CURRENT AND SPEED CONTROL OF THE SWITCHED RELUCTANCE MOTOR

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Summary The papers deals with the problem of the current and speed control of the switched reluctance motor (SRM) on the base of the proposed mathematical model of the SRM. The basic types of the controllers are described (proportional controller, PI-controller and controller with the on-line voltage calculation of the mathematical model) and the design of their parameters is proposed. Then the comparison of the simulation and the real drive experimental measurement results is presented.

1. INTRODUCTION

There are different types of the block schemes of the switched reluctance motor drives with the similar structure (see the references below). As a speed regulation control circuit scheme the SRM control circuit scheme can be described by cascade connection of the master speed controller and slave current closed loop directly controlling the power converter. However, the current closed loop phase angle of the SRM drive has to be controlled also. It is necessary for all AC motors. Concerning the DC motors, it is solved by the mechanical phase commutator. Accordingly, the structure of the SRM electric drive can be depicted by the scheme in Fig. 1:

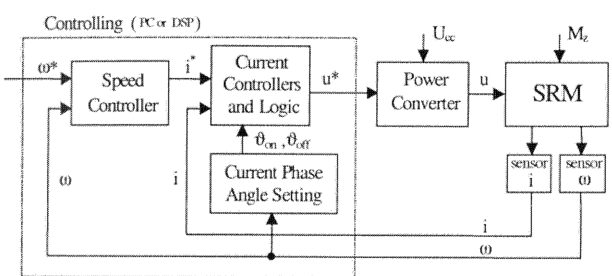

Fig. 1. SRM Drive Structure.

Principally the speed control does not depend so much on the type of controled motor. That is why the slave control loop is analysed at first.

2. CURRENT CONTROLLERS AND LOGIC BLOCK

Figure 2 shows one of the inside structure types of the current controllers and logic block (see Fig. 1). The scoring logic determines the motor-operated mode or reverse-current break mode on the base of required current (resp. torque). In consequence with it, the demand of the current magnitude is forwarded to one of the current regulators (switches S_1, S_2, S_3) so as the maximum possible torque is achieved in the actual rotor position.

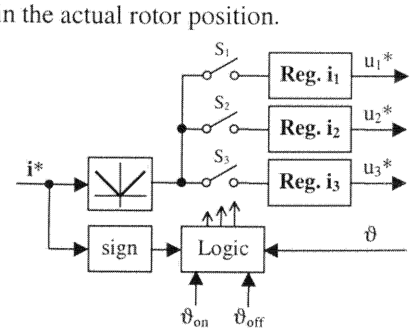

Fig. 2. Current controllers and logic block.

In the mode of very low speed, two switches can be switched on because the positive torque can arise from two phases. In contrast with it, in the mode of the high speed at most one switched is on, because the problem is on time field suppression. That is why there it starts to appear the "blank intervals" when no switch in on (each phase disconnect or suppressing). When the speed is rising, the blank intervals – period interval ratio is rising also. The problem of the on time field suppression determination (ϑ_{off}) is mean question of the SRM control especially for the great power motors.

3. CURRENT CONTROL

The current controllers (blocks **Reg. i_1**, **Reg. i_2**, **Reg. i_3** on Fig. 2) can be realised by all the types of the regulators (for example two-step control, proportional control, PI-control, fuzzy control, ...). Each of them has some advantages but also disadvantages. The on-line voltage calculation controller has been used because of the parameters of the available SRM. Another controllers were not suitable because of the computing requirements (two-step control, fuzzy control) or insufficient dynamic properties (P-control, PI-control).

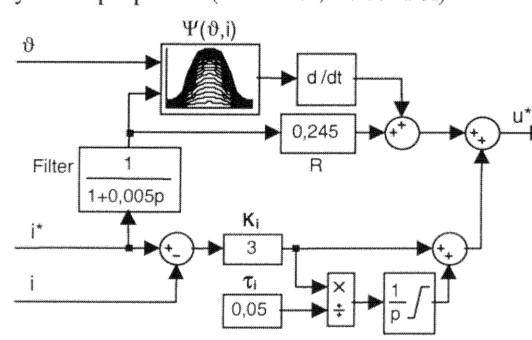

Fig. 3. Current PI-controller with voltage calculation.

In principle, the on-line voltage calculation controller is current PI-controller spread by the calculation of the voltage from the SRM mathematical model (see Fig. 3). The voltage is computed in accordance with the equation (1) where the knowledge of the magnetic flux function **Ψ(ϑ,i)** is supposed:

$$\mathbf{u}^* = \mathbf{R} \cdot \mathbf{i}^* + \frac{\mathbf{d}\Psi(\vartheta, \mathbf{i}^*)}{\mathbf{dt}} \qquad (1)$$

The value of **i*** is the required current in the phase, **R** is phase resistance and the last component of the equation correspond with the time change of the electromagnetic flux. This current regulator structure was satisfactorily verified by the measurement on the real machines (see below).

