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DTC of Switched Reluctance Motor Drive Using Simplified Torque Equation

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ABSTRACT: Due to double saliency structure of Switched Reluctance Motor (SRM) torque ripple is high, which causes vibration and noise. The torque ripple can be minimized by a novel control technique called Direct Torque Control (DTC). In DTC technique, torque is controlled directly through control of magnitude of the flux and change in speed of the stator flux vector. The flux and torque are maintained within set hysteresis bands. When the design specifications of the motor are not disclosed by the manufacturer, the torque is computed by Simplified Torque Equation. The torque ripple minimization of SRM drive with DTC is analyzed by computing torque with Simplified Torque Equation.

KEYWORDS: Direct Toque Control, Simplified Torque Equation, Torque Ripple

I.INTRODUCTION

The applications of SRM drive have increased in recent years because of advantages such as simple construction and low manufacturing cost [1, 2]. The main drawback of the motor is that, because of non-linear magnetic characteristics high torque ripple is high, which causes noise and vibrations [1, 2].The torque ripple minimization using DTC technique has been described in [3]. This scheme used the concept of a short flux pattern that links two separate poles of the stator. The major disadvantage of this scheme is that a new motor winding topology is required. This method is both expensive and inconvenient. In [4,5] a novel DTC technique is applied to 3-phase 6/4 SRM in which the difference between conventional DTC applied to ac machines and the new DTC proposed to SRM has been elaborately discussed. The DTC technique has been analyzed in detail through simulations in [6, 7]. The low speed and high speed operation of the DTC based 6/4 SRM drive is analyzed through simulations in [8]. DTC of 4 phase SRM is analyzed through simulations in [9].

In order to control the torque, DTC scheme requires torque feedback. The design specifications of SRM are not available or not disclosed by the manufacturer. Under such circumstances it is difficult to compute torque as a function of current and position. Alternately, the torque can be computed by Simplified Torque Equation [5].This paper analyses the performance of DTC based 4 phase 8/6 SRM in which torque is computed by Simplified Torque Equation

II. PRINCIPLE OF DTC

The approximate equation for torque developed by the SRM [5] is given by

$$T \approx i\frac{\partial \psi(\theta,i)}{\partial \theta} \qquad (1)$$

where $\psi(\theta,i)$ is phase flux-linkage as a function of rotor position θ and stator current i

As unipolar polar converters are used for SRM drives, the sign of the torque is directly related to the sign of $\frac{\partial \psi}{\partial \theta}$.

A positive torque is developed when the change in stator flux increases with respect to the rotor position and to produce a negative torque the change in stator flux should decrease with respect to the rotor movement. When $\frac{\partial \psi}{\partial \theta}$ is positive it may be defined as “flux acceleration” and when it is negative it may be defined as “flux deceleration” [5].

The DTC technique [4, 5] for SRM is defined as follows.

(i)The stator flux-linkage vector of the motor is kept at constant amplitude (within set hysteresis band)

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(ii)Torque is controlled by accelerating or decelerating the stator flux vector.
The objective (i) is achieved by selecting an appropriate Space voltage vector. The stator flux variation will have the same directional variation as the voltage vector and a change in amplitude is proportional to the magnitude of the voltage and the time interval of application. The objective (ii) is also achieved similarly to the conventional AC motor by DTC, because the torque is increased or decreased by acceleration or deceleration of the stator flux vector relative to the rotor movement [5].

Among different converters available for SRM drives, Asymmetrical converter is popularly used. When both the switches are turned ON, the state is defined as 'magnetizing' (state 1) as shown in Fig.1. When one switch is turned ON and other is turned OFF, the state is defined as 'freewheeling' (state 0). When both the switches are turned OFF, the state is defined as 'demagnetizing' (state -1). The 4 phase Asymmetrical converter can have a total of 81 possible space voltage vectors. However, in order to apply DTC to SRM, eight equal amplitude voltage vectors that are separated by π/4 radians, are sufficient. The space voltage vector states are shown in Fig. 2. These voltage state vectors are defined to lie in the center of eight sectors or zones where each zone has a width of π/4 radians.

