ON-LINE STATOR RESISTANCE IDENTIFICATION USING IMPROVED FREQUENCY ANALYSIS

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Abstract: This paper describes method of synchronous motor parameter identification. This is improved frequency analysis (IFA). This method is mainly used for off-line identification parameter and is very resistant to noise. Because it is useful for this identification we use this method for on-line identification parameter. The following article describes both off-line method and on-line method and its changes.

Keywords: Permanent magnet synchronous motor, stator resistance, parameters identification.

1. INTRODUCTION

Synchronous motors are widely used in many industrial applications and in home electrical appliances, mainly due to its high efficiency. During the development of motors, the efficient control evolved and higher knowledge of controlled engine parameters was demanded. If parameters are accurate, we can achieve more efficient control with higher performance. There is however, the question how to identify these key parameters. These parameters can be determined analytically or by analysis of the magnetic field during the machine design. We have got two kinds of these methods of identification. These kinds are off-line methods [1] [2] and on-line methods [3][4]. The off-line methods are used for initial setting of controller parameters and during the identification the motor is at rest. On the other hand, the on-line methods identify parameters when the motor is in running mode. Then on-line methods are used for setting of controllers. The following text describes improved frequency analysis method (IFA)[6], which is mainly used for off-line identification, but in this article it is also used for on-line identification.

2. IMPROVED FREQUENCY ANALYSIS METHODS (IFA)

The method uses knowledge of synchronous motor schema in d-q coordinates [5] (Fig. 1.) and it is based on mutual correlation signals. If we want to identify stator resistance R_s and inductance L_d or inductance L_q we have to connect just signals which will not move with rotor.

As we can see from equivalent schema of synchronous motor, it can be divided into two parts. One associated with the d-coordinate and one associated with q-coordinate. In our case, we aim that the q-part does not affect the identification when we identify d-parameters and vice versa. And we want the permanent magnet flux Ψ_f not to affect the identification, too. We achieve these conditions so that the identification signal is always connected to only one part. As d-part and q-part are nearly identical, the identification of stator resistance R_s is similar (Fig.1).If supply voltage is set that U_q (U_d) is not harmonic signal of identify frequency and voltage U_d (U_q) is identification signal, mutual bond between d-parts and q-part disappears and the first order system is created $F(j\omega) = \frac{\frac{1}{R_s}}{\frac{L_x}{R_s}p+1}$. But when we identify from q-part, we have to use high frequency signal so as to keep $\omega = 0$ and therefore the cross coupling equals to zero.

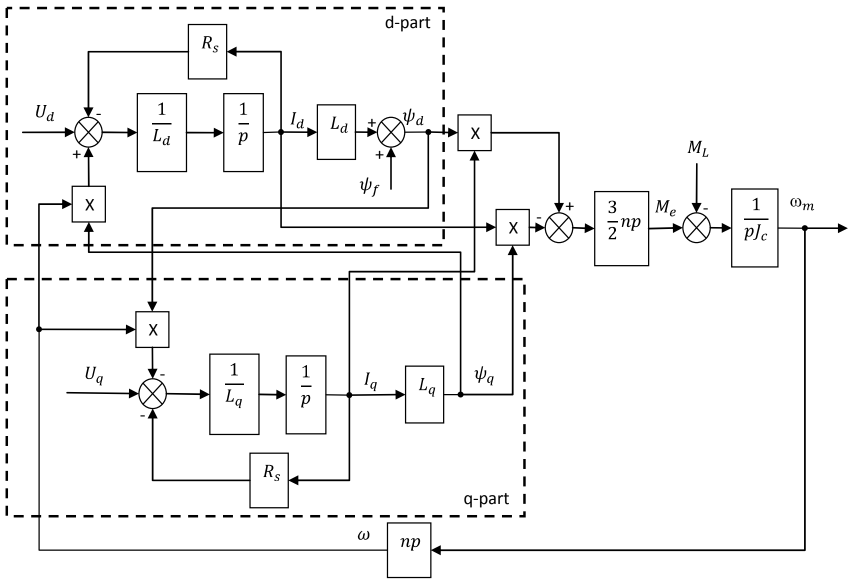

Fig 1: Synchronous motor schema

We know that the input signal U_d (U_q) is

$$u(t) = Asin(\omega t) \tag{2.1}$$

The following signal is the output, after stabilization of the transitional process

$$y(t) = Bsin(\omega t + \varphi) \tag{2.2}$$

Where B is amplitude of output signal

$$B = A|G(j\omega)| \tag{2.3}$$

$$\varphi = argG(j\omega) \tag{2.4}$$

After substitution we get the output equation, where all the variables are known

$$y(t) = A|G(j\omega)|sin\big(\omega t + argG(j\omega)\big) \tag{2.5}$$

During the identification we need to get two values for signal, which are needed for calculation.

