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Performance analysis of Switch Reluctance Motor Used as a Variable Speed Drive

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***Abstract*: -- Now day's electric motors are used in a wide range of industrial applications. What most applications have in common is the need for their motor to be as efficient as possible and to have the longest possible life while simultaneously not increasing maintenance demands or failures. The switched reluctance motor represents one of the oldest electric motor designs around. A variation on the conventional reluctance machine has been developed and is known as the "switched reluctance" machine. This development is partly due to the recent demand for variable speed drives and partly as a result of the development of power electronic drives. The name "switched reluctance", describes the two features of the machine configuration: (a), switched, the machine must be operated in a continuous switching mode, which is the main reason for the machine development occurred, only after good power semiconductors became available; (b), reluctance, it is the true reluctance machine in the sense that both rotor and stator have variable reluctance magnetic circuits or more properly, it is a doubly salient machine.. In this paper with the help of various techniques is used as a variable speed. The main problem is higher torque ripple and acoustic noise as compared to the conventional motor. To reduce torque ripple direct instantaneous torque control method is used. Direct instantaneous torque control is the fast and accurate response. This method can generate smooth torque as well as low losses as compared indirect instantaneous torque control method. This method gives the reference value of phase torque from the desired torque with the help of torque sharing function. Hysteresis controller is used for switching signals generated from reference phase torque and estimates phase torque.**

***Keywords:* - Switch reluctance motor, DITC, TSF.**

I. INTRODUCTION

The acceptance of SRM by the production for a variable speed application is just slow against their simple construction, powerful and large development over last decades. The main deficiency of SRM are the torque distortion and hearing noise. The torque distortion and hearing noise are not needed detrimental for the system in all cases, but it depends on the usance [1]. There are two methods for minimizing the torque ripple, one method is to enhance the machine design of motor while other is to need experience electronic control technique. The machine maker are design a machine by changing stator and the rotor pole construction to reduce a torque ripple. The electronic approach is minimizing the control factors which are supply voltage, turn-on angle, turn-off angle. This paper present DITC method for minimizing the torque distortion in the SRM. DITC method is Torque control technique which directly control motor terminal. In DITC methods all drawbacks of IITC method is reduced. The main benefit of DITC is counteracting the torque instantaneously with fast dynamic response. DITC method with TSF is used to impress the reference torque from the individual phases. There are distinct technique of TSF such as linear, sinusoidal, cubic and exponential torque sharing function. Instead of that this paper used sinusoidal TSF. Hysteresis controller get the switching sign to the power converter.

Torque formulation in SRM: The torque formulate by one phase at any rotor location is

$$T = \left[\frac{\partial W'}{\partial \theta}\right] i = \text{Const} \qquad (1)$$

$$\text{Since} W' = \text{Co} - \text{energy} = \tfrac{1}{2} F\phi = \tfrac{1}{2} NI\phi \qquad (2)$$

Equation (1) and (2) shows electrical power which is combination of stored magnetic energy (½L* i^2) and partly to provide mechanical output power (i^2/ 2 x dL /dΘ x ω), the latter being associated with the rotational e.m.f. in the stator circuit. Neglecting saturation non-linearity

$$L = \text{Inductance} = N\,\phi / I \qquad (3)$$

$$T = \tfrac{1}{2}\, i^2 dL/d\theta \qquad (4)$$

This mathematical statement shows that the developed torque is directly proportional to square of current and direction of dL/dθ.

Equation shows phase winding inductance in Fourier series as

$$L(\theta) = Lo + \sum_{n=1}^{N} [Ln \cos n(Nr\theta - \varphi 0)] \qquad (5)$$

$$\begin{aligned} L(\theta) = Lo &+ (L1 + L3)[1 - \cos(Nr\theta - \varphi 0)] \\ &+ L2[\cos 2(Nr\theta - \varphi 0) - 1] \\ &+ L3[\cos 2(Nr\theta - \varphi 0) - 1] \end{aligned} \qquad (6)$$

Where L0=L min, L min is the minimum phase winding inductance; $L1 = \frac{Lmax - Lmin}{2}$, Lmax is the maximum phase winding inductance;

L2=coefficients of absolute stator pole width, L3= coefficients relative pole width of rotor

$$U_k = R_k i_k + \frac{d\varphi k}{dt} \qquad (7)$$

$$Tek = \frac{d}{d\theta}\int_0^i \varphi k \, dik \qquad (8)$$

$$Te = \sum_{k=1}^{m} Tek \qquad (9)$$

$$T = Te - TL = J\frac{dw}{dt} \qquad (10)$$

Where, VK = Voltage, Rk= Resistance, ik= current, ?k=flux linkage of phase winding respectively, ?= Rotor position angle; ? = rotational velocity, Te k= Electromagnetic torque of phase winding, Te= electromagnetic torque of SRM, m = number of phase, TL = load angular force; D = coefficient; inertia of rotor and load of SRM.

