. Simulation result shows the best methodology to be used in SR motor drive system at different speed ranges.

Keywords- Direct Torque Control, Torque Sharing Function, Current Chopping Control.

I. INTRODUCTION

A simple motor robust in construction, which can be used in high speed as well as low speed operation as per the requirements is the Switched Reluctance Motor (SRM). Even this motor works efficiently in high temperature conditions. It is capable of controlling the faults, so fault tolerance is high in SRM and also a low cost machine which has a wide range application in mechatronics. SR motors produce high torque ripples than the conventional one. To reduce the torque ripple, many controlling technique have been used in recent years, such as Chopping Current Control (CCC), Torque Sharing Function (TSF) and Direct Instantaneous Torque Control (DITC).

In TSF Control method the switching of the one phase winding is regulated, reference torque value of the previous state act as the present reference value under certain current limit. For minimum torque ripple condition one phase winding is not suitable [8], hence the two phase winding regulation mode with TSF method provides minimum torque. DITC controlling method is explained in detailed [10] and it is optimized in [11], here switching modes are used for every sampling time, in DITC one or more switching modes can be used instead of using only one fixed switching mode. In CCC control method, initial reference value is given for the first step and then the difference between the reference current and the feedback current is given as input for the further procedure. According to the switching table and current values, also based on the switching rule, the switching signals are generated for the asymmetric convertor. For the TSF control initially the reference torque is given, then it is divided into individual torque which is used a reference for each phase with respect to rotor position and then the above method used in CCC control is employed for generation of switching signals. Difference of reference current and feedback current is calculated in both online and offline in this controlling method. For the DICT, the reference signals are generated as like CCC control method, the only difference in this control is the switching signals for the asymmetric convertor is based on torque error and its hysteresis switching table.
The output characteristics for the three methodologies differ at different speed ranges. In this paper the controlling methods performance is analyzed based on the torque ripples and maximum output torque. Simulation result for each methodology at different speed values is shown.

II. FEATURES OF SRM

A rotating electric machine in which the stator and rotor has salient poles. Stator winding consists of windings and rotor is made of lamination in order to reduce eddy current loss. Fig 1 shows the diagram of 4/2 two phase SR Motor Rotor position. The gap is to eliminate the dead zone and excitation of the motor is done sequence of current pulses. Fig 2 shows the phase inductance and current profile, it is triangular shaped, maximum inductance when aligned and minimum inductance while unaligned.

The individual phase A and Phase B are shifted electrically by 180degree relative to each other. When the respective phase is powered then it is known as Dwell angle $\theta_{Dwell}$. The turn on angle $\theta_{ON}$ and turn off angle $\theta_{OFF}$ values determines the Dwell angle. Depending upon the Voltage applied to the stator phase, torque is created by the motor in the direction of the increasing inductance value. When the phase is energized by the minimum inductance value then rotor will moves to the forth coming maximum inductance value.

III. CONTROL METHODOLOGY

The detailed explanation of the conventional control methods such as CCC, TSF, DICT are explained as follows

A. CURRENT CHOPPING CONTROL

A simple method used in SRM is CC Control, which consists of power convertor and current hysteresis controller is shown in Fig 3. In Fig 4, the detailed explanation of the controlling method is
shown in the block here the flux hysteresis controller and torque hysteresis controller depends upon the look up table values and certain rules.

Fig 3: Simple Block of CCC in SRM

Fig 4: Current Chopping Control for a SR motor

Fig 5: Phase inductance and Current Curves for CCC

The above graph is shown for a three phase inductance and current.
Region 1 is between $\theta_{\text{on},c}$ and $\theta_{\text{off},b}$.
Region 2 is between $\theta_{\text{off},b}$ and $\theta_{\text{on},a}$.
Region 3 is between $\theta_{on,a}$ and $\theta_{off,c}$

The phase current in the hysteresis band is limited by turning on and off by the switches.

1) If the phase current above the hysteresis band, switches will be OFF and negative voltage is given as input to the phase winding results in phase current decrease.

2) If the phase current below the hysteresis band, switches will be ON and positive voltage is given as input to the phase winding results in phase current increase.

B. TORQUE SHARING FUNCTION CONTROL

TSF control is simple as well as powerful to reduce the amount of torque ripples. Here the premeasured nonlinear torque informations and torque sharing reference curves are used for constant torque production.

C. DIRECT INSTANTANEOUS TORQUE CONTROL

A DITC system consists of hysteresis controller, a logical switching signals controller, power convertor and a torque calculation unit. The major key element is the hysteresis controller which is digital, it generates the switching signals based on difference of the reference torque and motor torque error. The power convertor is driven by the switching signals in order to control the output torque in SR Motor. Because of this error between the reference torque and actual motor torque can be limited in hysteresis band. In Fig 9 the curves of inductance, current and torque is shown.
Fig 9 Phase inductance, current and torque curves for DITC

IV. SIMULATION RESULTS

To verify the feasibility of the proposed strategy, simulations are carried out.

Fig.10. Proposed system Simulink diagram

Fig.11. PWM Pulses to the proposed converter
Fig. 12. Flux, torque and current waveform of the SR motor

TORQUE IMPROVEMENT

- EXISTING SYSTEM: 6.2 NM
- PROPOSED SYSTEM: 7 NM

Fig. 13. Torque improvement from existing topology

Fig. 14. Speed waveform of the SR motor using PI controller

V. CONCLUSIONS

In this paper three controlling methods used in Switched Reluctance Motors are explained in detailed. Comparison based on torque ripples and amount of output power obtained at different speed
range of values shows the optimal method for particular usage of the SR motor like DITC method for low speed operation, CCC method for medium range of operation and the TSF for high speed of operation. Simulation results for the three controlling method clearly distinguished the speed ranges.

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