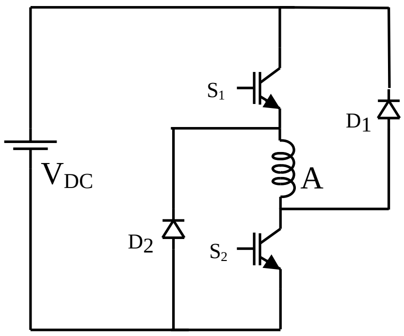

Fig. 1 Asymmetrical Converter

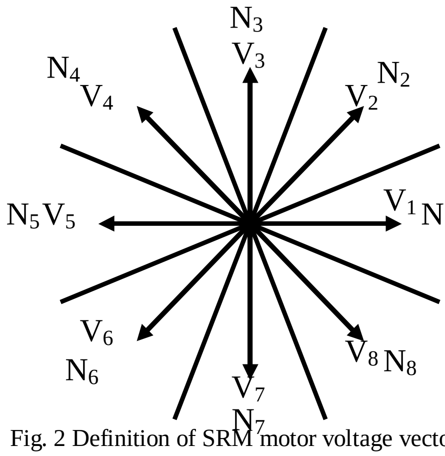

Fig. 2 Definition of SRM motor voltage vectors for DTC

III. SIMULATION AND ANALYSIS OF DTC USING SIMPLIFIED TORQUE EQUATION

When the design specifications of the SRM are not disclosed by the manufacturer, the instantaneous torque can be computed by simplified equation shown below [5]

$$T = p(\psi_\alpha i_\beta - \psi_\beta i_\alpha) \qquad (2)$$

where p is the number of pole pairs, i_α & i_β are respective currents in α and β axes and ψ_α & ψ_β are respective α and β components of flux-linkages in the stationary reference frame.

The simulation model of the 4 phase 8/6 SRM with DTC is shown in Fig. 3. The model consists of electrical system, mechanical system, position sensing block, Asymmetrical converter, torque computation block and DTC block. The reference flux is set at 0.25 Wb and flux hysteresis band is set at 0.02 Wb. The reference torque is set at 8 Nm and the torque hysteresis band is set at 0.40 Nm.

The DTC based SRM drive is analyzed for a Fan load of 8 Nm and at a reference speed of 800 rpm. Fig. 4 shows the simulation waveforms of the drive with DTC technique. The magnitude of the stator flux vector is shown in Fig. 4 (a). The flux is maintained at the reference value of 0.25 Wb by following a hysteresis band of 0.020 Wb. Fig. 4 (b) shows the total torque developed by the motor. It is observed that the torque is maintained within the hysteresis band of 0.4 Nm. Fig. 4 (c) shows the variation of ψ_α with ψ_β. It can be seen that the trajectory of fluxes between α and β axes is circular in nature.

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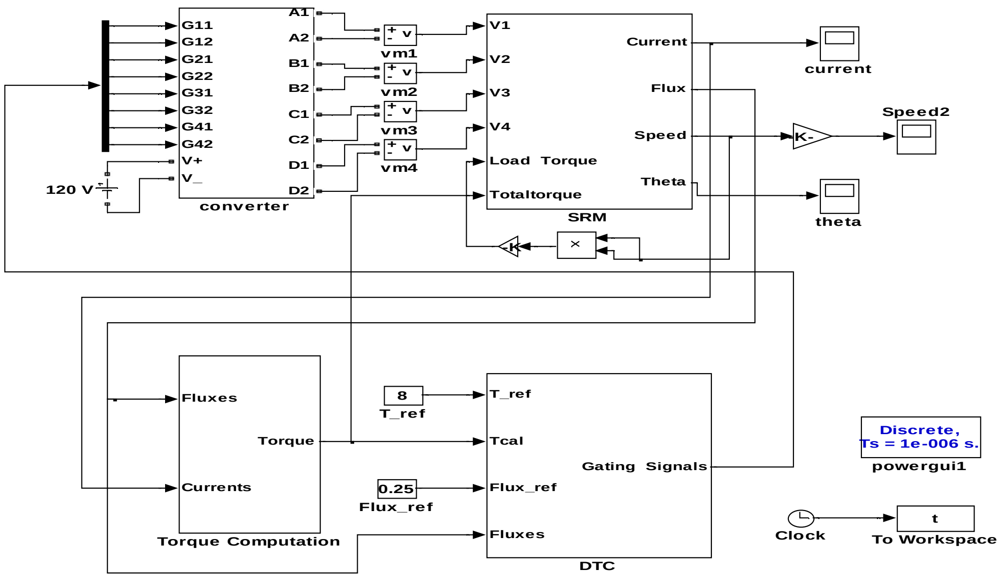
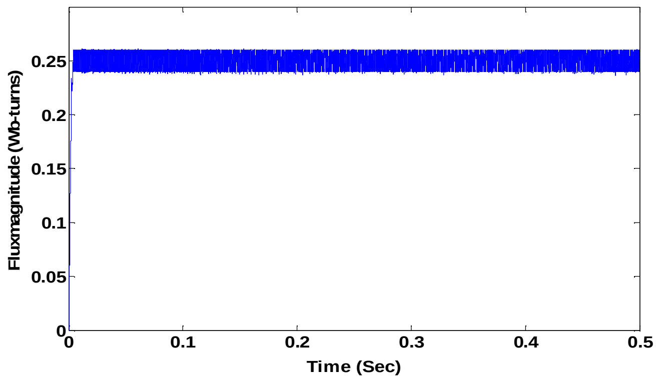
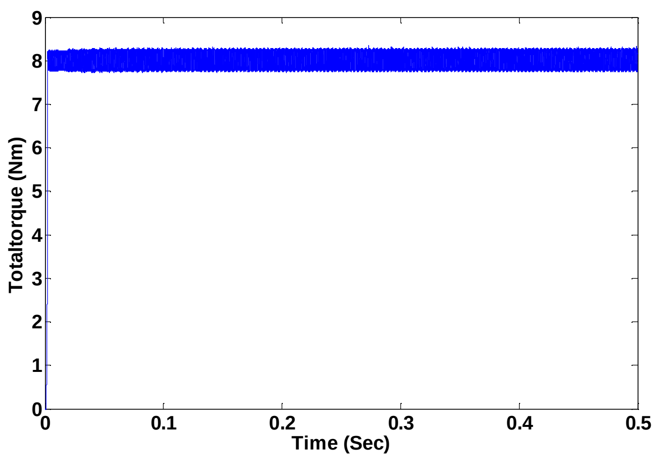