$$T = Te - TL = J\frac{dw}{dt} + Dw \qquad (11)$$

$$\frac{dw}{dt} = \frac{1}{J}[Te - Dw - TL] \qquad (12)$$

.

$$\theta = \frac{dw}{dt} \qquad (13)$$

Variation in rotor position with respect to time results in angular speed Hence θ is associated with w as the function of time.

II.BLOCK DIAGRAM OF DITC METHOD:

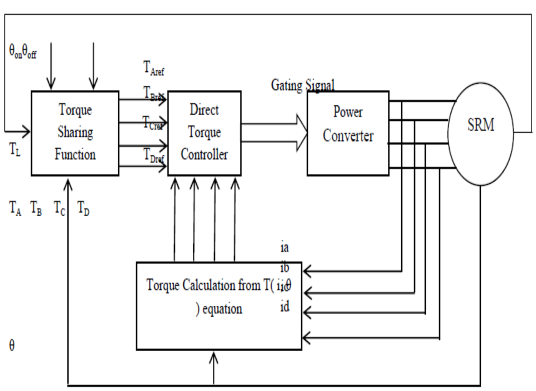


fig1. DITC method

The block diagram of the DITC method is shown in fig. The relating torque and the real torque are given to a torque hysteresis controller which output expanding or declining torque signal.

The magnitude of the reference phase torques can be calculated using the TSFs[3]. The phase torques is calculated from the measured phase currents and rotor region using the torque. The hysteresis controller outputs three discrete voltage levels + Vdc, 0, - Vdc will be applied to the motor.

The non-linear instantaneous torque equation becomes

$$T_{e,j} \approx \frac{\partial\lambda(\theta,i)}{\partial\theta}\int_0^i i \, di \approx \frac{\partial\lambda(\theta,i)}{\partial\theta} i \qquad (14)$$

Thus, the instantaneous torque of the saturated SRM can be found from the product of the flux linkage derivative (with respect to rotor position) and the phase current[4], as shown in above equation.

The phase voltage equation of SRM is given by,

$$V = Ri + \frac{\partial\lambda(\theta,i)}{\partial t}$$

$$V = Ri + \frac{\partial\lambda}{\partial i}\frac{\partial i}{\partial t} + \frac{\partial\lambda}{\partial\theta}\frac{\partial\theta}{\partial t}$$

$$V = Ri + I(i,\theta)\frac{\partial i}{\partial t} + \frac{\partial\lambda}{\partial\theta} w \qquad (15)$$

Resistive drop is negligible and current is considered constant, then voltage equation will be

$$V \approx \frac{\partial\lambda}{\partial\theta} w \qquad (16)$$

Consequently, the instantaneous phase torque equation of SRM can be simplified to

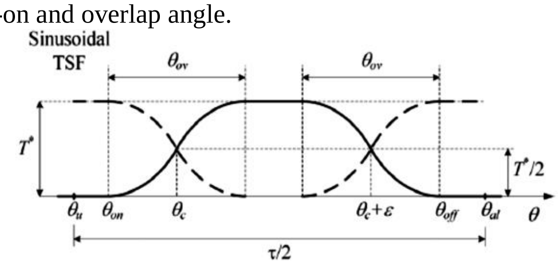
$$T = \frac{\partial\lambda}{\partial\theta} i \approx \frac{i}{w} V \qquad (17)$$

The rotor speed and the phase current are assumed constant during the control cycle.

As a result, the torque expression has been linearized and the phase voltage V becomes an effective control variable for the DITC.

III. TORQUE SHARING FUNCTION:-

The suitable electronics way for minimizing torque ripple is to coordinate the torque production of all separate phases. So total torque can track a reference value generated by a position of rotor [1].Sinusoidal torque sharing function is used in this paper. The sinusoidal TSFs means that the torque produced by the phases, during phase commutation, changes with the rotor region in terms of the sinusoidal functions[10]. It is only the function of turn-on, turn-off and overlapping angles. However, changes in number of stator and rotor teeth will variation in turn-on and overlap angle.