The required value of the current **i*** can be changed by jump but it does not correspond with the real current time response in the phase winding. That is why the scheme is completed by the block of the "filter". Concrete filter constant setting is based on the results of the simulations because it depends on lots of the parameters (parameters of the SRM, supply voltage, scheme of the power converter etc.).

The PI-controller parameters can be designed by common way (for example design with usage of the logarithmic frequency characteristics, see on Fig. 4). Important is to consider the change of the phase inductance (it means the time constant also) in accordance with the actual rotor position (eventually with the current magnitude).

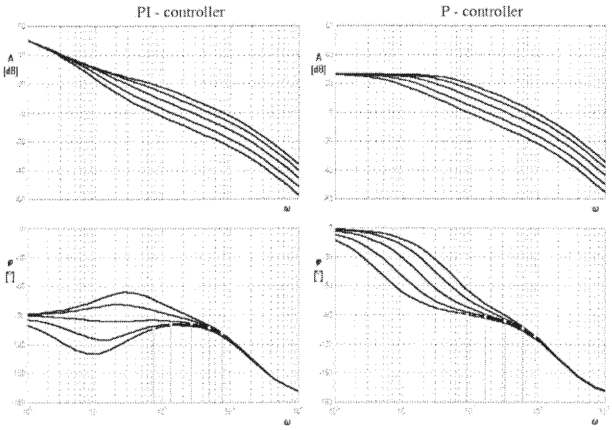

Fig. 4. Logarithmic frequency characteristics of the opened current loop.

The current and voltage time response in two basic modes are presented on Fig. 5. On the left side it is low speed mode when the controller hold the required value of the current. On the right side of figure it is the high speed mode when the current does not achieve the required value and the regulation converts to the rectangular control. The both modes time responses are measured on the real machine.

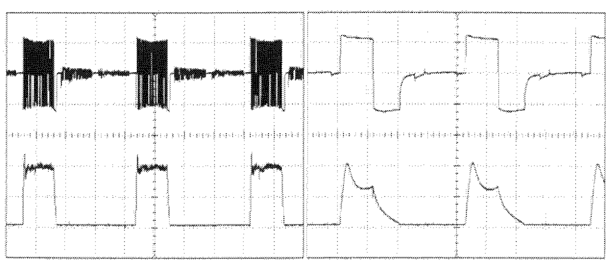

Fig. 5. Voltage and current time responses in one phase of the SRM. Left: low speed mode Right: high speed mode

The current PI-controller with the on-line voltage calculation required value of the current setting was sufficient either at the simulations or at real machine testing. That is why this way of the current control was chosen.

4. SPEED CONTROL

The speed control of the electrical machines is not so much influenced by the concrete type of the used motor.

If the controller cascade connection is used (see on Fig. 1), the design of the master speed control loop is similar as by the classic drives (for example with DC motors). The parameters of the speed regulator can be designed in consequence of the equivalent block diagram on the Fig. 6. It requires to solve the slave current control loop at first, as it was described in chapter 3.

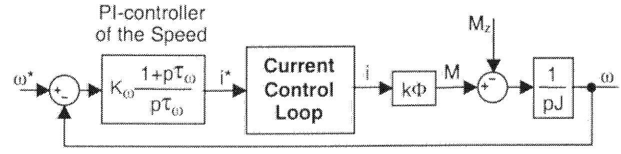

Fig. 6. Equivalent block diagram of the speed control loop.

Any of the common design method can be used for the concrete speed regulator parameters determination (for example the logarithmic frequency characteristics).

The Fig. 7 shows the simulation of the controlled start-up of the SRM set to the required mechanical speed with the constant load torque. In one moment, the step change of the load torque was assigned.

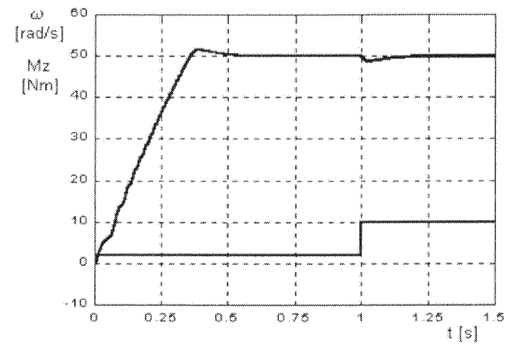

Fig. 7. Starting up of the SRM drive.

5. CONCLUSION

In accordance with the mechanical speed time response of the SRM drive, it is obvious that this type of speed controller is sufficient. The problem of the SRM speed control is analogic with the other types of the electrical motors. However, it requires the precise inside current control loop that is very different from the other types of the motors as was described in chapter 3.

Acknowledgement

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