One of them is obtained by the output signal $y(t)$ multiplied by $sin(\omega t)$ and the result is integrated over one or more periods (Fig. 2).

$$y_s(T) = \int_0^T y(t)\sin(\omega t)\,dt = \int_0^T Bsin\,(\omega t + \varphi)\sin(\omega t)\,dt + \int_0^T e(t)\sin(\omega t)\,dt \tag{2.6}$$

$$y_s(T) \cong \frac{BT}{2}\cos(\varphi) \tag{2.7}$$

The second value is obtained almost in the same way. Signal $y(t)$ is multiplied by $cos(\varphi)$ and also the result is integrated over one period or more periods this time (Fig. 2.).

$$y_c(T) = \int_0^T y(t)\cos(\omega t)\,dt = \int_0^T Bsin\,(\omega t + \varphi)\cos(\omega t)\,dt + \int_0^T e(t)\cos(\omega t)\,dt \tag{2.8}$$

$$y_c(T) \cong \frac{BT}{2}\sin(\varphi) \tag{2.9}$$

If we use equations (2.3),(2.4) we can write

$$y_s(T) = \frac{AT}{2}\Re[G(j\omega)] \tag{2.10}$$

$$y_c(T) = \frac{AT}{2}\Im[G(j\omega)] \tag{2.11}$$

Where $\Re[G(j\omega)]$ and $\Im[G(j\omega)]$ are real and the imaginary part of the transfer function of our first order system.

It is appropriate to connect harmonic signal to the engine with such a frequency which gives approximately the same amplitude of y_s and y_c to achieve good accuracy. It can be done by iterative selection of ω, which will ensure the same level of amplitude, but at the same time it must be sufficiently high not to start moving with the rotor. If we connect such harmonic signal to the engine, that values y_s and y_c are at least the same order, then method will have got better accuracy.

We can do this by right selection of ω, which will ensure the same level of amplitude, but at the same time it must be sufficiently high not to start moving with the rotor.

2.1. IDENTIFICATION OF R_s

We need transfer function of our first order system for identification. Transfer function for identification of R_s is $F(p) = \frac{\frac{1}{R_S}}{\frac{L_X}{R_S}p+1}$. First we need to get real and imaginary parts of transfer function.

$$F(j\omega) = \frac{\frac{1}{R_S}}{\frac{L_X}{R_S}j\omega+1} \tag{2.12}$$

$$\Re[G(j\omega)] = \frac{\frac{1}{R_S}}{1+\omega^2\left(\frac{L_X}{R_S}\right)^2} \tag{2.13}$$

$$\Im[G(j\omega)] = \frac{-\omega\frac{L_X}{R_S^2}}{1+\omega^2\left(\frac{L_X}{R_S}\right)^2} \tag{2.14}$$

Then the real and imaginary parts are substituted into equations (2.10) and (2.11).

$$y_s = \frac{AT}{2}\frac{\frac{1}{R_S}}{1+\omega^2\left(\frac{L_X}{R_S}\right)^2} \tag{2.15}$$

$$y_c = \frac{AT}{2}\frac{-\omega\frac{L_X}{R_S^2}}{1+\omega^2\left(\frac{L_X}{R_S}\right)^2} \tag{2.16}$$

Now we know all variables and we can calculate stator resistance R_s from equation (2.15),(2.16). (Fig. 2).

$$R_s = \frac{ATy_s}{2(y_s^2+y_c^2)} \tag{2.17}$$

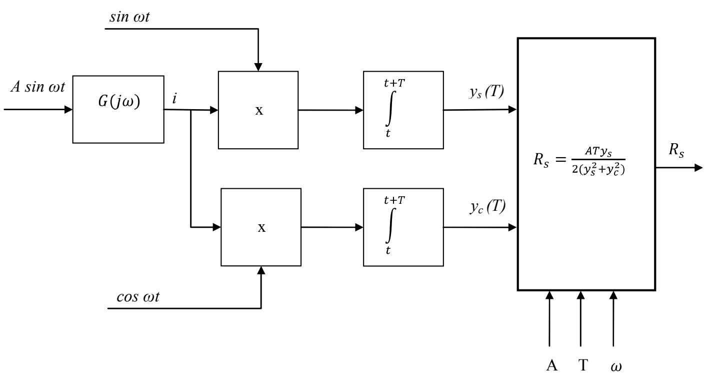

Fig 2: Calculation of stator resistance R_s

3. ON-LINE IMPROVED FREQUENCY ANALYSIS METHOD

The on-line methods are very important for control of motor with the changing parameters. The motor parameters can vary in tens of percent and then control doesn't work correctly. The parameters have to be identified for correct controller setting. These parameters are mainly stator resistance, direct inductance and quadrature inductance.

The identification of stator resistance is similar to off-line method. We connect harmonic signal to input (voltage) and measure output signal (currents). But the on-line method differs from the off-line method by control. In the on-line method the harmonic signal is added to control signal. This method is the best for use when the direct current is controlled to origin. Then the cross coupling contains only permanent magnet flux Ψ_f multiplied by the speed of rotor and therefore error of identification is smaller.