Fig. 3 Simulation diagram of SRM drive with DTC



(a)



(b)

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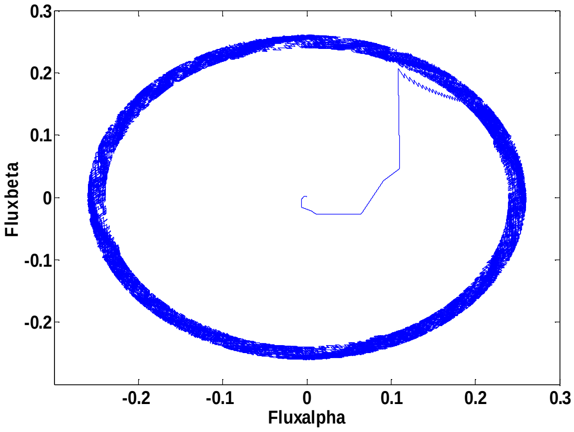

(c)

Fig. 4 (a) Flux magnitude (b) Total torque (c) Flux vector trajectory

IV.CONCLUSION

In Direct Torque Control technique, the torque is controlled directly by controlling the magnitude of the flux-linkage and the change in speed of the stator flux vector. If the specifications of the design are not disclosed by the manufacturer, the torque can be computed by Simplified Torque Equation. It is observed that torque and flux are maintained at their set limits with DTC technique in which torque is computed by Simplified Torque Equation.

REFERENCES

1. T. J. E. Miller, "*Switched Reluctance Motors and their Control*", Magna Physics &Oxford, 1993.
2. Rik De Doncker, Duco W.J.Pulle and Andre Veltman, "*Advanced Electrical Drives*: Analysis, Modeling and Control," Springer, 2011
3. P. Jinupun and P. C. K. Luk, "Direct torque control for sensorless switched reluctance motor drives," in *Proc. 7th Int. Conf. Power Electronics & Variable Speed Drives*, 1998, pp. 329–334.
4. D. Cheok and P. H. Hoon, "A new torque control method for switched reluctance motor drives," in 26th Annual Conf. IEEE Industrial Electronics Society, IECON 2000, Oct. 2000, pp.387–392.
5. A. D. Cheok and Y. Fukuda, "A new torque and flux control method for switched reluctance motor drives," *IEEE Trans. Power Electronics*, vol. 17, no. 4, pp. 543–557, Jul. 2002.
6. H. J. Guo, "Considerations of direct torque control for switched reluctance motors," in *Proc. IEEE Int. Symposium on Industrial Electronics, ISIE 2006*, Jul. 2006, pp.2321–2325.
7. Guiying Song, Zhida Li, Zhenghan Zhao and Xiang Wang, "Direct torque control of switched reluctance motors," *in Proc. IEEE Int. Conf. Electrical Machines and Systems, ICEMS 2008, Oct. 2008,* pp. 3389-3392.
8. R. Jeyabharath, P. Veena, and M. Rajaram, "A Novel DTC strategy of torque and flux control for switched reluctance motor drive," in *Proc. IEEE Int. Conf. Power Electronics, Drives and Energy Systems*, PEDES, December 2006, pp. 1–5.
9. B. H. Jeong, K. Y. Lee, J. D. Na, G. B. Cho and H. L. Baek , "Direct torque control for the 4-phase switched reluctance motor drives," in *Proc. IEEE Int. Conf. Electrical Machines and Systems*, ICEMS, September 2005, pp. 524-528.