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For 8/6 SRM , the inductance increasing and decreasing period for each phase will be π/6 and conduction angle to be π/8. So the overlapping angle for each phase is π/24. The sinusoidal torque sharing function for phase a in a rotor period can be given as

$$\mathrm{Fact}_2(\theta) = \begin{cases} \frac{1}{2} - \frac{1}{2}\cos 24(\theta - \theta_{onj}) & \text{for } \theta_{onj} \le \theta < \left(\theta_{onj} + \frac{\pi}{24}\right) \\ 1 & \text{for } \left(\theta_{onj} + \frac{\pi}{24}\right) \le \theta < \left(\theta_{offj} + \frac{\pi}{24}\right) \\ \frac{1}{2} + \frac{1}{2}\cos 24\left(\theta - \theta_{offj} - \frac{\pi}{24}\right) & \text{for } \left(\theta_{offj} - \frac{\pi}{24}\right) \le \theta < \theta_{offj} \\ 0 & \text{otherwise} \end{cases}$$

IV. RESULT

In this paper DITC method is used and simulation in Matlab for a 4 phase SRM. Direct ITC method gives fast response as well as small data required. This method improves torque ripple factor. Fig.3 shows the torque distortion factor without DITC and with DITC method. Torque distribution factor from the turn-on and overlap angles can be calculated. Hence TSF is beneficial to fulfilling the best torque ripple minimization.

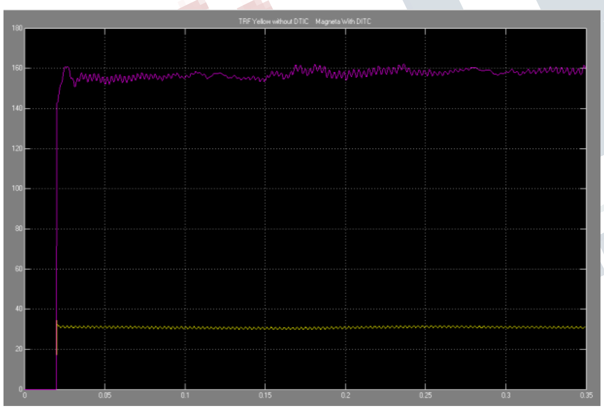

Fig.3 Torque generate by DITC method

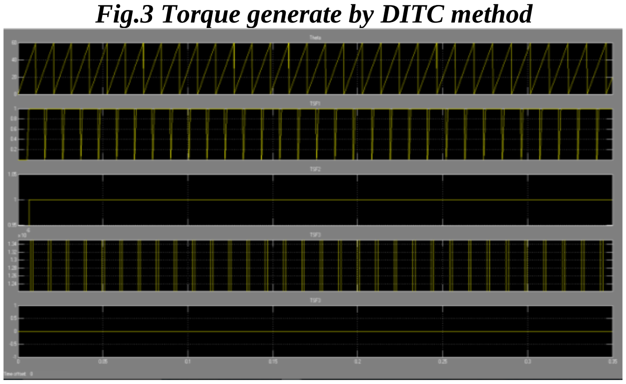

Fig.4 shows the TSF waveform one phase

Due to that TSF torque ripple minimize and smooth torque is given.

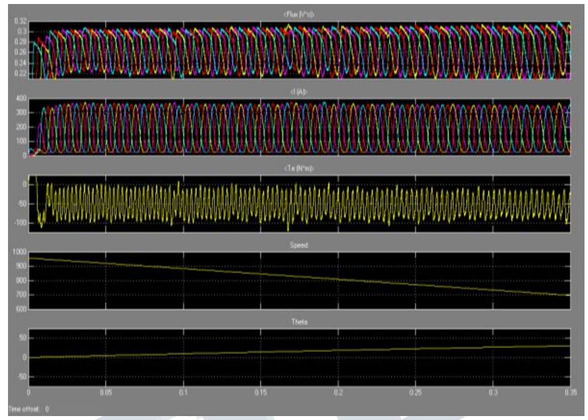

Fig. shows a flux, current, torque and speed waveforms of 8/6 switch reluctance motor. The torque distortion factor can be minimizing by DITC method. With the help of TSF and hysteresis controller gives the output of SRM is run at variable speed.

V. CONCLUSION

The torque distortion in SRM is not necessarily minimizes but depends on application. The distortion can be reduced for a variable speed application but an increases complications and cost of controller. The considerable survey of the available torque ripple minimizing methods should be both design and control point of view. The recent approaches of torque distrotion minimization smooth torque over a wide range are DITC method. Although torque distortion is increases with increase in speed. This new method of DITC is highly desirable for application where speed range varies. With DITC TSF is used. TSF are good selection of torque distortion minimization. This paper uses Sinusoidal TSF for minimizes torque ripple. It is beneficial to increases performance of SRM.

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