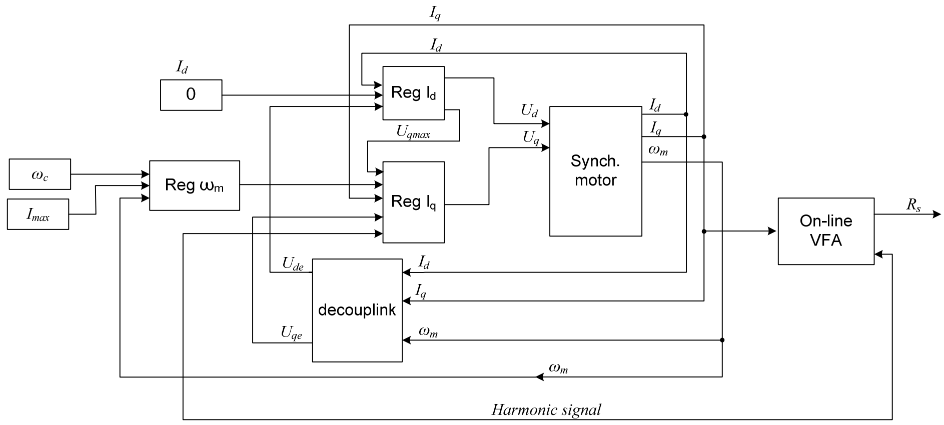

Fig 3: Control of synchronous motor with identification

The simulation of on-line identification VFA was realized in the Matlab Simulink. There was the field oriented control with decoupling used for control of motor. And direct current I_d is controlled to origin. VFA generates harmonic signal, which is added to control signal (Fig.3) and its frequency is $f = 400Hz$ and amplitude is $A = 1V$. And identification was done in q-part of motor. Therefore, the identify harmonic signal was added to quadrature voltage U_q.The input signal of on-line VFA (VFA input) is current I_q. Because VFA method uses correlation, the input signal does not have to be filtered and the stator resistance R_s is calculated as well as in off-line method.

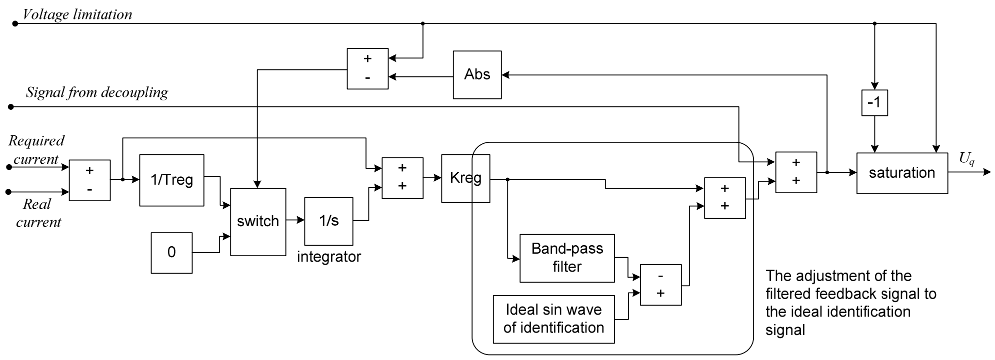

Fig 4: Controller I_q

The biggest problem of the on-line VFA identification is altered harmonic signal in the feedback of control. Its filtration off is very complicated because the filters don't filtrate off whole harmonic signal or it has got long delays. In our case the harmonic signal is not filtrated off. It is only subtracted from ideal sin wave of identification and the difference is added to signal from controller (Fig.4). This operation ensures that the harmonic signal in the circuit has got the ideal amplitude and frequency (Fig.5).

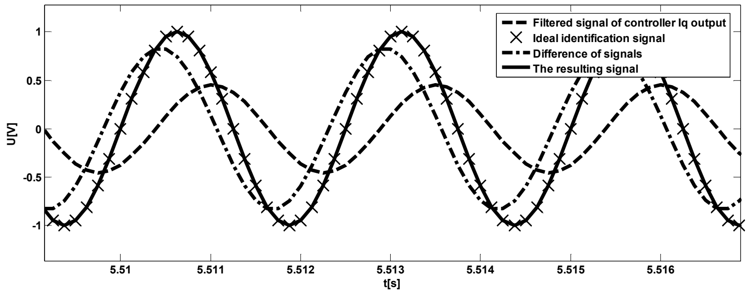

Fig 5: The adjustment of the filtered feedback signal to the ideal identification signal

4. CONCLUSION

The article describes improved frequency analysis (VFA). From previous tests we know that this method is very effective for identification of stator resistance. Its advantage is an immunity to noise [7]. But this method was used mainly for off-line identification. In previous text is described the application of this method in on-line identification. The calculation of stator resistance is the same as with off-line method but harmonic signal of identification is added in different way. In the feedback of control is altered harmonic signal which must be modified to the ideal identification signal. The amended feedback signal is filtered. It is modified by math operations and the result is added back to the control signal. The method identifies the stator resistance without serious problems, because the ideal harmonic signal is still in the circle.

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